CITY OF HAMILTON

PUBLIC HEALTH SERVICES
Health Protection Division

TO: Mayor and Members Board of Health	**WARD(S) AFFECTED:** CITY WIDE
COMMITTEE DATE: September 26, 2011	
SUBJECT/REPORT NO: Child Blood Lead Prevalence Study Findings (BOH11030) (City Wide)	
SUBMITTED BY: Elizabeth Richardson, MD, MHSc, FRCPC Medical Officer of Health Public Health Services Department **SIGNATURE:**	**PREPARED BY:** Matthew Lawson (905) 546-2424 ext. 5823

RECOMMENDATIONS:

(a) That Report BOH11030 - *Child Blood Lead Prevalence Study Findings*, be received;

(b) That Public Works continue to offer Hamilton residents the "Check Size and Type Inspection" service for identifying lead service lines for water, free of charge;

(c) That the City of Hamilton continue to offer low interest loans to residents who wish to replace their portion of any residential water service line that is made of lead;

(d) That the Board of Health send a letter to the Ministry of Community and Social Services (MCSS) requesting that MCSS and the Ministry of the Environment (MOE) work together to provide 100% provincial funding for low-income households to access on-tap water filters;

(e) That Public Health Services, in collaboration with internal and external partners, develop and deliver an environmental lead awareness program that will attempt to reduce exposure to environmental lead for high-risk groups (children under age 7 and pregnant women and/or women who may become pregnant) and refer resource implications, if any, to the 2012 budget process.

EXECUTIVE SUMMARY

Public Health Services initiated a child blood lead prevalence study in 2008 that sought to find out if Hamilton has a lead exposure problem among young children. A total of 643 children under the age of 7 were successfully recruited from North Hamilton to participate in the research study. Blood samples, parent interviews and water, dust and soil samples from select households were all collected to provide data for the study.

Results show that slightly less than 1% of children in the study sample had blood lead levels at or above the current Health Canada guidance value for blood lead (0.48umol/L). Because the study targeted high-risk areas, the prevalence of elevated blood lead in the general population of children in Hamilton would likely be lower than 1%. Although it is challenging to make direct comparisons, as there are no suitably comparable Canadian data on young children's blood lead levels available at this time, comparisons with U.S. 2007 data for children 1 to 5 years of age indicate an identical proportion of children (0.9%) at or above the Health Canada guidance value for blood lead (0.48umol/L).

The study also confirmed existing evidence found in the literature that environmental sources of lead exposure such as older housing and lead water service pipes can all contribute to a child's blood lead burden. The study provided useful findings that can be used to refine and target public health efforts to reduce lead exposure among North Hamilton children and families.

This report summarizes key findings of the North Hamilton Child Blood Lead Study Public Health Report (see Appendix "A"). The report also provides some interpretation as to what the findings mean and outlines recommendations for going forward with the goal of reducing lead exposure to individuals at risk.

Alternatives for Consideration – see page 11

FINANCIAL / STAFFING / LEGAL IMPLICATIONS (for Recommendation(s) only)

Financial: No new costs are proposed. Any future resource implications will be brought forward to the Board of Health for consideration.

Staffing: No new staffing is proposed. Any future resource implications will be brought forward to the Board of Health for consideration.

Legal: There are no foreseen legal implications arising from the above recommendations.

HISTORICAL BACKGROUND (Chronology of events)

Study Rationale and Objectives

The removal of lead used in paint in the 1970's and the phase-out of leaded gasoline in the early 1980's have resulted in a substantial lowering of average blood lead levels in children. However, because lead is present in virtually all urban soil due to historical use of leaded gasoline and is still used in some manufacturing processes, there is still concern regarding exposure of high-risk individuals to lead. Research is providing increasing evidence that exposure to lead at low levels can represent a risk that, although decreasing, is still not zero. Children are at greatest risk because of their exposure patterns and because they are undergoing vulnerable processes such as brain development.

In May 2008, Board of Health members carried a motion of support for Public Health Services (PHS) to conduct a Child Blood Lead Prevalence Study. The rationale for the study was due to concerns about whether or not the City of Hamilton has a lead exposure problem among young children. Young children (under 7 years of age) were chosen as the target population for the study because they are the most vulnerable to the effects of lead, which can act as a neurotoxin, disrupting a child's brain development and ability to function normally.

The study proposed to investigate blood lead levels (BLLs) of children living in an area of North Hamilton with increased theoretical risk of environmental lead exposure due to old housing stock, aging water delivery infrastructure, and historic and current social and industrial activities that emit lead. The scientific literature tells us that these factors increase risk of exposure to lead through household dust, lead-based paint, soil, and drinking water. Certain areas within north Hamilton are also characterized by a number of social and economic disadvantages compared with other areas within the city. These include indicators such as lower average household income, poor health status, and lower education levels. As a result, residents in these areas may face greater challenges when it comes to reducing exposure to environmental lead.

At the time the study was conceived and implemented, no information about blood lead levels among City of Hamilton residents was available. Study results would provide data to understand how BLLs are distributed among children living in the study area and to establish a baseline estimate of the number of children that are above the Health Canada guidance value for blood lead (0.48 umol/L). A guidance value is the level above which follow-up actions should be considered to reduce exposure to lead. The study also sought to explore and identify potential risk factors associated with BLLs.

Study Components

The main components of the study included:

- A community awareness campaign to recruit participants
- Community clinics for blood lead testing
- Household interviews
- Collection and analysis of household dust, water, and soil samples

Blood collection clinics were established at various locations throughout the study area such as city-run community and recreation centres, and Ontario Early Years Centres. In total, 60 clinics were implemented at 16 sites between October 2008 and December 2009.

A questionnaire was developed to collect information on various risk factors and behaviours associated with BLLs. A phone interview was conducted in households within 2 weeks of their child providing a blood sample to collect information about where the child spends daytime hours, access to soil, hand-washing frequency, household hygiene practices, adults' occupations, recent household renovations, and water sources, as well as other questions related to risk factors associated with BLLs.

Some participant households within the study area were willing to have drinking water, house dust and soil samples collected from the home. These samples were used to further explore associations between BLLs and risk factors for exposure to lead. Other secondary sources of data such as the 2006 Census Community Profile, Municipal Property Assessment Corporation (MPAC) Property Database, and the Ontario Ministry of the Environment (MOE) Air Sampling Program were also used to assist in the data analysis.

All of the data required for the study was collected by the end of summer, 2009. The data for the study was then prepared for analysis. The data analysis was performed by a biostatistician consultant contracted by Public Health Services.

POLICY IMPLICATIONS

Recommendations (a) and (b) are affected by Public Works, Water and Wastewater policies. These recommendations are being made in effort to bring to the attention of Board Members about the benefit they provide in assisting with reducing environmental lead exposure.

All of the recommendations within this report seek to advance Hamilton's desire to be the best place to raise a child. They also support a healthy population that can participate in innovation. These recommendations would help the City of Hamilton to continue to offer good service to citizens.

RELEVANT CONSULTATION

Public Health Services consulted with the following stakeholders regarding this report:

City of Hamilton Public Works
Dan McKinnon, Director of Water & Wastewater Operations was consulted regarding the development of recommendations (b) and (c). Mr. McKinnon is supportive of these recommendations.

City of Hamilton Community Services Department
Kerry Lubrick, Director of Employment and Income Support was consulted regarding the development of recommendation (d). Ms. Lubrick is supportive of this recommendation.

McMaster Institute of Environmental Health (MIEH)
Dr. Bruce Newbold, Director of MIEH was consulted regarding the development of recommendation (e). Dr. Newbold is supportive of recommendation (e) and has offered assistance from MIEH to help provide further analysis of study data that will aid Public Health Services in the development of an environmental lead awareness program.

Ministry of the Environment (MOE)
MOE staff were supportive of the study and provided guidance and resources toward it's completion.

ANALYSIS / RATIONALE FOR RECOMMENDATION

(include Performance Measurement/Benchmarking Data, if applicable)

This section will attempt to provide summary information related to:

- Population characteristics of the study area
- Sample achieved in the study
- Factors potentially associated with blood lead levels
- Findings on blood lead levels
- Interpretation of the findings

Population Characteristics of the Study Area

The study area is generally characterized by lower levels of family income, home ownership, and post-secondary education when compared with the rest of Hamilton. Within the study area, there is some diversity with respect to various social and economic factors, but overall, it is at a greater disadvantage than the City of Hamilton average on a number of indicators including, but not limited to, the following:

- The proportion of families living in the study area with income below the low income cut-off (25%) is higher than the City of Hamilton average (14%)
- The rate of home ownership in the study area (49%) is lower than the City of Hamilton overall (68%)
- The rate of working age adults (25-64 years) who do not have post-secondary education was higher in the study area (60%) when compared with the overall City of Hamilton (42%)

The study area is also home to recent immigrants with approximately 5% of residents having immigrated to Canada within the past five years, a rate that is slightly higher than the overall City of Hamilton (3%). The rate of study area residents that do not speak either official language at home is 14%. This is similar to the rates in the City of Hamilton overall (13%). Within the study area, there are neighbourhoods that extend north and east from the downtown core with greater than 20% of the population who do not speak either official language at home.

Sample Achieved

Within the study area, an attempt was made to recruit approximately 1300 children (under age 7) from select, randomized neighbourhoods. Despite an aggressive awareness campaign to generate interest among families living in the study area, there was a low early response rate from the neighbourhoods selected for analysis. This low response prompted the research team to change the study design to a self-selected sample from the overall study area.

Once the study design was changed to invite any child living in the study area, the participation rate increased. Below are some key descriptive statistics that help describe the study sample population:

- 643 children from 453 households successfully recruited to provide a capillary blood sample
- 406 households (representing 580 children) completed phone interviews
- A slightly higher proportion of boys (55%) participated in the study than girls (45%)

Study results show that people were more likely to participate if they lived in neighbourhoods with the following characteristics: higher median incomes, higher rates of home ownership, higher levels of post-secondary education, and more likely to speak an official language at home.

The study team also examined participation rates according to geographical distribution, proximity to industry, air lead zone and age of housing. Participation rates were lower in the north end and downtown core of the study area, and highest in the southwest of the study area. Similarly, families who lived closest to industry (within 1200 meters of a current or historic lead-emitting industrial site; industry adjacent air lead zone) were the least likely to participate in the study.

Factors Potentially Associated with Blood Lead Levels (BLLs)

The study collected information from participating households about factors that are known to be associated with children's BLLs (e.g., socio-economic, environmental, and characteristics and behaviours). The following brief summaries provide information about the sample population that participated in the study with respect to factors associated with BLLs.

Socio-economic factors (e.g., income status, education level): The interviewed sample was primarily English-speaking, with a small proportion reporting having immigrated to Canada within the past five years. The sample was relatively well-educated with over one-half of the families indicating that an adult in the household has a university education. In contrast, approximately one-fifth of the families interviewed reported that none of the adults in the household had post-secondary education. Associated with the higher levels of education, annual household income was over $60,000 for the majority of the sample. Of note, 6% of households reported a household income of less than $20,000 per year. The vast majority of the sample reported owning their own home with a smaller proportion renting. The sample population is likely not reflective of the study population overall, and is characterized by higher incomes, higher rates of home ownership, and higher levels of post-secondary education when compared to the overall study area population.

Environmental factors (e.g., old paint, proximity to current and/or historic lead-emitting industries, water pipes): A majority of families lived in housing that was constructed prior to 1945, a period during which paints typically contained substantial amounts of lead. A significant proportion of the sample households also reported flaking or deteriorating interior paint. According to the study hypotheses, these two factors (older housing, flaking paint) indicate a higher risk of lead exposure potentially contributing to higher BLLs for children living in these households.

Higher tap water lead levels generally corresponded to neighbourhoods with very old housing stock. All of the study neighbourhoods had median water levels below the current Ministry of Environment (MOE) drinking water standard for lead of 10 μg/L, however, almost all neighbourhoods had at least one sample that exceeded this standard.

The soil lead levels were found to be higher in neighbourhoods in the western-central and central parts of the study area, and lower in the more southern neighbourhoods that run along the escarpment. There was no study neighbourhood that exceeded at or above 200μg/g (or 200ppm), the level below which the MOE advises that there is minimal risk from exposure to soil. According to the MOE, lead levels in surface soil in older residential areas may be found to be higher than 200 ppm. This was the case for most areas for which there was at least one sample with a soil lead level above 200 μg/g.

The neighbourhoods with higher median living room dust levels were in the western-central neighbourhoods, which corresponds to the areas with higher median yard soil lead levels, and the areas with very old housing stock. Currently, there are no MOE standards or guidance levels for lead in dust.

Characteristics and behaviours (e.g., age, sex, diet, hygiene and cleaning habits, tap water consumption): Most of these factors that potentially influence the uptake of lead from the environment are related to the characteristics of the child, while others are related to various behaviours of the child and members of the household and should only be an issue if there is source lead in the child's environment. Toddlers (18 - 36 months old) made up approximately one-third of the sample, while older children (36 months to under 84 months) made up the largest proportion of the sample. The sample consisted of slightly more male children. Overall, there were very few children taking either calcium or iron supplements, which can prevent lead uptake by the child when taken.

The majority of households reported cleaning floors at least weekly. Children's hygiene was assessed by asking parents/guardians to estimate how frequently children's hands were washed before eating. The largest proportion of children had their hands washed usually (75-100% of the time), while relatively equal proportions had their hands washed some of the time (50-75% of the time), or less frequently (less than 50% of the time). For all household and personal hygiene questions, parents/guardians responses were likely influenced by what is known to be socially desirable, so the data for these questions should be interpreted with caution.

Findings on Blood Lead Levels

The current Health Canada guideline value for blood lead is 0.48 μmol/L. Approximately 1% of children tested were at or above this guideline value. Despite small differences between male and female children and the different age groups outlined in Table 1, none of these were found to be statistically significant.

Table 1: Distribution of Blood Lead Levels in Study Area

GROUP	N	% At or Above the Health Canada Guideline Value (≥0.48 µmol/L)
Overall	643	0.9
Sex		
Male	352	1.1
Female	291	0.7
Age Category		
Infant (0m to <18m)	120	1.7
Toddler (18 m to<36m)	154	1.3
Preschooler (36m to <74m)	369	0.5

It is difficult to make valid comparisons between the BLLs obtained from children in North Hamilton to BLLs of children living in other places due to the likely difference in sources of potential exposures. Currently, there is no overall national comparison for children under 7 years of age in Canada. However, there has been ongoing monitoring of children's BLLs in the United States, and there have been a number of recent, smaller studies that have been conducted with young children in Canadian communities that would be considered at high-risk for exposure to lead, primarily due to soil lead levels (see Table 2).

The study findings indicate that blood lead is a problem in North Hamilton for a small percentage of the population. Given the large sample size of children (n=643), the findings are likely indicative of the BLLs of this population, taking into account the limitation that the sample was voluntarily self-selected. The distribution of BLLs in the study area followed a similar pattern found in other jurisdictions, although it is challenging to make direct comparisons as there are no suitably comparable Canadian data on young children's BLLs available at this time. Comparisons with available U.S. data show that the study sample is similar, with a slightly higher average BLL, but identical proportions of children (0.9%) at or above the current Health Canada guidance value of 0.48umol/L.

The lower participation rates from children living in higher-risk neighbourhoods may have resulted in slightly lower assessments of overall BLLs. In other words, the average BLL of the study group might have been higher if more children living in areas at higher risk of lead exposure had participated in the study. The study concluded that overall, the sample of children have similar levels of lead exposure when compared with other populations, and there is a small number of children who are being exposed at levels that would require medical attention.

Table 2: Blood Lead Concentrations in Other Communities
Interpretation of the findings

Age	Community	Date of Measurement	Exposure Concerns	N	Geometric Mean (µmol/L) (CL)	% at or above Health Canada guideline value (≥ 0.48µmol/L)	Reference
CURRENT NORTH HAMILTON STUDY							
Children 0-6 years old	**North Hamilton**	**2008**	Current Study	**643**	**0.107 (0.102-0.112)**	**0.9%**	**Current Study**
NATIONAL STUDIES*							
Children 1-5 years old	U.S. NHANES (2007-08)	2007-08	General Exposure	817	0.073 (0.068-0.082)	0.9%	U.S. CDC 2009
STUDIES OF COMMUNITIES WITH SIGNIFICANT EXPOSURES							
Children 0-6 years old	Flin Flon Area, MB (near smelter)	2009	Soil	202	0.133 (0.121-0.142)	2.0%	Intrinsik Inc. 2010
Children 0.5-5 years old	Trail, BC (near smelters)	2007	Soil	132	0.246	—	Trail Health and Environment Committee 2007
Children 3-6 years old	Belledune, NB (near smelter)	2004	Soil	10	0.171	—	Government of New Brunswick 2005
Children 5 years old	Nunavik, QC	2000-2003	Local Food	110	0.256	—	Fraser *et al*., 2006
Children 0-6 years old	Port Colborne, ON (near smelter)	2001	Soil	42** 56***	0.11 0.10	2.9%**	Regional Niagara Public Health Department 2001
Children 0-6 years old	West Carleton, ON (mine tailings)	2000	Dust	196	0.092	1.7%	Region of Ottawa Carleton 2000

*No Canadian national level data are available for children less than 6 years of age
** East side community of Port Colborne
*** Greater Port Colborne

One of the secondary objectives of this study was to explore associations between potential lead sources, specific risk and mitigating factors, environmental lead levels and BLLs. The study analyses regarding environmental associations with BLLs were exploratory, and the findings should be interpreted with caution given that the study was not designed to collect data for these types of analyses. The study shows that environmental and protective factors did influence BLLs of the sample population, but only a small amount of the variation between BLLs can be explained by these factors. In other words, it was confirmed that factors such as (but not limited to) older housing, proximity to historic and current lead-emitting industries, household income and hygiene practices are good predictors of BLLs, but the study could not identify one sole factor that is most responsible for determining a child's BLL.

Another secondary study objective was to describe the presence of sources of lead and specific risk and protective factors that have been shown in previous studies to be associated with BLLs. The study achieved this objective by providing details on not only the sample for specific risk and mitigating factors (e.g., hygiene behaviours, occupation), but also more in-depth description of population-wide factors (e.g., education levels, age of housing, household income). This study suggests that lower socioeconomic status, higher rates of recent immigration, and older housing are characteristic of the study area's population (i.e., North Hamilton), and that many of the other hypothesized risk factors are present in this area (e.g., proximity to historical and current industry). These descriptive findings can potentially be used to refine and target ongoing public health efforts and initiatives to reduce lead exposure among North Hamilton children and families.

The study on child blood lead levels was designed to find out if Hamilton has a lead exposure problem among young children. The findings showed that Hamilton is similar to other North American jurisdictions for which blood lead data is available. The matter of environmental lead exposure is often a "man-made legacy" issue in urban centres like Hamilton. The widespread use of leaded gasoline and lead-based paint in previous decades has contributed to the environmental lead burden that exists today. There is no single cause of environmental lead exposure in Hamilton, as there are many sources that children may be exposed to (e.g. house dust, soil, water, consumer products, etc.). A sound strategy for dealing with environmental lead is to focus on modifiable actions that will reduce risk of exposure. Strategies such as education and awareness of those at risk are critical in this regard, as well as working with family medical practitioners to better inform them of issues related to lead exposure.

ALTERNATIVES FOR CONSIDERATION:

(include Financial, Staffing, Legal and Policy Implications and pros and cons for each alternative)

The recommendations put forth are believed to be the most feasible and appropriate way to reduce the risk of exposure to environmental lead.

The Board of Health could direct staff not to pursue an awareness campaign, to discontinue the "Check Size and Type Inspection" program, or to discontinue the loan program for lead service line replacement. However, the elimination of these low-cost programs and services would reduce the ability of citizens to protect themselves against lead exposure.

The Board could also not choose to pursue advocacy at the provincial level for funding for water filters. However, this would reduce the likelihood that the Province would play a role in reducing lead exposure in Hamilton.

CORPORATE STRATEGIC PLAN (Linkage to Desired End Results)

Focus Areas: 1. Skilled, Innovative and Respectful Organization, 2. Financial Sustainability,
3. Intergovernmental Relationships, 4. Growing Our Economy, 5. Social Development,
6. Environmental Stewardship, 7. Healthy Community

Intergovernmental Relationships

- Influence federal and provincial policy development to benefit Hamilton
- Maintain effective relationships with other public agencies

Social Development

- Residents in need have access to adequate support services
- The research findings will allow PHS staff to more-effectively focus efforts to reach high-risk groups

Healthy Community

- An engaged community
- This study helped draw attention to the issue of lead exposure and raised the awareness level of many of the over 700 participants

APPENDICES / SCHEDULES

Appendix A to Report BOH11030 – North Hamilton Child Blood Lead Study Public Health Report

North Hamilton Child Blood Lead Study Public Health Report

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Executive Summary

Study context, rationale and objectives

This report outlines the main findings and conclusions from the North Hamilton Child Blood Lead Study conducted in 2008-2009 by City of Hamilton Public Health Services (HPHS). Environmental lead exposure continues to concern the general public, environmental professionals, researchers, regulators, public health professionals, physicians and politicians. In the City of Hamilton, the main impetus for studying environmental lead exposure was the recognition that lead water service lines and plumbing in older homes and public buildings could be potential sources of lead exposure. In the City of Hamilton, older housing stock is concentrated in the North Hamilton Area located near historic and current industrial activities, which serve as potential sources of air, soil and dust lead, as outlined in the literature.

The main research question addressed by the study was: *What proportion of City of Hamilton children under the age of 7 years has blood lead levels that require medical attention?* To address this research question, HPHS defined one primary study objective, and four secondary study objectives. The primary study objective was to determine the distribution of blood lead levels (BLLs), and the prevalence of BLLs greater than the current blood lead guidance value (0.48 µmol/L) in a sample of children under 7 years of age who resided in the targeted geographic higher risk area of North Hamilton (study area). The four secondary study objectives were: 1) to describe the presence of potential lead sources, and specific risk and mitigating factors shown in previous studies to be associated with BLLs; 2) to describe the public's awareness of the available services promoted in the "Get the Lead Out" campaign; 3) to evaluate participant compliance with study-recommended clinical follow-up and interest in available public health services as part of study follow-up; and 4) to explore associations between potential lead sources, specific risk and mitigating factors, environmental lead levels and BLLs.

Methods

The original study design was a stratified, random cross-sectional design. This was converted to a non-random, self-selected cross-sectional design once it was realized that participation rates were not sufficient to support the original study design. Study inclusion criteria were children under 7 years of age who had lived in the study area for at least three months. Participation included attending a local, mobile clinic to provide parental/guardian informed consent for the study and to provide a capillary sample of the child's blood (n=643 children). Other study components were a risk factor survey conducted over the phone with parents/guardians (offered to all parents/guardians; n=580 children), and environmental sampling of yard soil, household dust and tap water (offered to a sub-sample of households; n=281 children).

In total, 60 clinics were implemented at 16 sites between October 28 and December 11, 2008. The chosen study period allowed for the BLLs to be measured immediately following the summer months. It was hypothesized that children would have a high exposure to lead found in the soil and air during the summer, as they would be likely to spend time playing outside. In addition, the return to school and work schedules after the traditional summer vacation period facilitated participation in the study. Recruitment of children and their families for the study took place over a 14-week period and was achieved through an extensive public awareness campaign for the study. The campaign focused on study rationale, participation requirements, and the importance of this type of study for the community.

The overall participation was 7.2% and was relatively lower among neighbourhoods characterized by low income, new immigrants and households speaking non-official languages. Given the paucity of newer housing in the study area, the study was not able to recruit the planned number of households from the various stratified quota for the environmental sampling component of the study.

Individual participant follow-up

As one component of the study design, study researchers selected a study follow-up threshold value (≥ 0.19 µmol/L), and then developed a detailed algorithm for follow-up with the parents/guardians of children who met or exceeded this threshold. The study threshold value was purposefully selected to be significantly lower than the current Health Canada guideline value (0.48 µmol/L). This provided those children with capillary blood lead levels in an above average range the opportunity to be referred for a venous re-test for blood lead and additional blood tests (hematocrit and hemoglobin). The main steps for follow-up of children with capillary BLLs at or above the study threshold level were: 1) parents/guardians were contacted by a public health nurse to review capillary results and a referral was made to have the child submit a venous sample for re-testing; 2) parents/guardians were contacted by a public health nurse to review venous re-test results; 3) the child was referred to the family physician and/or study paediatrician depending on venous blood lead results; 4) home visit by a public health inspector depending on venous blood lead results; and 5) parents/guardians were sent a personalized letter with their child's capillary and venous blood test results and any recommendations pertaining to follow-up along with general information to reduce environmental lead exposure.

Findings for distribution and prevalence of BLLs in North Hamilton

The geometric mean for BLLs in the study area was 0.107 µmol/L with 0.9% of children (n=6) with capillary BLLs above the Health Canada guidance value of 0.48 µmol/L. The distribution of BLLs in the study area was highly positively skewed. Despite small differences between male and female children and the different age groups examined, none of these were statistically significant. However, BLLs varied across the study area to some extent.

The distribution of BLLs in the study area followed a similar pattern found in other jurisdictions, although it is challenging to make direct comparisons as there are no suitably comparable Canadian data on young children's BLLs available at this time. Despite the identification of medium-risk exposure levels in the study population, the study sample is similar to data from a US national study for children 1 to 5 years of age, with a slightly higher geometric mean (0.107 µmol/L North Hamilton vs. 0.073 µmol/L US population), but very similar proportions of children at or above the current Health Canada guideline of 0.48 µmol/L. The mean and proportion above the guideline within this study is lower than some studies involving point-source exposures.

Findings for presence of lead sources and risk/mitigating factors in North Hamilton

Numerous risk factors for child lead exposure were found to be characteristic of the study area in North Hamilton. Older housing was a main characteristic of the study area's population with the vast majority of families living in housing constructed prior to 1945 (84%). A significant proportion of the sample households reported that there were interior painted surfaces in the home that were deteriorating or flaking (45%) and almost 40% reported having renovated their home in the previous 6 months. Other risk factors of the area included proximity to industry (historic and current), lower income levels, lower education levels, living in rental dwellings. In general, there was a large proportion of families that reported practicing lead-reduction behaviours. The vast majority of households reported that members remove their shoes before home entry (84% at least half of the time), children mostly wash their hands before eating (71% at least half of the time), and parents/guardians clean the floors once a week or more (89%), most often with a wet mop.

The geographic distribution of environmental lead sources across the study area was uneven and there some neighbourhoods were characterized by relatively higher risks of multiple lead sources. In particular, the areas defined in the study as being proximal to lead-associated industry were also those that were long-established built environments retaining historic risks from emissions from lead-based gasoline, lead-based paint, lead piping, and known and unknown industrial sources. In addition, many of these areas were also characterized by low-socio-economic status.

Findings for awareness of available services promoted in the “Get the Lead Out” campaign

It appears there was moderate awareness of available services promoted in the “Get the Lead Out” campaign as one-half (52%) of participant households within the highest risk area of the City of Hamilton were aware of the free water service pipe inspection. The levels of awareness were somewhat lower among those with low household incomes, tenants in rented accommodations, those who did not speak either English or French at home, and households where no adults had a post-secondary education. Similar patterns were also found among awareness of steps to reduce children’s exposure to lead from tap water and awareness that older homes may be serviced with lead water service pipes.

Findings for compliance and interest with clinical and public health follow-up

The evaluation of uptake and compliance with the public follow-up study component (i.e., recommendations for venous re-testing, referral for medical follow-up, and home visit a public health inspector) demonstrated a high degree of interest and willingness to comply. One the other hand, a meaningful proportion did not follow-up with venous re-testing (18%) despite considerable efforts made by the HPHS (e.g., offers to provide public health support, transportation to the laboratory for re-testing, coverage of costs for those who may not have had health insurance).

Findings for factors associated with BLLs in children

The overall model of associating primary sources and various other risk/mitigating factors with children’s BLLs found that only a small proportion of variance in BLLs could be accounted for by these factors (14%). The factors that were found to be significant predictors for children’s BLLs were consistent with other research (e.g., older housing, proximity to historical and current industry, home renovations in the previous six months, household income, floor hygiene practices, male sex). As well, intermediary sources of environmental lead (i.e., yard soil, tap water, household dust) were also statistically significant predictors of BLLs but these models also accounted for a small proportion of the variance in BLLs (yard soil - 14%; tap water - 14%; household dust - 18%). Regression models developed that included all three environmental media along with the other modifiers highlighted that lead levels in tap water and household dust were significant predictors of BLLs, however, lead levels in yard soil were not. In this study, yard soil appears to be a strong contributor to household dust lead levels (along with age of housing), but does not appear to make much of a unique contribution to BLLs beyond dust. This study’s measure of industry emissions was a proxy measure (proximity to industry) that may reflect long-established, urban neighbourhoods that are also adjacent to long-established lead-emitting industry with unmeasured risks from multiple sources. This factor demonstrated a significant and strong association with BLL at or above the study follow-up threshold (OR 20, CI 4 – 95; p = <.001). These analyses were exploratory, and the findings should be interpreted with caution given that the study was not designed to collect data for these types of analyses.

Discussion and conclusions

This study benefited from the large sample size (n=643), and among the participants there was a range of environmental risk factors and responses to the questionnaire for most study variables. Despite the limitation that the sample was self-selected, the findings are believed to be generally reflective of the BLLs of the study population. The lower participation rates from the more at-risk groups may have resulted in a slightly lower estimate of overall BLLs. Within the stated limitations, the study concluded that North Hamilton children are experiencing levels of lead exposure that are likely consistent with other populations residing in long-established urban communities, and there is a small proportion of children who are being exposed at levels that would require interventions at an individual, clinical level.

The results suggest that there is a substantial audience for public health promotional materials about reducing lead exposure, and that the effectiveness of promotional activities may be improved by targeting specific groups within the population. In addition, there is evidence that public health lead exposure reduction services will be well-received in this community, and there will be significant interest and uptake of programming. However, we expect there will be a segment of the population that will not seek to benefit, despite available public health services.

The findings suggest that many families in the study area are already engaged in mitigating practices, however, this should be interpreted with caution given the potential for socially desirable responses to hygiene practice questions. A comprehensive education strategy would benefit from continued emphasis on the importance of behaviours that can mitigate the potential risks, such as proper renovation techniques, wet mopping, and household entry and individual hygiene practices.

The factors that were found to be significant predictors of children's BLLs were consistent with other research. These include older housing stock, proximity to historical and current industry, household income, recent renovations, and male sex. As well, intermediary sources of environmental lead such as yard soil, tap water, and household dust were also statistically significant predictors of BLLs in this study. These risk factors and sources, as well as others from the literature such as recent immigration, rental housing, and an unofficial language spoken at home, were found to be characteristic of the study area in North Hamilton. The high proportions of older residences and recent renovations suggest that home renovation in older housing stock is an important component for consideration in public health lead exposure interventions. Neighbourhoods characterized by low income, new immigrants and households speaking non-official languages may have fewer resources to remove or counteract the hazards of lead exposure. Rental housing participants are challenging to reach and often have less control over the home environment. These findings are relevant in the planning of public health efforts and for developing policies that may impact these communities. Long-established, urban neighbourhoods with risks from multiple sources that are also adjacent to long-established lead-emitting industry are particularly important to target by public health in lead-exposure reduction strategies.

The results of this study may be used to inform and refine ongoing public health efforts and initiatives to reduce lead exposure among North Hamilton children and families. Recommendations resulting from the study findings and conclusions will be developed and presented in a separate report submitted to the City of Hamilton Board of Health.

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It should be noted that the analyses and conclusions in this report do not necessarily reflect the opinions of the acknowledged experts or their affiliated organizations.

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Acronyms

AAQC	Ambient Air Quality Criterion
BLL	Blood Lead Level
DA	Dissemination Area
HHS/FHS REB	Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board
HPHS	City of Hamilton Public Health Services
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
LOD	Limit of Detection
MOE	Ontario Ministry of the Environment
MPAC	Municipal Property Assessment Corporation
NHANES	National Health and Nutrition Examination Survey
OLS	Ordinary Least Squares
PHI	Public Health Inspector
QA/QC	Quality Assurance/Quality Control
SES	Socio-economic Status

1.0 Introduction

This report outlines the main findings and conclusions from the North Hamilton Child Blood Lead Study conducted in 2008-2009 by City of Hamilton Public Health Services (HPHS). After this initial brief introduction which outlines the study rationale and objectives, the report describes the various methods used for the study, key characteristics of the study area, and the children and families who participated. The central sections of the report present the findings with respect to capillary blood lead levels (BLLs), public health follow-up with children who tested at or above the study follow-up threshold, and hypotheses generated from analyses conducted to assess factors associated with BLLs in these children. The final sections of the report outline the main limitations of the study, various lessons learned in conducting a community study of this magnitude, and discussion of study results and conclusions. Recommendations based on the study findings will be included in a separate report to the City of Hamilton Board of Health. In addition to this report, a set of detailed technical documents including study protocols have been prepared for reference.[1]

1.1 Study rationale

Environmental lead exposure continues to concern the general public, environmental professionals, researchers, regulators, public health professionals, physicians and politicians. In the City of Hamilton, the main impetus for studying environmental lead exposure has been the recognition that lead water service lines and plumbing in older homes and public buildings could be potential sources of lead exposure. According to the literature, additional potential sources of environmental lead exposure could also include household dust, lead paint in older homes, soil, food, and occupational or recreational exposures.[2]

In the City of Hamilton, older housing stock is concentrated in the North Hamilton Area located near historic and current industrial activities, which serve as potential sources of air, soil and dust lead, as outlined in the literature. As was detailed in the local media[3] and further described in this report, the North Hamilton Area is also characterized by a number of social and economic disadvantages compared with other areas within the City of Hamilton. These include indicators such as lower average household income, poor health status, and lower education levels. As a result, residents in this area may face greater challenges to undertake measures to mitigate environmental lead exposure.

The literature also identifies the most susceptible groups to lead exposure in the population to be infants, children and pregnant women. While several studies have been conducted in Canada, with few exceptions, they have included children at risk of point source lead emissions or contaminated sites. In contrast, not much information has been produced about children's exposure to lead especially among 'ordinary children'. The impact of current guidelines on children's blood lead levels (and hence exposure) has never been evaluated. Without available baseline information, there is no basis to evaluate the impact of these population level interventions.

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[1] In addition to the appendices attached to this report, two volumes of technical documents that contain study protocols and more detailed technical discussion have been developed: *North Hamilton Child Blood Lead Study Technical Documents Volume I-II.*
[2] An overview of research literature reviewed during the development of this study is provided in Appendix A.
[3] http://www.thespec.com/topic/codered

At the point the study was developed and implemented, HPHS did not have any data on BLLs among City of Hamilton residents. In order to understand whether or not the City of Hamilton has a lead exposure problem among young children, and to address concerns raised by community representatives, HPHS conducted a study with children under 7 years of age from North Hamilton living in an area of the City with increased theoretical risks of environmental lead exposure. Study results provided quantitative data to understand the distribution of BLLs and to establish a baseline estimate of the prevalence of BLLs that are above recognized guideline levels among City of Hamilton young children. As well, the study explored and identified potential risk factors associated with BLLs.

1.2 Study objectives

The main research question addressed by the study was: *What proportion of City of Hamilton children under the age of 7 years has blood lead levels that require medical attention?* To address this research question, HPHS defined one primary study objective, and four secondary study objectives.

The primary study objective (P) was:

- (P1) To determine the distribution of BLLs, and the prevalence of BLLs greater than the current blood lead guidance value (0.48 µmol/L) in a sample of children under 7 years of age who resided in the targeted geographic higher risk area of North Hamilton (study area).

The four secondary study objectives (S) were:

- (S1) To describe the presence of potential lead sources and specific risk and mitigating factors shown in previous studies to be associated with BLLs;
- (S2) To describe the public's awareness of the available services promoted in the "*Get the Lead Out*" campaign;
- (S3)To evaluate participant compliance with study-recommended clinical follow-up and interest in available public health services as part of study follow-up; and
- (S4) To explore associations between potential lead sources, specific risk and mitigating factors, environmental lead levels and BLLs.

2.0 Study Methodology

This section provides an overview of the various methods implemented for the study including an overview of the study design, description of the ethics review process, detailed clinic procedures and follow-up processes for BLL reporting, interview process, collection of environmental samples, variable validation exercise and data analyses. Additional details with respect to specific protocols and materials are contained in the two volumes of technical documents prepared for the study.[4]

2.1 Study design

The study was originally designed as a population-based, stratified, random cross-sectional survey of BLLs and risk factor information. This was to be followed by a stratified random sub-sample to explore associations between environmental measures of soil, dust and household water lead levels and BLLs. Within the study area, Dissemination Areas (DAs) were initially randomly selected and concerted recruitment efforts within the selected DAs were undertaken (e.g., targeted letters to households, phone campaign). Despite these efforts, there was limited response from these DAs within the first two weeks of the study implementation. At the two-week mark, the contingency plan was then implemented which involved converting the study design from a stratified, random cross-sectional design to a non-random, self-selected cross-sectional design (*primary sample*).

At the same time, the design for the random sub-sample for environmental measures was converted to a quota sub-sample selection process during which households were invited to participate according to the age of their housing and residential geographic zones developed according to industry proximity (*environmental sample*). In order to produce some variation across the study area for the association analyses, a quota sampling methodology was used which took into consideration four geographic zones based on air lead levels (i.e., Industry-Adjacent Zone; Middle Zone; Escarpment Adjacent Zone and Old Recycling Plant) and two categories of age of housing (i.e., older housing built prior to 1950; housing built 1950 or later). The sampling plan consisted of quota sampling 50 households from each of four categories: 1) Older Housing in Industry-Adjacent Zone; 2) Newer Housing in Industry-Adjacent Zone; 3) Older Housing in Escarpment-Adjacent Zone; and 4) Newer Housing in Escarpment Adjacent Zone. As well, all households in the Old Recycling Plant Zone with children who visited the clinic were invited to participate in the environmental sample.

There were three main study inclusion criteria which children had to meet in order to be considered part of the study. These criteria were:

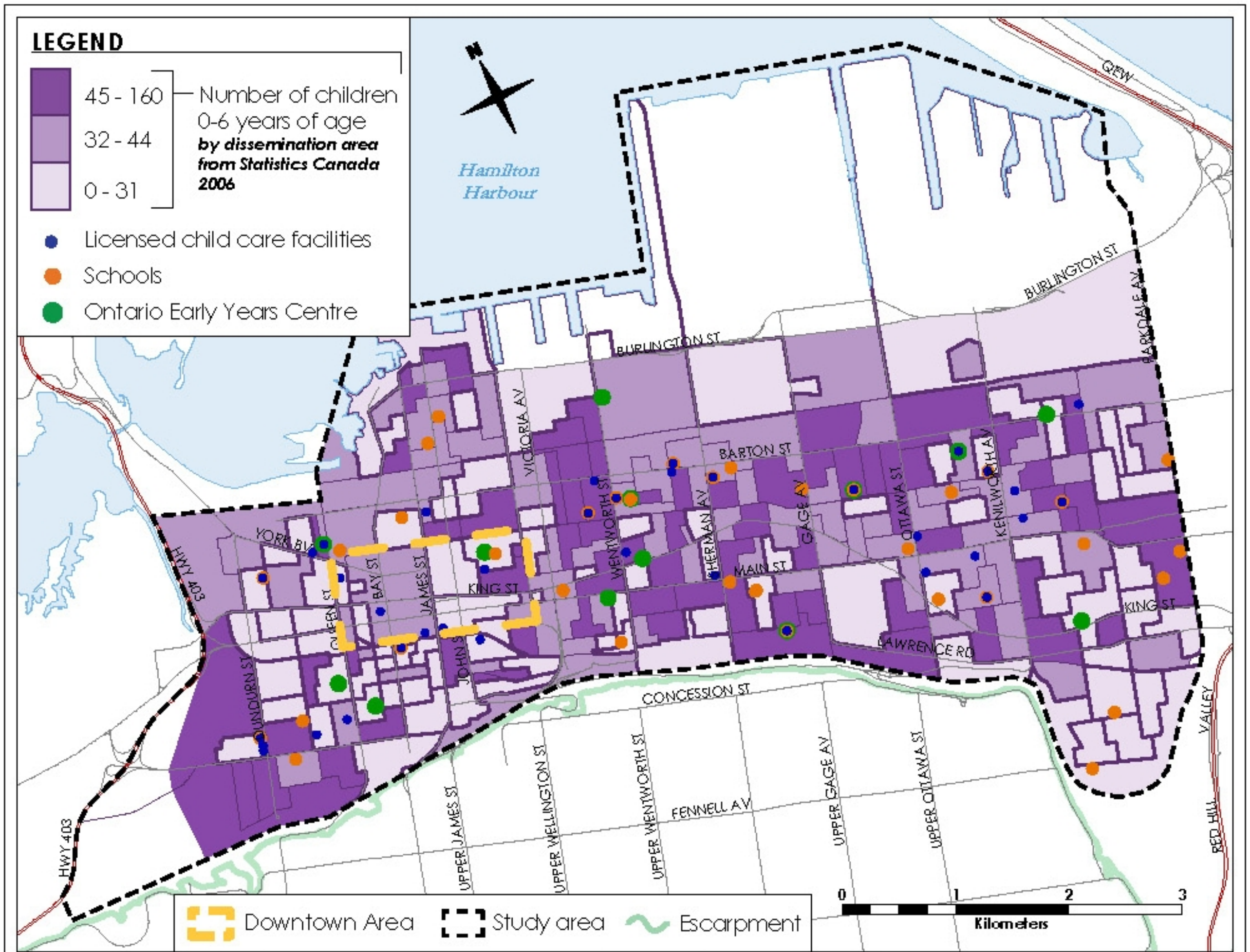
- Child had to be under 7 years of age at the date of the capillary blood draw;
- Child had to be currently living in one of the DAs within the defined study area; and
- Child had to have lived at least three months in the study area, unless they were less than three months old at the time of the capillary blood draw.

Children who attended a clinic but did not meet the residency requirements were still provided with the opportunity to provide a capillary blood sample with his/her parent/guardian receiving the results and any opportunities for follow-up, but their results were not included in the study. Children who did not meet the age criterion were referred to their family physician.

[4] *North Hamilton Child Blood Lead Study Technical Documents Volume I-II*

The study area was defined within North Hamilton, and included the "downtown core" area. As illustrated in Figure 2.1, the study area is bounded to the north by Hamilton Harbour, to the south by the Escarpment, to the west by Highway 403, and to the east by Parkdale Avenue. According to the 2006 Census, approximately 9,000 children under 7 years old were living in the study area. Figure 2.1 demonstrates that the geographic distribution of children is uneven across the study area, with some areas having greater concentrations of children under 7 years old (e.g., south-east, central). In contrast, the recruitment points for the study (e.g., child care facilities, schools, Ontario Early Years Centres) were relatively well dispersed across the study area.

Figure 2.1: Distribution of children and recruitment points in study area[5]



*Note: Peripheral dissemination areas were cropped to more accurately reflect the location of residential housing.

The study was implemented in the fall of 2008. The data collection period allowed for BLLs to be measured immediately following the summer months. It was hypothesized that children would have a high exposure to lead found in the soil and air during the summer, as they would be likely to spend a considerable amount of time playing outside. In addition, the return to school and work schedules after the traditional summer vacation period facilitated participation in the study.

[5] Additional information about maps used throughout the report is contained in Appendix B.

Recruitment of children and their families for the study took place over a 14-week period and was achieved through an extensive public awareness campaign for the study. The campaign focused on study rationale, participation requirements, and the importance of this type of study for the community. Activities included media briefings and releases, media interviews with the local Medical Officer of Health, radio and newspaper advertisements, flyers sent to parents through schools, daycares and Ontario Early Years Centres, letters sent to households, and a phone campaign.

2.2 Ethics review process

Prior to study implementation, HPHS applied for and received ethics approval for the study from the Hamilton Health Sciences Faculty of Health Sciences Research Ethics Board (HHS/FHS REB) at McMaster University. To ensure that the accepted ethical standards for this type of study as outlined in the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (1998) were met, the HHS/FHS REB reviewed the study rationale/objectives, study design, methods, detailed protocols, recruitment materials, consent forms, study follow-up threshold, follow-up procedures, and reporting of results to parents, guardians and physicians.

2.3 Capillary blood collection at community clinics

HPHS implemented portable clinics to collect capillary blood samples from study participants. The entry point for the study was at one of the clinics. In response to the public awareness campaign, parents brought their child to a clinic, provided informed consent and some basic information about the child (e.g., age, sex, residency) and household (e.g., address, year built). This information was subsequently used by the study research team to determine eligibility and assignment into the environmental sample. A capillary blood sample was then collected from each child whose parent/guardian provided informed consent. Parents/guardians were then asked whether they were willing to participate in a phone interview at a later date. Clinics were staffed by a certified phlebotomist and an administrative team member. Clinics were established in various convenient locations throughout the study area such as municipally-run community and recreation centres, and Ontario Early Years Centres. In total, 60 clinics were implemented at 16 sites between October 28 and December 11, 2008.

The preparatory process for collecting the capillary blood sample involved washing the child's hand with an antiseptic impregnated surgical soft scrub brush for three minutes, wrapping the washed hand in sterile gauze, and then placing an infant heel warmer on the hand for another five minutes. Once the child's hand was sufficiently warmed, the phlebotomist lanced the middle finger on the child's hand with a contact-activated disposable lancet, and proceeded to collect a blood sample of approximately 200-300µl in a BD Microtainer © containing lithium heparin. Children under 12 months had a blood sample drawn from their foot (heel). Tubes were immediately labeled by the phlebotomist and stored in a portable refrigerator following an established quality assurance/quality control (QA/QC) process. Samples were shipped to the [Toronto] Central Public Health Laboratory of the Ontario Ministry of Health and Long Term Care where they were analysed for lead by graphite furnace atomic absorption spectrophotometry. The limit of detection for lead in whole blood was less than 0.05µmol/L.

Once blood analyses were completed, parents/guardians were provided with their child's BLL result. If consent had been provided by the parent/guardian, family physicians were also provided with their patient's BLL. The follow-up procedures and outcomes are described in more detail in Sections 2.4 and 6.0.

2.4 Overview of study follow-up process

The current Health Canada blood lead guidance value for the general population is 0.48 μmol/L (10 μg/dL). A guidance value is the level above which follow-up actions may be considered to reduce exposure. This guidance value is presently under review. Recent estimates are that approximately 1% of the general Canadian population would have BLLs above the guidance value (Wong & Lye, 2008).[6] The study also set a lower follow-up threshold level of ≥ 0.19 μmol/L for children to be referred for a venous re-test of their BLL. The study threshold value was purposefully selected as lower than the current Health Canada guideline value. This lower value facilitated opportunities for children with capillary blood lead levels in an above average range to be referred for a venous re-test and additional blood tests (hematocrit and hemoglobin). In addition, this lower level ensured a sufficient sample size for the purpose of exploring associations between risk and mitigation factors with BLLs. As one component of the study design, the study team developed a detailed algorithm for follow-up with the parents/guardians of children who met or exceeded this threshold. The main steps for follow-up of children with capillary BLLs at or above the study threshold level were:

1. ***Parents/guardians contacted to review capillary results*** – A public health nurse contacted parents/guardians by phone to initially review the capillary BLL results and to recommend that the child have a venous re-test within 3 to 5 days in order to further assess levels of blood lead, hemoglobin and hematocrit. Arrangements were made to provide the family with a laboratory requisition form and transportation to the hospital collection centre, if required.[7]

2. ***Parents/guardians contacted to review venous re-test results*** – Once the venous results were available, the HPHS public health nurse contacted parents/guardians by phone to discuss the results, and to make appropriate referrals, if required.

3. ***Referrals to family physicians and/or study paediatricians*** – Three possible outcomes according to venous blood results:
   a. *BLL < 0.19 μmol/L and hematocrit and hemoglobin within normal limits* – no further follow-up
   b. *BLL < 0.19* μ*mol/L and hematocrit and/or hemoglobin not within normal limits* –the study team would notify the family physician of the results by phone and fax and a request was made that the child be subsequently followed up by the family physician
   c. *BLL ≥ 0.19* μ*mol/L* – the study team referred the child to one of two study paediatricians. The referral package for the study paediatrician included capillary and venous laboratory results, information collected as part of the risk factor questionnaire, and as available, any environmental sampling results (tap water lead, dust lead) collected from the child's home once available.

4. ***Home visit by public health inspector*** – For children referred to a study paediatrician, their parents/guardians were offered the opportunity of having a HPHS public health inspector conduct a home visit to perform a home risk assessment, review the risk factor survey, and to provide various information and resources on available programming as well as methods to reduce lead exposure.

[6] Wong, S.L. & Lye, E.J.D (2008). Lead, mercury and cadmium levels in Canadians, Health Reports, Vol 19(4) p.31-36; Statistics Canada, Catalogue no. 82-003-XPE
[7] Approximately one-quarter of families (24%) indicated needing assistance with transportation to and from the local hospital laboratory for venous re-testing.

5. ***Dissemination of results and information*** – As the final stage of the follow-up process, the study team sent parents/guardians a personalized letter with their child's capillary and venous blood test results and any recommendations pertaining to follow-up, along with a copy of the completed and signed study enrollment consent form, and general information to reduce environmental lead exposure. For families that had also participated in environmental sampling, they were also provided the results from their dust, water and soil samples. If the family had consented, family physicians were provided with the capillary and venous blood lead results. As well, if applicable, the family physician was provided with a copy of the study paediatrician's consultation note.

2.5 Phone interviews with parents/guardians

HPHS developed a questionnaire designed to collect information on various risk and mitigation factors potentially associated with BLLs. Parents/guardians of children who agreed to the interview were followed up on average within 14 days by a member of the research team. The interview covered various areas including but not limited to: where the child spends daytime hours, access to soil, hand-washing frequency, household hygiene practices, adults' occupations, recent household renovations, and water sources. Interviewers used a computer-assisted telephone interviewing system in order to ask questions and to capture responses in a systematic, controlled manner. The interview took on average 20 minutes to complete, depending on the number of children in the household. Households that were not able to easily converse in English or French were provided with a translation service. Interviews were conducted between November 4, 2008 and January 30, 2009.

2.6 Collection of water, dust and soil samples

A sub-sample of parents/guardians at clinics were asked if they would be willing to have a member of the research team come to their house to collect water, dust and soil samples. Households were selected into this quota-based environmental sub-sample according to their geographic location and the age of their housing, but were excluded if a phone interview was not completed. For those who agreed, a research team member arrived at the house at an agreed upon time and collected one water sample from the kitchen faucet, and one swipe dust sample from each of the living room, kitchen and child's bedroom. Samples were collected between November 10, 2008 and January 22, 2009. Soil samples were collected by the MOE during the summer of 2009.

Water samples were collected using methods developed by the Ontario Ministry of the Environment (MOE). The kitchen tap was flushed for five minutes and then left to stand unused for 30 minutes (along with other water faucets/toilets in the house), after which water samples were drawn. Water samples were labeled and shipped to Maxxam Analytics (Mississauga, ON), for analysis by inductively coupled plasma mass spectrometry (ICP-MS). The limit of detection for lead in water was 0.5μg/L.

Dust samples were collected according to the American Society for Testing and Materials standard E 1728-03. The procedure involved using a square foot template within which a dust wipe was passed back and forth in a specific pattern across the floor within the template using a gloved hand. This was repeated for each of the sites that were tested (i.e., living room, kitchen, bedroom). Dust samples were labeled and shipped to A&L Laboratories Inc. (London, ON) for analysis by ICP-MS. The limit of detection for lead in dust was 1.0 μg/ft^2.

Soil samples were collected with a tube-type soil corer. A sample consisted of soil to a depth of 5 cm collected from a household's front, back or side yard depending on where the child played most frequently and/or where there was sufficient conditions to sample. No soil samples were obtained off-property. Samples were analysed at the MOE Phytotoxicology Laboratory (Toronto, ON) using atomic absorption spectrophotometry. The limit for detection for lead in soil was 5 µg/g dry weight.

2.7 Other secondary data sources

In addition to the primary data collected specifically for the purposes of this study, data were also accessed, compiled and analysed from a number of secondary sources to assist with addressing the study objectives. The main sources of secondary data included:

- *2006 Census Community Profile* – Data from the 2006 Census were used to develop profiles and descriptions of the target population, outline the sampling strategy, assess response rates, and assist in post-hoc weighting.

- *Ministry of Environment (MOE) Air Sampling Program* – Data collected in 2008 from five air monitors located within the study area, and a map designating three air lead level zones[8] for the City of Hamilton developed by the MOE were used to develop the sampling strategy for selection of households for further environmental sampling (e.g., water, soil, dust), and as a measure of potential air lead exposure for study participants.

- *City of Hamilton Hydrant Water Sampling Program* - The 2007-08 data measuring lead levels from water samples collected from city hydrants was used for sub-analyses to determine relationships with lead levels in tap water.

- *Municipal Property Assessment Corporation (MPAC) Property Database* – Extractions from the 2008 MPAC Property Database were used to assess year of construction for housing in the study area to serve as a proxy measure for potential exposure to lead paint and pipes, and to develop the sampling strategy for selection of households for further environmental sampling (e.g., water, soil, dust).

2.8 Variable validation

Once the primary and secondary data were collected and compiled, the study team undertook an extensive process to validate the various variables and their associated measures. Initially, this process involved reviewing a concept map developed *a priori* by the research team that depicted the main theoretical constructs and hypotheses (see Appendix C for full schemata). Each main construct contained in the concept map was aligned with the specific measure(s) intended to represent that construct. Following this, the validity of each measure was then assessed based on the quality of the data collected from either primary or secondary sources. From this assessment, some variables were deemed to not have sufficient validity for inclusion in the study and were removed from further analyses. These included seasonality, as well as some of the self-reported variables collected during the interviews such as presence of lead pipes in house, worker hygiene practices, food security issues, and flushing water system prior to use.

2.9 Data analyses

Descriptive analyses

[8] The air lead zone map was developed with contours of common concentration that could be reasonably drawn through the geographic distribution based on seven stations' geometric means in 2006.

Extensive descriptive analyses were undertaken to address the primary research question (*What proportion of City of Hamilton children under the age of 7 years has blood lead levels requiring medical attention?*), as well as one of the secondary study objectives (*describe the presence of potential lead sources and specific risk and mitigating factors shown in previous studies to be associated with BLLs*). Analyses included measures of central tendency (e.g., median, arithmetic means[9], geometric means[10]), frequencies, and cross-tabulations. Key aspects of these analyses included the following processes:

- *Assessment of impact of post-weighting adjustments* – The 233 DAs of the study area were grouped into 17 geographically contiguous "neighbourhoods" based on similar socio-demographic characteristics assessed according to 2006 census data as well as geographic risks of lead exposure (e.g. proximity to industry, age of housing stock, and participation rate to maximize homogeneity within boundaries). From these groupings, post-hoc weights were developed based on ratios of responses to population within each area. The assessment of the impact of post-weighting determined that while the weighting appeared to adjust the sample characteristics to more closely resemble the population, the actual impact of weighting on the outcome variable (BLLs) was minimal. Given this assessment, the study team decided to continue the descriptive analyses using unweighted data.

- *Treatment of censored values* – The laboratory analytic procedures for the capillary blood resulted in a small proportion of samples below the limit of detection (LOD) (0.05 µmol/L). Two methods of substitution (LOD/2; LOD/√2) and one method of estimation (maximum likelihood estimate) were used to assess the extent of impact each method had on exposure estimates quantified by arithmetic and geometric means.[11] The three methods produced geometric means that were nearly identical, all within 0.003 µmol/L of one another. This is likely due to the small proportion of censored values (8.8%) and the relatively large overall sample size (n=643). The values reported are those that were obtained by using the substitution method of LOD/√2.

- *Assessment of distribution of BLLs* – The initial assessment of the distribution of BLLs indicated that the values were not normally distributed. The study team proceeded to log-transform the BLLs which improved the fit of the BLLs to a normal distribution, but statistically significant differences between the distribution of the logarithm of the BLLs and a normal distribution remained. As a result, the descriptive analyses presented use the non-transformed values. Given that the lack of fit to a lognormal distribution suggests that systematic rather than random variations may be affecting the distribution of BLLs in the sample population, this was further explored in some of the multivariate analyses.

- *Outliers* – During the variable validation phase, data were reviewed for potential outliers. An extreme outlier that was identified was one living room dust value that was nearly three times higher than the second highest value, and over 60 times the median value. A case analysis could not determine any probable cause for this extreme value, and it was not in the same range with the other dust values collected for that residence. As a result, this one

[9] Also called the average or average value, the ***arithmetic mean*** is the quantity obtained by summing two or more numbers or variables and then dividing by the number of numbers or variables.
[10] The ***geometric mean*** is a type of average, which indicates the typical value of a set of numbers. It is similar to the arithmetic mean, except that the numbers are multiplied and then the nth root (where n is the count of numbers in the set) of the resulting product is taken. Geometric mean is a useful summary measure for highly skewed data.
[11] Finkelstein, M. & Verma D. (2001) Exposure Estimation in the Presence of Nondetectable Values: Another Look. *AIHAJ* 62:195–198.

value was removed from the analyses including graphical depiction of the data (e.g., maps, scatterplots).

- *Missing data* – One aspect of the variable validation process was to review the patterns of missing data both within and across measures. Where there were copious amounts of missing data, this contributed to considering a measure as invalid (e.g., type of water pipes in housing). For the descriptive analyses, the proportion of missing data (primarily from the measures collected during interviews) was reviewed and only reported in the frequency tables if greater than 5% of the sample.

- *Non-random and non-independent samples* - As the sampling was not based on a simple random sample, there was some clustering in certain neighbourhoods and also within households when two or more siblings were brought to the clinics. Several different statistical procedures were utilized to test the sensitivity of the findings to these sampling issues including neighbourhood weighting and jack-knifing procedures. Generally there were only minor differences between the different analysis approaches. For reporting and interpretation purposes, the final descriptive and modeling analysis used unweighted data given these minor differences. Moreover, no samples from within a shared household were excluded due to reasons of non-independence.

Multivariate analyses (modeling)

The study team conducted multivariate analyses to address the secondary objective (S4) of exploring associations between:

- Potential lead sources, specific risk and mitigating factors and BLLs; and
- Potential lead sources, specific risk and mitigating factors and environmental lead levels; and
- Environmental lead levels, mitigating factors and BLLs.

Prior to conducting the multivariate analysis with the natural log-transformed BLLs and environmental lead levels, Ordinary Least Squares (OLS) regression models were run with the untransformed variables to more easily interpret expected findings and identify potential outliers. Iterative tests were run entering variables at different stages of the model to assist in understanding the potential linkages between the predicted and predictor variables. Testing different stages of the model allowed the study team to identify the unique variance contributed by a predictor as it entered the model. Levels of multicollinearity among the predictors were also examined as different predictors entered the model to identify potentially problematic variables.

Once the preliminary iterative model testing was completed, the final models were developed using log-transformed values for BLLs and environmental lead levels for the water soil and dust levels. The models were guided by the hypothesized associations depicted in the concept map developed by HPHS. Based on the hypothesized associations, the following analyses were conducted:

- A separate model predicting intermediary sources of lead levels (dust, water, and soil) based on specific risk and mitigating factors (included only survey respondents who had environmental samples taken);
- A model predicting BLLs based on primary lead sources, and specific risk and mitigating factors (conducted for the entire sample surveyed);
- Separate and combined models for the intermediary lead sources with associated mitigating factors predicting BLLs (included only survey respondents who had environmental samples taken).

For continuous predictor variables, tests were conducted to determine if converting to categorical variables would significantly improve the fit of the model over a simple continuous format. All environmental level measures were left as continuous variables in the final models, although some other measures such as housing age and income were found to provide more predictive power as categorical variables. The removal of some larger values for the environmental measures was also tested to determine the impact of potential extreme values. The only value that was eliminated from the analysis was one extreme dust level discussed previously. When there were sufficient cases, missing values for categorical variables were included as a separate dummy variable in the regression modeling. For some “yes/no” variables, where there were only a few missing cases, these were included with reference group to keep the sample size as large as possible for the analysis and also avoid multicollinearity problems with multiple small numbers of missing cases being coded as separate dummy variables.

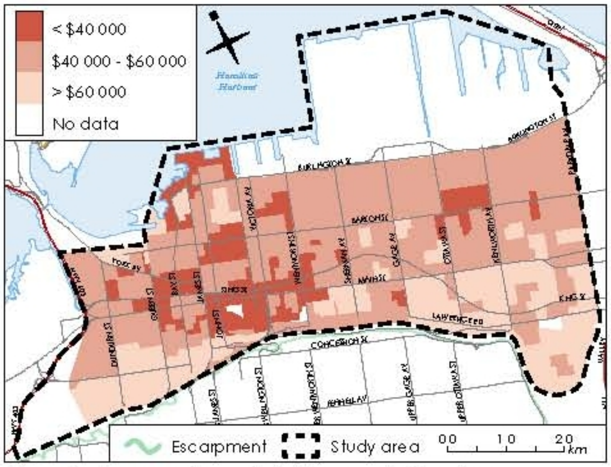
3.0 Study Area, Target Population and Samples Achieved

The section provides an overview of the study area in terms of the key characteristics of the target population, as well as the various potential environmental lead sources within the study area. Also included in this section is a description of the samples that were obtained by the study (primary, interview, environmental), and the response rates achieved according to various geographic and socio-demographic characteristics.

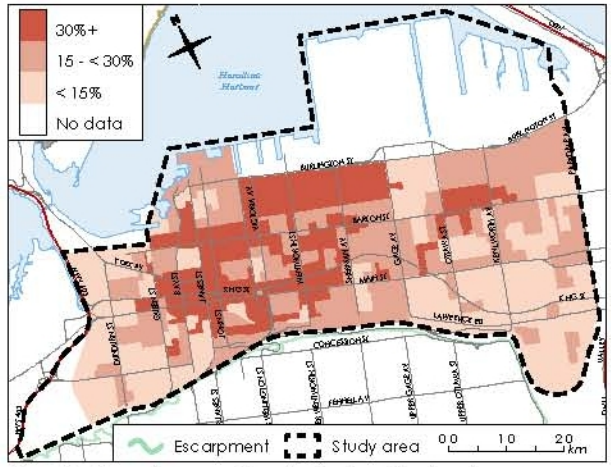
3.1 Study area and population characteristics

The study area has some diversity with respect to various social and economic factors. There are areas characterized by high measures of socio-economic status; however, in general, the study area has high concentrations of low socio-economic markers. The proportion of families living in the study area with income below the low income cut-off in 2005 was 25%, somewhat higher than the City of Hamilton overall (14%). As illustrated in Figure 3.1, families with lower household incomes tend to cluster in the central, downtown core area where the prevalence of people living in low income families is over 30% in many of the DAs. Similarly, while approximately one-half of families in the overall study area own their dwelling (49%), a larger majority of families live in rental accommodations within the downtown core area. The rate of home ownership in the study area is lower than that found in the City of Hamilton overall (68%). The rate of working age adults (25-64 years) who did not have post-secondary education was higher in the study area (60%) when compared with the overall City of Hamilton (42%). Within the study area, the lower rates of post-secondary education appear to be associated with neighbourhoods closer to the industrial area along the north shore, and not necessarily with the downtown core area. The study area is also home to recent immigrants with approximately 5% of residents having immigrated to Canada within the past five years, a prevalence rate that is slightly higher than for the City of Hamilton (3%). As illustrated in Figure 3.1, recent immigrants are more likely to live in the downtown core area extending south. Overall, 14% of the study area residents do not speak either official language at home. This is similar to the rates in the City of Hamilton overall (13%). Within the study area, there are neighbourhoods that extend north and east from the downtown core with greater than 20% of the population who do not speak either official language at home.

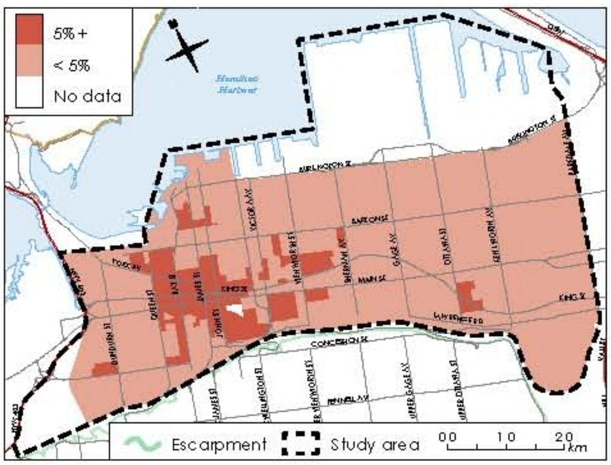
Figure 3.1: Distribution of socio-demographic factors in study area



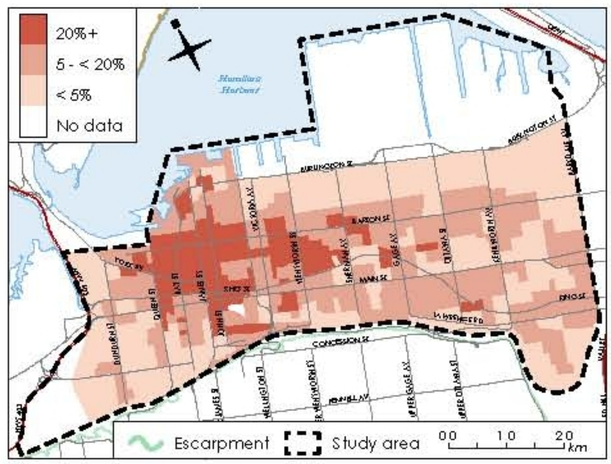
Map A: Average household income before tax



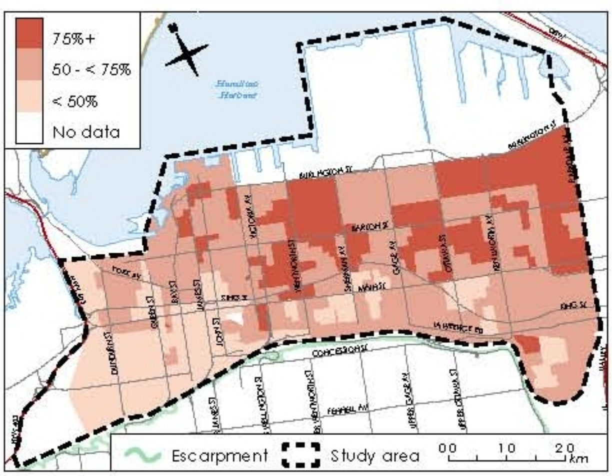
Map B: Prevalence of families below the low income cut-offs



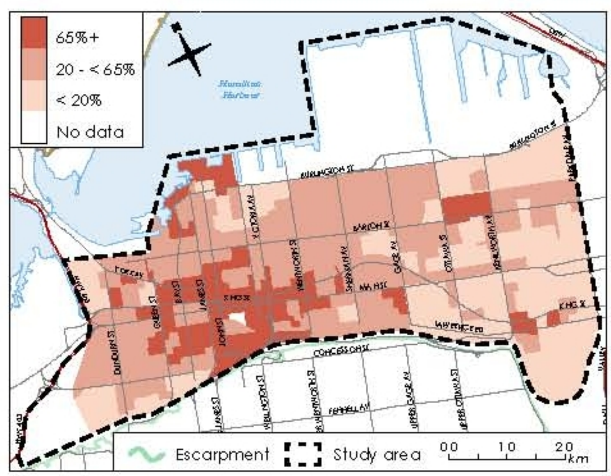
Map C: Prevalence of recent immigrants



Map D: Prevalence of non-official language most often spoken at home



Map E: Proportion of individuals aged 25 to 64 years without post secondary education



Map F: Prevalence of rental dwellings

Note: *Areas displayed by dissemination area from Statistics Canada 2006. Peripheral dissemination areas were cropped to more accurately reflect the location of residential housing.*

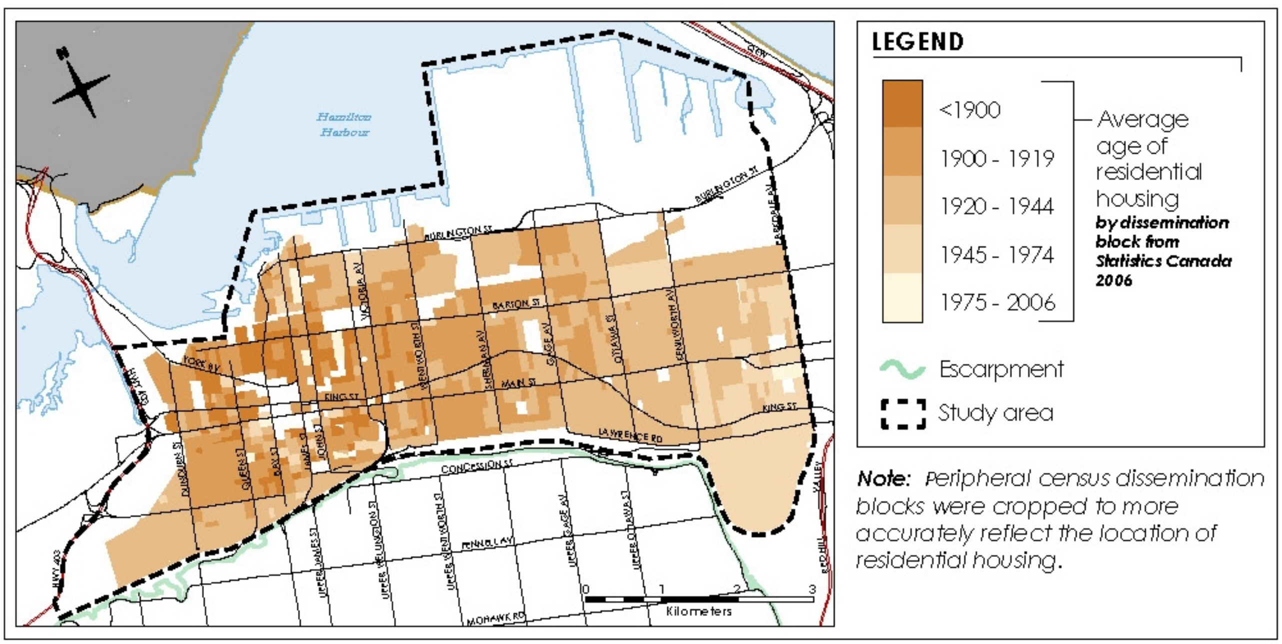
3.2 Potential environmental lead sources within study area

The main potential environmental lead sources identified within the study area were related to age of residential housing (e.g., lead paint, lead water pipes), City of Hamilton water distribution (e.g., lead service pipes), current and historic lead-emitting industries (e.g., air, soil), and ambient air. Each of these potential sources is described below.[12]

Age of Housing in Study Area

Overall, the study area is characterized by older residential housing and neighbourhoods with the median residential house age being 89 years. It was anticipated that many homes may still have lead paint on the interior or exterior surfaces, and that the soil in most neighbourhoods in the area would likely have some lead present. Within the older neighbourhoods, there are a small number of new infill properties that are less likely to present the same levels of potential exposure due to newer construction and changed/added soil. In addition, there are a few neighbourhoods in the study area that were primarily constructed after 1945 in the south-western and eastern portions of the study area, and one relatively new neighbourhood in the extreme southeast (see Figure 3.2).

Figure 3.2: Distribution of residential housing by period of construction in study area



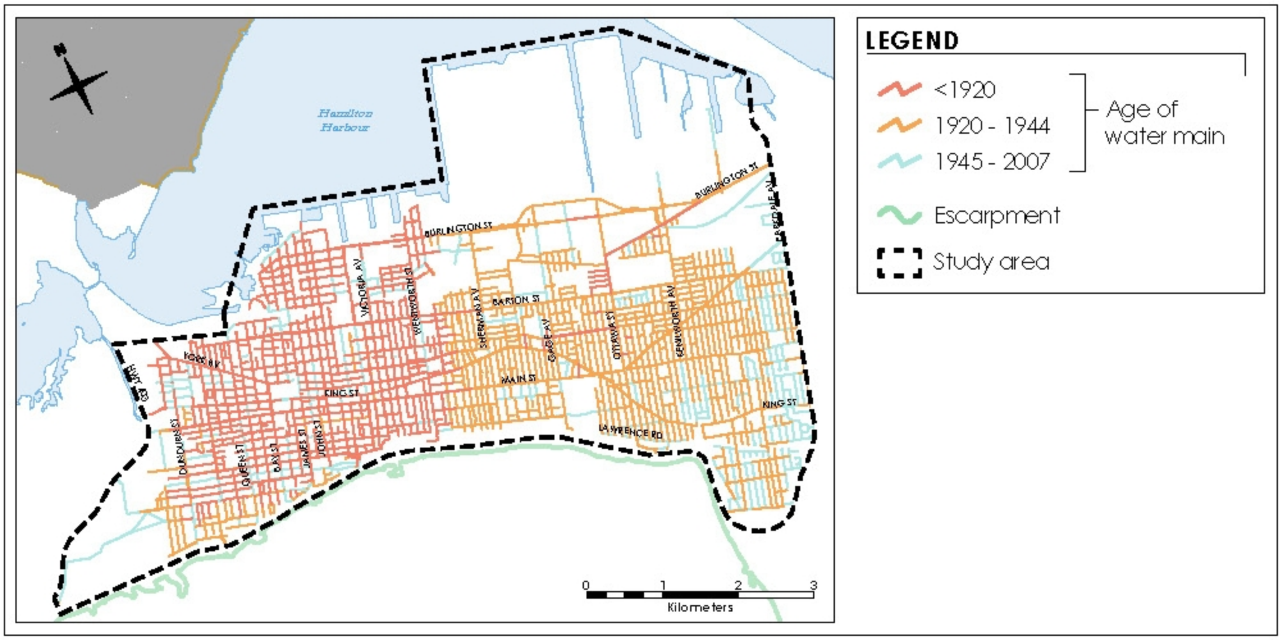
City of Hamilton Water Distribution in Study Area

Similar to the old housing stock in the study area, the vast majority of the water mains were laid prior to 1945 and many residential homes could potentially have lead service pipes. The geographic pattern is similar to that of the age of residential housing, with the only area with newer pipes being located in the extreme southwest and southeast corners of the study area (see Figure 3.3). Although the age of the pipes varied over the study area, an analysis of municipal water supply collected at hydrants throughout the study area demonstrated that the water lead levels did

[12] Lead from gasoline vehicle emissions was also considered as a potential source (historical); however, there were no data or reasonable measures that the study could obtain for this source.

not vary across the study area. Therefore the authors assume variation in water lead levels to be reflective of lead in service and household piping.

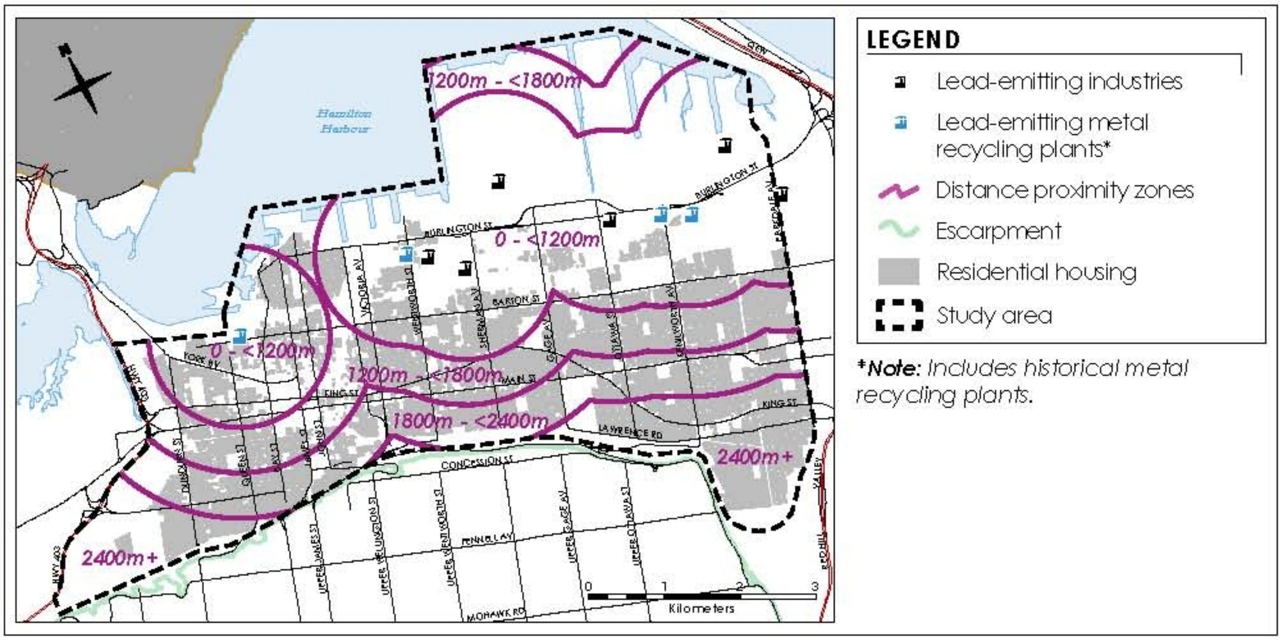
Figure 3.3: Distribution of water mains by period of construction in study area



Current and Historic Lead-Emitting Industries in Study Area

Within the study area there are both historic and current lead-emitting industries. As illustrated in Figure 3.4, most of these industries are located in the northern portion of the study area which is an industrial zone. In addition, there is one area in the northwest corner of the study area that housed a metal recycling plant (near the intersection of Queen Street and Barton Street) that historically emitted lead and other metals. In 1994, the Ontario Ministry of the Environment and Energy performed a survey of soil lead levels on properties in close proximity to the former metals recycler that revealed numerous residential soil concentrations for lead exceeded the MOE's 200 µg/g health-based guideline. For display purposes, the study area was divided into four zones based on rough quartiles of the proximity of the residential properties to the closest current or historic lead-emitting industry, as outlined in Figure 3.4.

Figure 3.4: Distribution of historic and current lead-emitting industries in study area

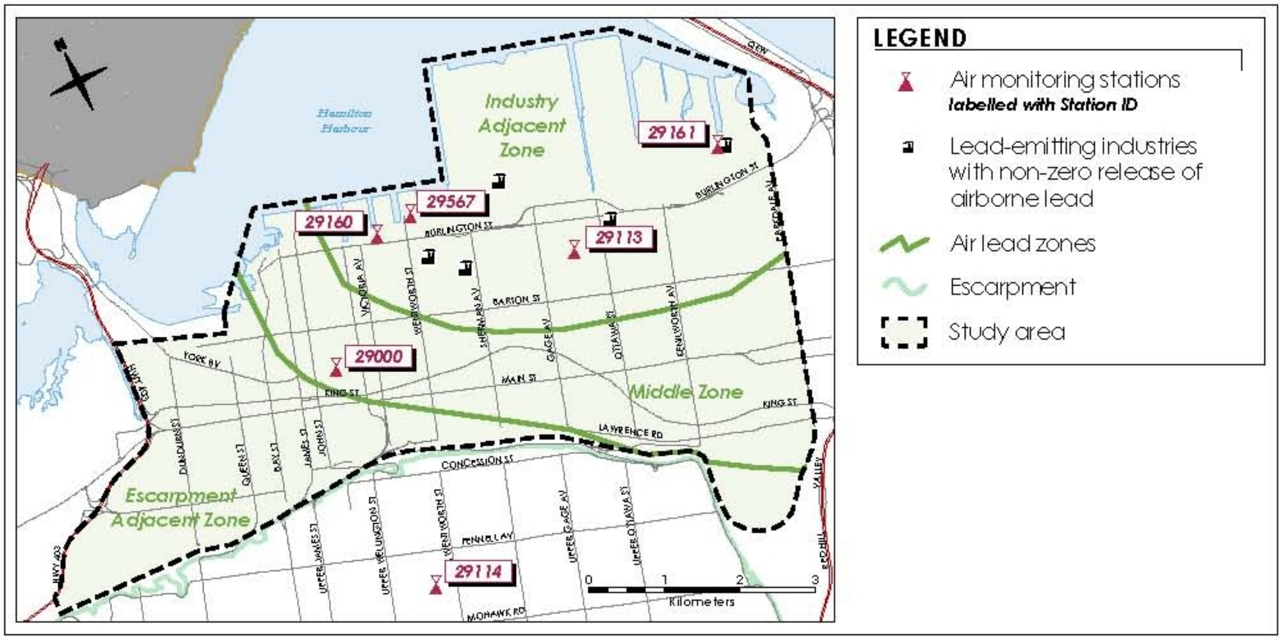


Ambient Air Lead

There are five air monitoring stations that are operated within the study area and one additional station adjacent to the study area (south and downwind of prevailing wind) that measure ambient air lead levels. As illustrated in Figure 3.5, the MOE has outlined air lead levels characterized via three main zones based on contours of common concentration that could be reasonably drawn through the geographic distribution based on seven stations' geometric means in 2006. Air lead levels in the City of Hamilton have been below the standards since lead was removed from gasoline in the 1970's. Analysis of 24-hour ambient air lead data found that the study area median air lead levels have continued to decrease from 1980 to 2008. In 1980, median air lead levels ranged from approximately 0.3 to 0.6 µg/m^3, and by 1990 median levels had fallen to 0.2 µg/m^3 or lower. Current air lead standards are: 1) a 30-day Ambient Air Quality Criterion (AAQC) of 0.2 µg/m^3 (micrograms per cubic metre of air); 2) a 24-hour AAQC of 0.5 µg/m^3; and 3) a half-hour AAQC of 1.5 µg/m^3.

Analysis also found that air lead levels varied by both zone and season with air lead levels highest in the industry-adjacent zone, while air lead levels in the middle zone and escarpment-adjacent zone were similar. The air lead levels were highest in March, April and May and lowest in October, November and December. It was noted that while there is a slight gradient from the northeast industrial corner to the escarpment and some seasonal variations, all ambient air lead levels are low and well below standards and guidelines.

Figure 3.5: Distribution of air monitoring stations and air lead zones in study area



3.3 Samples achieved

As described in Section 2.1, the original study design was a population-based, stratified, random cross-sectional survey of BLLs and risk factor information. This was to be followed by a random sub-sample to explore associations between environmental measures of soil, household dust and water lead levels and BLLs. Given the low early response rates from the 54 randomly selected DAs, the study was converted to a self-selected sample from the overall study area (233 DAs). Households were invited to participate in an additional component of environmental sampling of water, soil and dust according to a stratified, quota sampling design.

There were three main samples of study participants. These included:

- *Primary sample* – a self-selected sample of children aged less than 7 years (84 months) who provided a capillary blood lead sample, and who at the time of participation had been living in the study area for at least 3 months prior (n=643 children);
    - *Interviewed sample* – a sub-sample of the primary sample whose parents/guardians completed a telephone interview with the study team. (n=580 children); and
        - *Environmental sample* – a sub-sample of the interviewed sample selected using a stratified quota sampling process based on housing age and air lead zone (n=281 children).

Primary and interviewed samples

The study successfully recruited 643 children from 453 households to provide a capillary blood sample (*primary sample*). As illustrated in Table 3.1, the overall participation rate was 7.2%. There were slightly higher participation rates among boys compared with girls; and among younger children compared with older children. From the 453 households that had children provide capillary blood samples, parents/guardians from 406 households also agreed to be interviewed by the study team to collect additional information on various aspects of the child's environment (580 children – making up the *interviewed sample*).

Table 3.1: Primary and interviewed samples overall and by age and sex

Child Factor Categories		Study Area Population	Primary Sample Population	Participation in Primary Sample (%)	Interviewed Sample Population	Participation in Interviewed Sample (%)
Overall		8,922	643	7.2	580	6.5
Age	**0 – 4 years**	6,440	489	7.6	443	6.9
	5 – 6 years	2,482	154	6.2	137	5.5
Sex	**Female**	4,391	291	6.6	264	6.0
	Male	4,531	352	7.8	316	7.0

Source: Source: 2006 Census -Profile for Canada, Provinces, Territories, Census Divisions, Census Subdivisions and Dissemination Areas, 2006 Census; Study data

The study team examined the participation rates according to specific DAs (neighbourhoods) to determine the representativeness of the sample obtained on selected socio-economic indicators when compared with the overall population. As illustrated in Table 3.2, by using data available from Statistics Canada 2006 Census profiles, the study team found that people were more likely to participate in the study if they lived in neighbourhoods with the following characteristics: higher median incomes, higher rates of home ownership, higher levels of post-secondary education, more likely to speak an official language at home, and fewer recent immigrants.

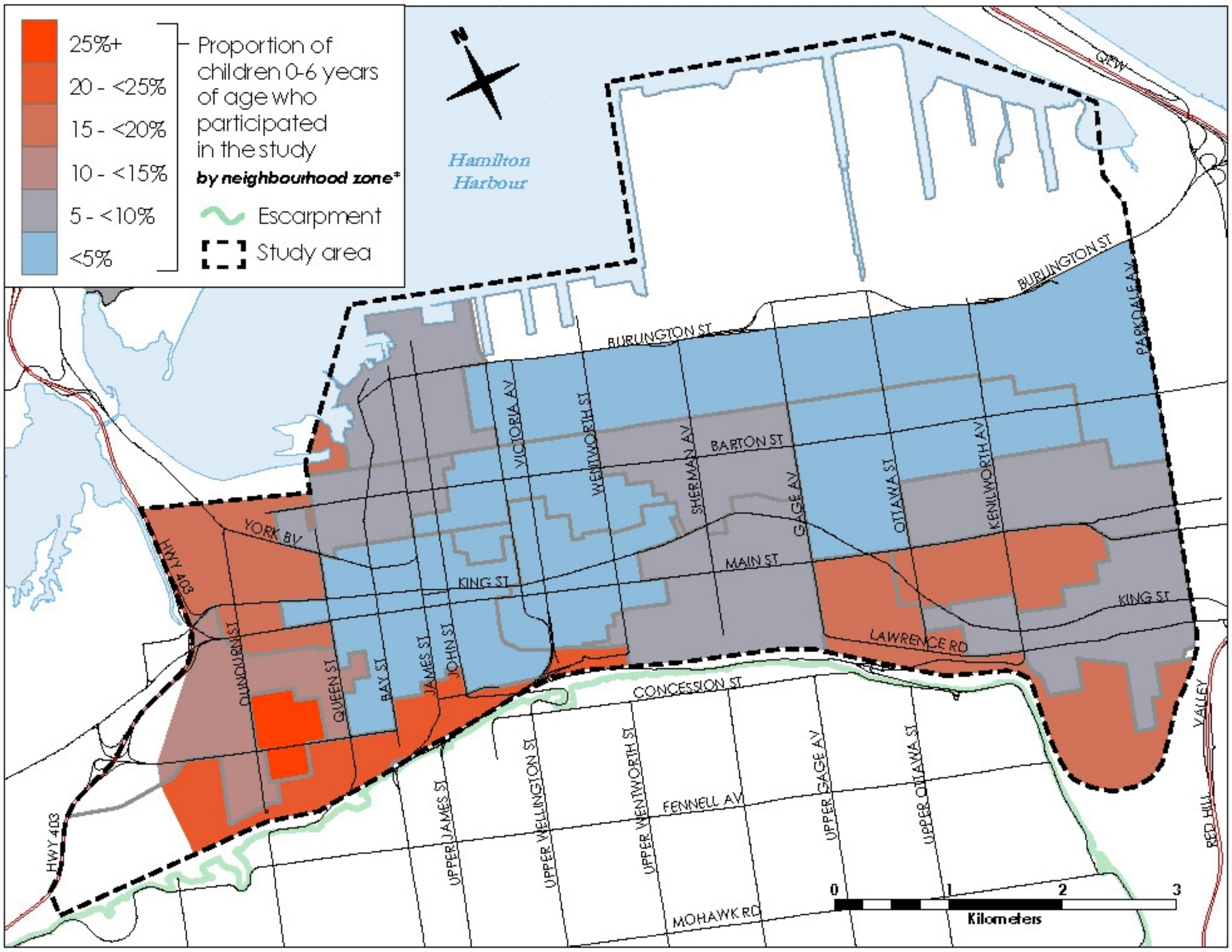
Table 3.2: Participation rates according to key socio-demographic characteristics

Neighbourhood Measure	Category Descriptions	Number of DAs (N=233)	Study Population (N=8922)	Primary Sample (n=643)		Interviewed Sample (n=580)	
				Count	Participation (%)	Count	Participation (%)
Average household income before tax	> $60,000	52	1928	279	14.5	261	13.5
	$40,000-$60,000	121	4427	303	6.8	267	6.0
	< $40,000	57	2506	60	2.4	51	2.0
	Missing	*3*	*61*	*1*		*1*	
Prevalence of families below the low income cut-offs	< 15%	66	2275	330	15	301	13
	15% - < 30%	95	3570	224	6	202	6
	≥ 30%	69	3016	88	3	76	3
	Missing	*3*	*61*	*1*		*1*	
Prevalence of recent immigrants	< 5%	181	6615	569	8.6	514	7.8
	≥ 5%	51	2276	73	3.2	65	2.9
	Missing	*1*	*31*	*1*		*1*	
Prevalence of non-official language most often spoken at home	< 5%	70	2416	272	11.3	258	10.7
	5% - < 20%	107	4004	287	7.2	247	6.2
	≥ 20%	55	2471	83	3.4	74	3.0
	Missing	*1*	*31*	*1*		*1*	
Proportion of individuals aged 25 to 64 years without post secondary education	< 50%	56	1986	219	11.0	209	10.5
	50% - < 75%	118	4534	303	6.7	268	5.9
	≥ 75%	58	2371	120	5.1	102	4.3
	Missing	*1*	*31*	*1*		*1*	
Prevalence of rental dwellings	< 20%	57	1980	216	11.0	197	10.0
	20% - < 65%	114	4368	355	8.1	319	7.3
	≥ 65%	61	2574	71	2.8	63	2.5
	Missing	*1*	*31*	*1*		*1*	

Source: 2006 Census -Profile for Canada, Provinces, Territories, Census Divisions, Census Subdivisions and Dissemination Areas, 2006 Census; Study data

The study team also examined participation rates according to geographical distribution, proximity to industry, air lead zone and age of housing. Illustrated in Figure 3.6, participation rates were lower in the northern end and downtown core of the study area, and highest in the southwest corner. Similarly, as illustrated in Table 3.3, families who lived closest to industry (within 1200 meters of a current or historic lead-emitting industrial site; industry adjacent air lead zone) were the least likely to participate in the study. Participation rates across the different age of housing categories showed no discernible pattern.

***Figure 3.6: Participation rates*[13]**



***Note:** *Neighbourhood zones are aggregates of dissemination areas, based on homogeneity of neighbourhood characteristics related to lead exposure. Peripheral neighbourhood zones were cropped to more accurately reflect the location of residential housing.*

Table 3.3: Participation rates according to potential lead sources

Potential Source of Lead	Category Descriptions	Study Area Households (N=7572)*	Primary Sample Households (n=453)		Interviewed Sample Households (n=406)	
			Count	Participation (%)	Count	Participation (%)
Proximity to Current or Historic Lead-emitting Industry	0-1200m	2687	113	4.2	101	3.8
	1200m -<1800m	2404	120	5.0	101	4.2
	1800m-<2400m	1618	135	8.3	128	7.9
	>=2400	863	84	9.7	76	8.8
Age of House	Before 1900	997	61	6.1	55	5.5
	1900-1919	3023	161	5.3	143	4.7
	1920-1944	2413	156	6.5	143	5.9
	1945-1974	896	59	6.6	51	5.7
	1975+	242	15	6.2	14	5.8
Air Lead Concentration	Industry Adjacent Zone	1491	48	3.2	42	2.8
	Middle Zone	4335	226	5.2	200	4.6
	Escarpment Adjacent Zone	1746	178	10.2	164	9.4

*Estimated by weighting the number of private residences (from MPAC) in a Census Dissemination Area by the proportion of households in the Dissemination Area having children under 6 years old

[13] The 233 census Dissemination Areas were grouped into 17 larger zones that are visually homogenous for the SES characteristics and potential sources of environmental lead

Table excludes one record with missing address.
Source: MPAC Property Database and Study data

Environmental Sample

A stratified sub-sample of households was selected from the primary sample (excluding households without a completed interview) for additional environmental sampling (i.e., dust, water, soil). A total of 196 households (281 children) from the primary sample participated in the environmental sampling. Given the paucity of newer housing in the study area, the study was not able to recruit the planned number of households from the various stratified quota (see Section 2.1). As a result, during the recruitment phase, the study team opened up the quotas to include households from the Middle Zone, and families from any new housing within the study area. Despite this change, the majority of environmental samples were collected in older housing, with only a small number of samples from housing that was built in 1950 or later.

4.0 Description of Potential Sources of Lead, Risk and Mitigating Factors, and Environmental Lead in Study Samples

This section describes the interviewed and environmental samples according to the data collected during phone interviews on factors associated with children's BLLs (e.g., socio-economic, exposure, uptake), and from analyses of dust, soil and water samples collected from children's households. These analyses were completed to address the secondary study objective (S1): *To describe the presence of potential lead sources and specific risk and mitigating factors shown in previous studies to be associated with BLLs*. As illustrated in the concept map[14] used to outline the main study hypotheses, assumptions and measures, the following factors are described:

1. ***Socio-economic-cultural factors potentially associated with blood lead levels*** (e.g., income status, education levels)

2. ***Potential exposure to sources of lead in the environment***:
    - Exposure to primary sources of lead in the environment (e.g., paint, proximity to current and historic emitting industries, water pipes)
    - Exposure to intermediate sources of lead in the environment (e.g., soil lead, air lead)
    - Factors that influence the deposition of lead between primary and intermediate sources (e.g., home renovations, pets, type of dwelling)

3. ***Potential factors associated with uptake of lead from the environment***:
    - Child characteristics (e.g., age, sex, diet)
    - Household characteristics and behaviors (e.g., floor hygiene, personal hygiene, frequency of exposure to soil, tap water consumption)

In addition to questions about potential risk and mitigating factors, the interview questionnaire also collected information regarding available services promoted in the *"Get the Lead Out"* public awareness campaign that had been implemented by HPHS prior to the child blood lead study.

4.1 Socio-economic-cultural factors potentially associated with blood lead levels

The study assessed various socio-economic-cultural factors that from previous studies have been found to be associated with BLLs in children. These included factors such as household income, education levels, recent immigration, and home ownership. As illustrated in Table 4.1, the interviewed sample was primarily English-speaking, with a small proportion reporting having immigrated to Canada within the past five years. The sample was relatively well-educated with over one-half of the families with a university educated adult. In contrast, approximately one-fifth of the families interviewed reported that none of the adults in the household had post-secondary education. Associated with the higher levels of education, annual household income was over $60,000 for the majority of the sample. Of note, 6% of households reported a household income of less than $20,000 per year. The vast majority of the sample reported owning their own home with a smaller proportion renting.

[14] Refer to Appendix C which contains the concept map developed for the study that outlines the main hypotheses, assumptions and measures used to structure the interview questionnaire.

The interviewed sample obtained is characterized by higher incomes, higher rates of home ownership, and higher levels of post-secondary education when compared to the overall study area population. Given the characteristics of the sample, the overall geometric mean BLL and prevalence of BLLs above the Health Canada guideline value may be lower than what would have been found in a more representative sample of the study area. Interestingly, the post-weighting that was conducted taking into account neighbourhood socio-economic characteristics and potential sources of lead exposure to have the sample look more representative of the study area, was found to have little impact on the geometric means of BLLs (see Section 2.0).

Table 4.1: Socio-economic-cultural factors

FACTOR	% Households	% Children
Language spoken most often at home	*(n= 406)*	*(n=580)*
English	95.1	94.5
French	0.7	0.9
Other	4.2	4.7
Immigration to Canada within past 5 years	*(n= 406)*	*(n=580)*
Yes	5.7	5.7
No	94.3	94.3
Highest level of education among adults in household	*(n= 406)*	*(n=580)*
No post-secondary	19.0	18.5
Community college and non-university	25.1	24.0
University	55.9	57.6
Total household annual income	*(n= 361)*	*(n=517)*
Less than $20,000	6.9	8.3
$20,000 to < $40,000	12.5	11.0
$40,000 to < $60,000	18.8	19.9
$60,000 to < $80,000	21.9	21.3
$80,000 and greater	39.9	39.5
Property ownership	*(n= 406)*	*(n=580)*
Owner occupied	84.0	85.5
Rented	15.5	14.1
Public housing	0.5	0.3

Source: Study data

4.2 Potential exposures to sources of lead in the environment

Parents/guardians of the interviewed sample provided a variety of information about their children's potential exposure to primary and intermediary sources of lead in the environment, as well as factors that can influence the deposition of lead between primary and intermediary sources, as illustrated in the study concept map in Appendix C.

The study hypothesized that the primary sources of environmental lead for the area were likely to be house paint, proximity to historical and current lead-emitting industrial sources, historic vehicle emissions, lead water pipes, household objects and materials that contain lead, and parents' occupations that may transfer lead into the household environment. The study used both direct and proxy measures of these factors with the exception of historical vehicle emissions for which a valid measure could not be obtained.

Direct measures of lead in household paint were not available, so the study used the proxy measure of year that a house was constructed as the main indicator of paint as a source of lead in the children's environment. As illustrated in Table 4.2, the vast majority of families lived in housing that was constructed prior to 1945, a period during which paints typically contained substantial amounts of lead. A significant proportion of the sample households reported that there were interior painted surfaces in the home that were deteriorating or flaking. According to the study hypotheses, these two factors (older housing, flaking paint) indicated a higher risk of lead exposure potentially contributing to higher BLLs for children living in these households.

Proximity to industrial lead-emitting sources (either historical or current) was measured by initially identifying potential sources (see Figure 3.4) and then mapping individual properties to determine the nearest source and the distance to this source. It was hypothesized that the closer in proximity of a household to an industrial lead-emitting source, the higher the risk of a child's exposure to lead (via air, soil, dust). As illustrated in Table 4.2, one-half of the households in the interviewed sample were within 1,800 metres of an industrial lead-emitting source.

For the interviewed sample, a proxy measure of lead water pipes as a source of environmental lead was used rather than making direct assessments of households' water pipes, or asking parents/guardians as many were largely unsure whether or not there were lead water pipes in their house. As a result, the study considered the age of housing (discussed above), and the extent to which tap water was used for drinking and cooking as a proxy measure of potential exposure to lead from water pipes for the interviewed sample. It was assumed that older housing would be more likely to have lead water pipes or connectors, and families that used this tap water for drinking and cooking would have potentially greater exposure. As illustrated in Table 4.2, the vast majority of households report ingesting tap water through drinking and cooking activities. This combined with the generally older housing stock (and thus more likely to contain lead water pipes characteristic of the study area) may be contributing to greater lead exposure in children.

Given that lead was frequently used in the past for making metal toys and is currently used by some other countries in manufacturing jewelry and toys, parents/guardians were asked if their children play with or are exposed to jewelry, toys or cosmetics purchased or made outside of Canada, or play with toys/jewelry that are more than 50 years old. Overall, slightly less than one-half of children were reported to have been exposed to these objects that may contain lead. Similarly, potential exposure to lead from materials used by parents/guardians for various hobbies was also assessed by asking parents if they participate in hobbies such as stained glass, fish fly-tying, or auto/boat repair using white lead. Approximately one-fifth of households reported that there was an adult in the house who had a hobby that was potentially associated with materials containing lead.

Another primary source of environmental lead was hypothesized to be adults' occupations. One-fifth of households had one or more adults that were employed in occupations that are associated with potential exposure to lead.

Table 4.2: Primary sources of environmental lead

FACTOR	% Households	% Children
Year housing was constructed	*(n= 406)*	*(n=580)*
Pre 1900	13.6	12.8
1900 to 1919	35.2	37.2
1920 to 1944	35.2	34.8
1945 to 1974	12.6	11.9
1975 or later	3.5	3.3
Deteriorated interior painted surfaces	*(n= 406)*	*(n=580)*
Yes	44.8	46.6
No	55.2	53.5
Distance from house to nearest lead-emitting industry (current & historical)	*(n= 406)*	*(n=580)*
Less than 1,200 m	24.9	24.1
1,200m to < 1,800m	24.9	24.3
1,800m to < 2,400m	31.5	32.2
2,400m or greater	18.7	19.3
Type of water used for drinking and cooking	*(n= 406)*	*(n=580)*
Tap water only	58.1	58.5
Tap water and bottled water	37.9	37.2
Bottled water only	3.9	4.3
Child's exposure to lead-containing objects		*(n=580)*
Toys/jewelry purchased outside of Canada	--	35.7
Toys/jewelry over 50 years old	--	9.2
Makeup/cosmetics made outside Canada	--	6.5
Any of the above	--	42.7
Family member with lead-associated hobby	*(n= 406)*	*(n=580)*
Yes	21.9	21.9
No	78.1	78.1
Adult in household has an occupation associated with lead	*(n= 406)*	*(n=580)*
Yes	20.0	19.7
No	80.1	80.3

Source: Study data

The intermediary sources of lead were hypothesized as yard soil, house dust, tap water, and air lead. Exterior paint and industry/vehicle emissions were expected to contribute to lead levels in yard soil. Interior and exterior paint, household hobbies, and yard soil were anticipated to contribute to lead levels in household dust. Lead water pipes were hypothesized as contributing to tap water lead levels. Air lead levels were expected to be associated with current industry/vehicle emissions. For the sub-sample of households that participated in the environmental testing component of the study, direct measures of soil, dust, and tap water were obtained for each household. For the interviewed and environmental samples, air lead measures were available by zone as defined by the MOE. Given the low participation among new households, graphical displays of environmental test results was restricted to houses built prior to 1950.

As illustrated in Figure 4.1, median tap water lead levels are higher in the neighbourhoods in the more western-central portions of the study area, which generally correspond to the areas with very old housing stock (see Figure 3.2). All of the study sub-areas had median water levels below the current MOE drinking water standard for lead of 10 µg/L[15], although, with one exception, each sub area had at least one sample that exceeded this standard as illustrated by the maximum value greater than 10 µg/L in 11 out of 12 sub-areas.

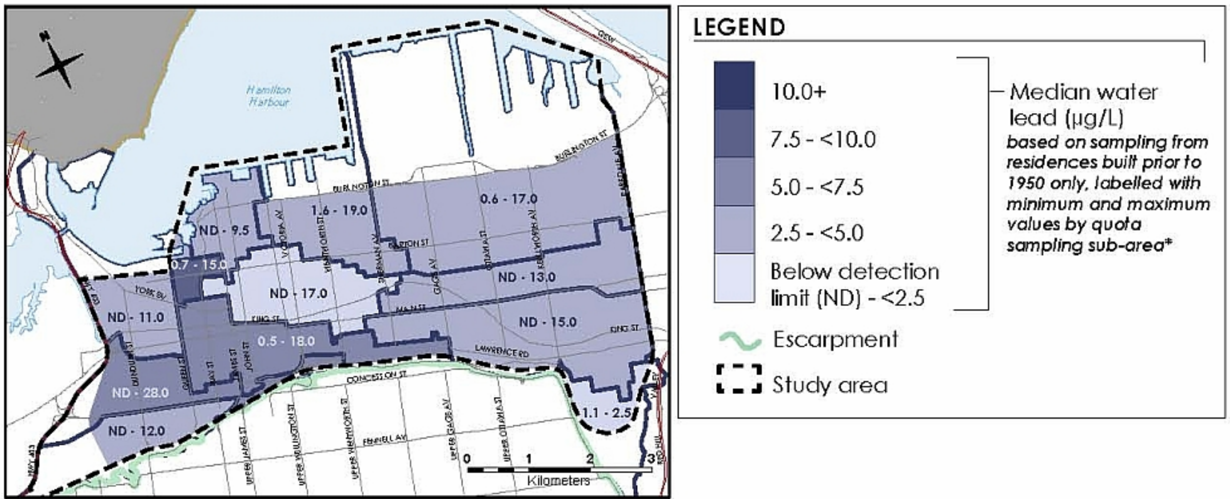
[15] Ontario Ministry of Environment (2010) *Lead In Drinking Water: Questions and Answers - PIBS 6325e*

Figure 4.1 illustrates how median soil levels are higher in neighbourhoods in the western-central, and central portions of the study area, and lower in the more southern portions running along the escarpment. There was no study sub-area with a median soil lead level at 200 µg/g (or 200 ppm), the level below which MOE advises that there is minimal risk from exposure to soil.[16] According to the MOE, lead levels in surface soil in older residential areas may be found to be higher than 200 ppm. This was the case for 10 of the 12 sub-areas for which there was at least one sample with a soil lead level above 200 µg/g.

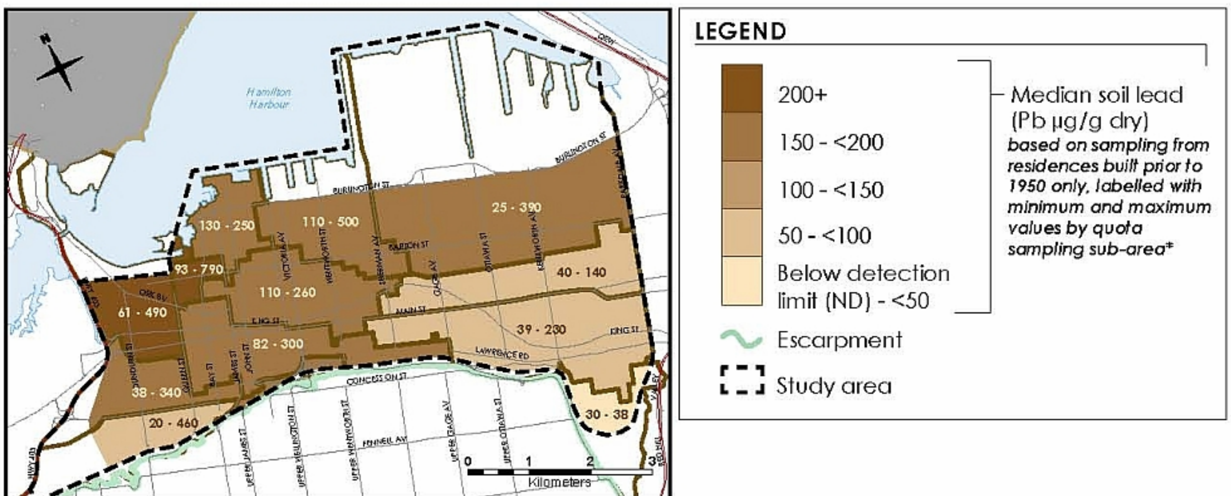
As illustrated in Figure 4.1, the neighbourhoods with higher median living room dust levels were in the western-central neighbourhoods, which correspond to the areas with higher median yard soil lead levels, and the areas with very old housing stock (see Figure 3.2). With respect to living room dust, most areas had median dust lead levels measured below 5.0 µg/ft^2. Currently, there are no standards or guidance levels for dust lead levels.

Figure 4.1: Environmental sample median results by neighbourhood

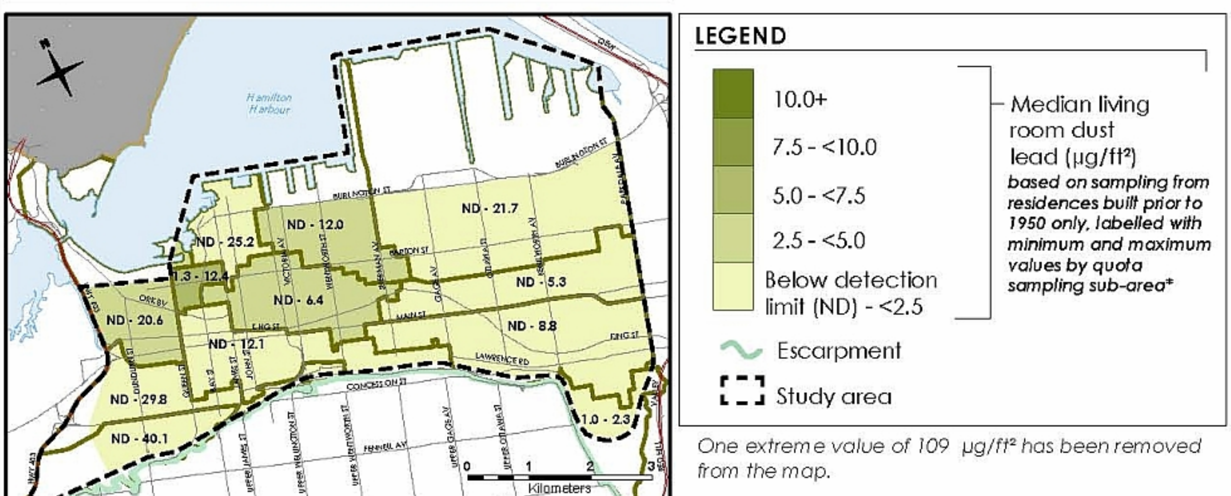
[16] Ontario Ministry of Environment (2008) Fact Sheet - *What You Should Know About Lead in Soil - PIBS 6683e*



Map A: Tap Water Lead Levels



Map B: Exposed Soil Lead Levels



One extreme value of 109 µg/ft² has been removed from the map.

Map C: Living Room Dust Lead Levels

***Note:** *Quota sampling sub-areas are aggregates of dissemination areas, based on homogeneity of the area characteristics related to lead exposure. Peripheral quota sampling sub-areas were cropped to more accurately reflect the location of residential housing.*

The study hypothesized that various factors could influence the deposition of lead from primary to intermediate sources. These included factors such as home renovations, practice of removing shoes before entering the house, pets that go both indoors and outdoors, and the type of dwelling (house vs. apartment). All of these modifiers are only important if the lead levels in primary sources are high. If the lead levels in the primary sources are low, then it is anticipated that there would be no modifier effects, and consistently low lead levels in the intermediate sources.

As illustrated in Table 4.3, among the interviewed sample, over one-third of households reported that they had undertaken home renovations in the past 6 months, although the extent of the renovations was not noted. The majority of households in the interviewed sample indicated that family members usually removed their shoes before entering the home. Slightly over one-third of households had pets that go both indoors and outdoors. The vast majority of households were houses that had direct access to the outdoors compared with apartments or other types of dwellings.

Table 4.3: Factors that influence deposition of lead from primary to intermediate sources

FACTOR	% Households *(n= 406)*	% Children *(n=580)*
Home renovation in the past 6 months		
Yes	38.7	39.0
No	61.3	61.0
Family members remove shoes before entering home		
75% to 100% of time	68.0	67.6
50% to 75% of time	16.0	15.7
Less than 50% of time	16.0	16.7
Pets in household that go both indoors and outdoors		
Yes	37.7	37.2
No	62.3	62.8
Type of dwelling		
House (including duplex, row housing)	93.3	94.2
Apartment	6.2	5.3
Other	0.5	0.5

Source: Study data

4.3 Factors that influence uptake of lead from environment

In addition to socio-economic-cultural factors and sources of lead in the environment, the interview also focused on assessing various factors that potentially influence the uptake of lead from the environment. Some of these factors are mostly related to the characteristics of the child, while others are related to various behaviours and practices of the child and members of the household and should only be an issue if there is source lead in the child's environment.

Child factors that were hypothesized to be related to the uptake of lead in the environment included the child's age, sex, and dietary factors. The main dietary factors measured (as they relate to lead uptake in children) were whether or not the child took calcium or iron supplements. Studies indicate that deficiencies in calcium and iron may increase the amount of lead absorbed, since lead molecules will attach at sites in body cells which these mineral nutrients would otherwise fill.

As illustrated in Table 4.4, toddlers (18 months to under 36 months old) made up approximately one-third of the sample, while older children (36 months to <84 months) made up the largest proportion of the sample. The sample consisted of slightly more male children. Overall, there were very few children taking either calcium or iron supplements.

Table 4.4: Child physiological factors that influence uptake of lead from environment

FACTOR	% Children *(n=580)*
Child's age	
Infants (0 to <18 months)	19.1
Toddlers (18 months to < 36 months)	23.6
Pre-school (36 months to < 84 months)	57.2
Child's sex	
Male	54.5
Female	45.5
Child receives calcium supplements	
Yes	1.7
No	98.3
Child receives iron supplements	
Yes	2.4
No	97.6

Source: Study data

Other factors hypothesized as being associated with uptake of lead from the environment included household and personal hygiene factors, child's exposure to soil and paint chips, and the amount of time the child spends in the home environment. An attempt was made to measure parents/guardians' responses to government recall of products containing lead; however, during the validation process, the variables used to measure this construct were assessed as eliciting socially desirable responses resulting in what appears to be an inaccurate, biased measure (as outlined in Section 2.0).

As illustrated in Table 4.5, household hygiene was assessed by asking parents/guardians how floors were cleaned in the household, and how frequently they were cleaned. The most frequently cited method for cleaning floors was using a wet mop. Other popular methods included vacuuming and dry sweeping. The vast majority of households reported cleaning floors at least weekly. Children's hygiene was assessed by asking parents/guardians to estimate how frequently children's hands were washed before eating. The largest proportion of children had their hands washed usually (75-100% of the time), while relatively equal proportions had their hands washed some of the time (50-75% of the time), or less frequently (less than 50% of the time). For all household and personal hygiene questions, parents/guardians responses were likely influenced by what is known to be socially desirable, so the data for these questions should be interpreted with caution.

If there is lead in yard soil, then it was hypothesized that children's contact with soil would likely be associated with their BLLs. The majority of children were reported by parents/guardians as being exposed to dirt or un-sodded grass only "sometimes" or "rarely". Approximately one-fifth of children had been observed by their parents/guardian eating dirt or soil in the previous 12 months. As would be expected, this tended to be most frequently observed in toddlers (36.5%) and infants (25.2%) compared with the older children (9.9%).

Approximately fourteen percent of children were reported by parents/guardians as having been seen peeling or picking at paint, with a small proportion having been observed eating chips of paint. The frequency of eating paint chips was highest among infants (7.2%) compared with either toddlers (2.2%) or older children (0.9%).

Table 4.5: Factors that influence uptake of lead from environment

FACTOR	% Households (n= 406)	% Children (n=580)
Methods for cleaning floors in household		
Wet mop	83.0	82.2
Dry sweep	66.5	66.6
Vacuum	71.2	70.9
Frequency of cleaning floors in household		
Once per month	10.8	9.8
Once per week	41.4	40.5
Every 2-3 days	33.7	34.0
Once per day	14.0	15.7
Frequency of child's hand-washing before eating		
75% to 100% of time	--	44.0
50% to 75% of time	--	27.4
Less than 50% of time	--	27.7
Don't know / no response	--	0.9
Frequency of child's exposure to dirt / unsodded grass		
Often	--	15.5
Sometimes/Rarely	--	83.6
Don't know / no response	--	0.9
Child observed eating soil in past 12 months		
Yes	--	19.1
No	--	78.6
Don't know / no response	--	2.2
Child observed peeling or picking at paint chips		
Yes	--	14.0
No	--	84.3
Don't know / no response	--	1.7
Child observed eating paint chips		
Yes	--	2.4
No	--	96.0
Don't know / no response	--	1.5
Average daytime hours spent at home during the week		
< 4 hours	--	2.1
4 to < 8 hours	--	22.6
8 to < 12 hours	--	41.6
12 to 16 hours	--	33.7

Source: Study data

4.4 Awareness of available services promoted in the "Get the Lead Out" campaign

The interview with parents/guardians also provided data to address the study's secondary objective (S2): *To describe the public's awareness of the available services promoted in the "Get the Lead Out" campaign.*

Prior to the launch of the study, HPHS Safe Water Program had launched a public awareness campaign in 2007 entitled *"Get the Lead Out".* The campaign was designed to:

- Increase public awareness about the potential risk of exposure to elevated tap water lead concentrations in older homes that have a lead water service pipe;

- Advise residents of older homes to determine if the water service pipe to their home is made of lead; and
- Advise residents of older homes that have a lead water service pipe to follow public health advice related to lowering their risk of exposure to lead.

HPHS took the opportunity provided by surveying families about risk and mitigation factors for environmental lead exposure to also describe the awareness about available services related to safe drinking water provided by the City of Hamilton. In addition, the survey provided the opportunity to describe the knowledge about key activities designed to reduce exposure to lead in tap water among residents.

As illustrated in Table 4.6, there were relatively high levels of awareness among interviewed households overall that the tap water in older homes may be serviced with lead water service pipes. The level of awareness was lower among those who did not speak either official language at home, did not have post-secondary education, or had lower household incomes.

Approximately one-half of respondents were able to identify at least one step that could be undertaken to reduce children's exposure to lead from tap water such as flushing water pipe systems, installing adequate filters, etc. While levels of awareness were similar among recent immigrants as compared to overall survey respondents, awareness levels were lower among those who did not speak an official language at home, had no post-secondary education or had household incomes under $20,000.

One-half of respondents reported that they were previously aware of the free service provided by the City of Hamilton to inspect water service pipes, and approximately one-third indicated that they had used this service. Patterns of awareness and usage of service were similar among the overall group and recent immigrant families, but lower among families that spoke a language other than English at home, had no post-secondary education, had lower household incomes, or rented their homes.

Table 4.6: Awareness of available services related to safe drinking water provided by the City of Hamilton

	Overall	Non-official Language	Recent Immigration	No Post-Secondary Education	<$20K Income	Houses built prior to 1945	Rental Housing
FACTOR	% Households *(n= 406)*	% Households *(n=20)*	% Households *(n=23)*	% Households *(n=77)*	% Households *(n=25)*	% Households *(n=341)*	% Households *(n=63)*
Aware that older homes may be serviced with lead water service pipes							
Yes	80.0	45	74	56	56	83	49
No	17.5	25	9	34	24	16	37
Don't know	3.0	30	17	10	20	1	14
Aware of steps to reduce children's exposure to lead from tap water							
Yes	55.9	20	61	27	12	59	21
No	44.1	80	39	73	88	41	79
Aware of free water service pipe inspection							
Yes	52.0	30	44	33	16	53	22
No	46.8	50	48	62	72	47	71
Don't know	1.2	20	9	5	12	1	6
Have had water service pipe checked to see if made of lead							
Yes	35.5	25	35	16	16	38	10
No	60.8	55	56	78	68	59	78
Don`t know	3.7	20	9	7	16	3	13

Source: Study data

5.0 Capillary Blood Lead Levels in Study Area

This section reports on the findings that address the primary objective of the study (P1), namely the determination of the distribution of BLLs, and the prevalence of BLLs greater than the current blood lead guidance value (0.48 µmol/L) in a sample of children under 7 years of age who resided in the targeted geographic higher risk area of North Hamilton (study area).[17] This section describes the overall distribution of BLLs, outlines average BLLs, and then provides a brief comparison with other communities' measures of BLLs.

5.1 Distribution of blood lead levels in the study area

As illustrated in Figure 5.1, the distribution of BLLs in the study area was positively skewed with values ranging from below detection limit (<0.05 µmol/L) to 0.94 µmol/L with a small number of values (n=6) above the Health Canada guidance value of 0.48 µmol/L (as depicted by the solid vertical line). Figure 5.2 demonstrates that while the log transformation improved the fit of BLLs to a normal distribution, the transformed data still maintained a slight positive skew.

Figure 5.1: Distribution of blood lead levels in study area (n=643)

[17] A preliminary analysis of distribution of BLLs was provided in a report entitled *Interim Report on Blood Lead Levels in North Hamilton, Ontario, 2008 (July 31, 2009)*. The findings were presented from a preliminary analysis and took place prior to the full validation stage so numbers vary slightly between this report and the preliminary report.

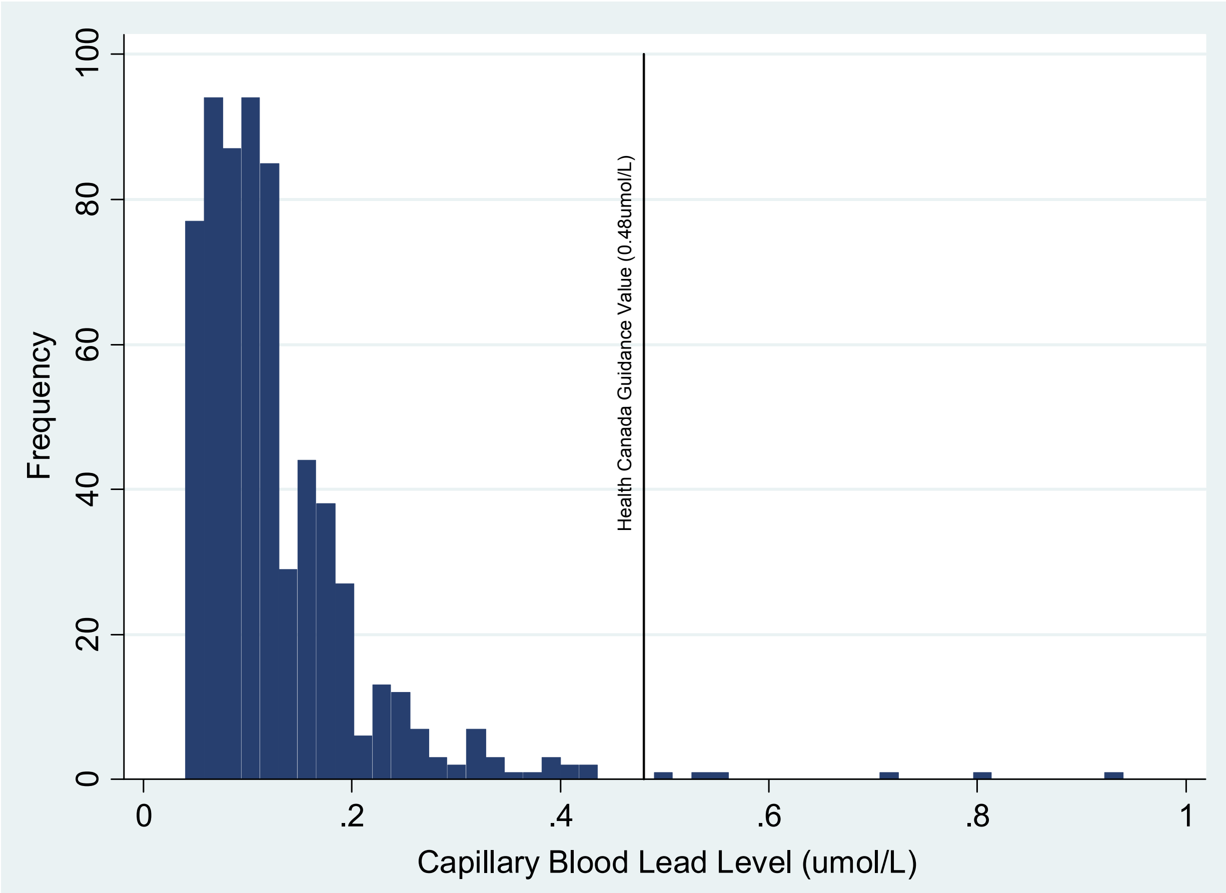
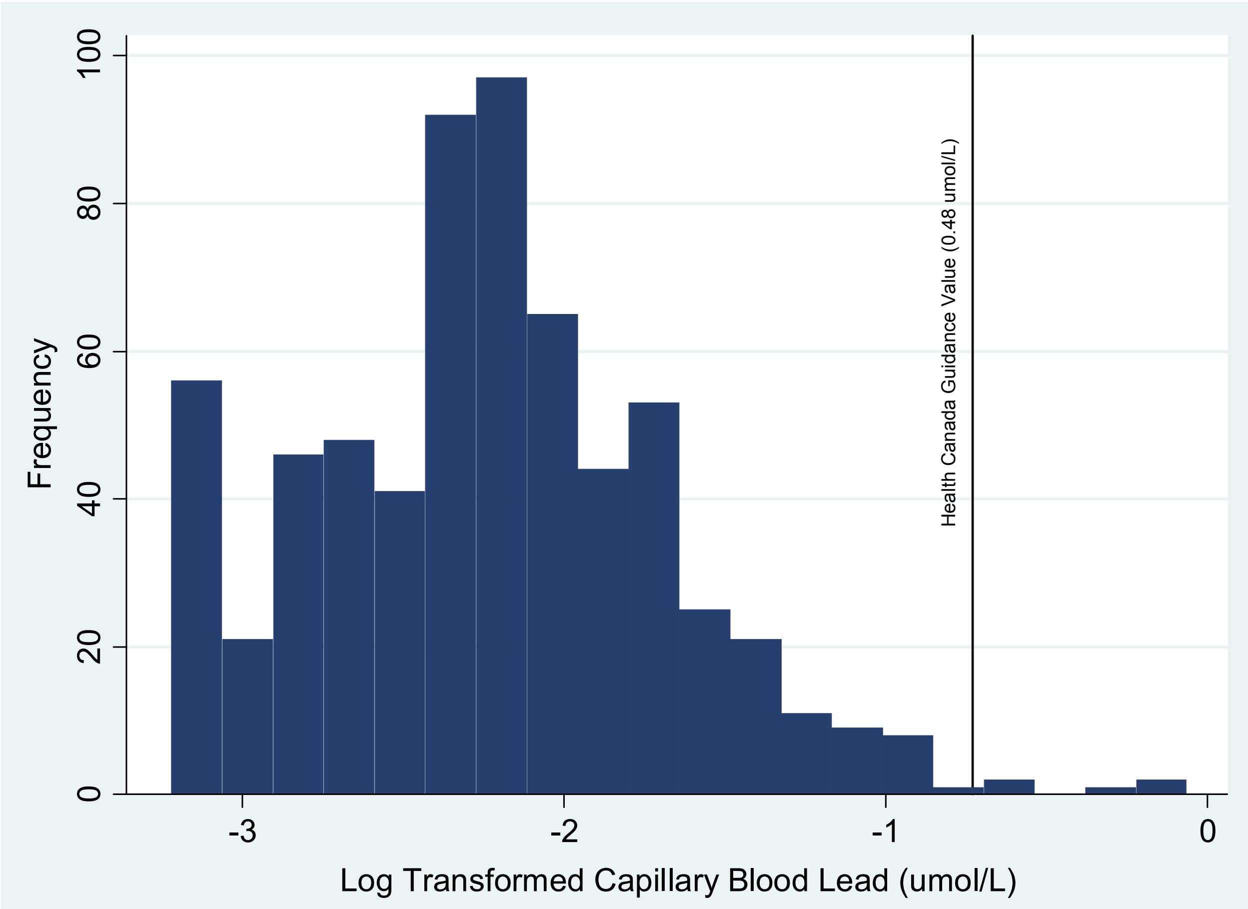


Figure 5.2: Distribution of log-transformed blood lead levels in study area (n=643)



When the distribution of BLLs according to age group and sex were examined, it was found that there were a small number of comparatively elevated BLLs observed consistently across age groups and sex. No distinctive pattern of high levels could be discerned from the data for these two characteristics.

As illustrated in Table 5.1, the proportion of children with BLLs below the detection limit (0.05 µmol/L) was 8.8%. The guideline value that Health Canada has established is 0.48 µmol/L. Approximately 1% of children tested were at or above this guideline value. Despite small differences between male and female children and the different age groups outlined in Table 5.1 below, none of these were statistically significant.[18]

[18] Differences between groups were tested with a χ^2 at $p<0.05$.

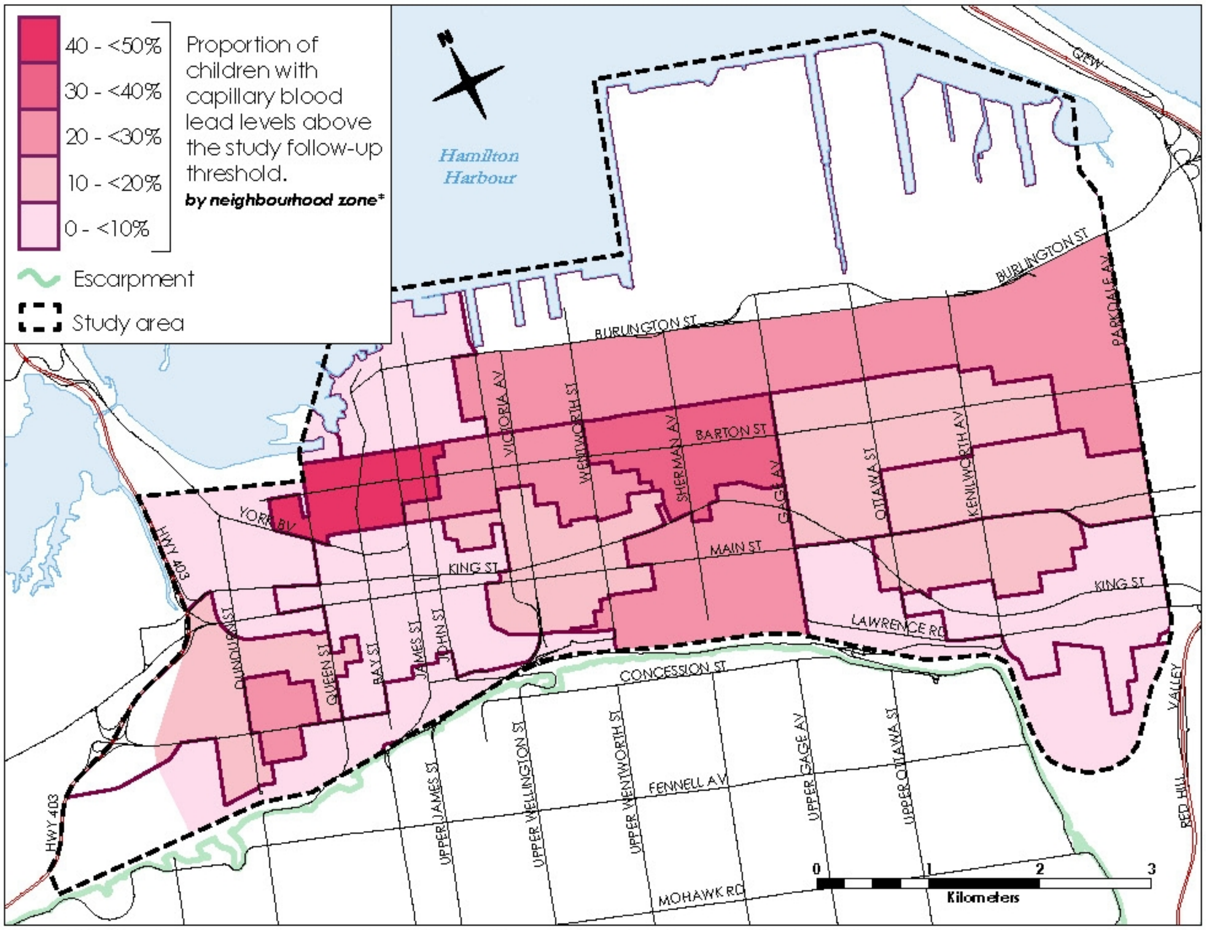
Table 5.1: Distribution of blood lead levels in study area

GROUP	n	% Below Detection (<0.05 µmol/L)	% Health Canada Guideline Value (≥0.48 µmol/L)
Overall	643	8.8	0.9
Sex			
Male	352	7.7	1.1
Female	291	10.0	0.7
Age Category			
Infant (0m to <18m)	120	10.8	1.7
Toddler (18 m to<36m)	154	7.8	1.3
Preschooler (36m to <74m)	369	8.4	0.5

Approximately 15% of children were at or above the conservative study follow-up threshold level of 0.19 µmol/L. The most likely participants to be referred for a follow-up venous blood lead re-test were males. There were no significant differences between age groups.[19] As illustrated in Figure 5.3, the neighbourhoods with higher proportions of children with BLLs that were referred for follow-up venous tests were found in western-central, and central portions of the study target area.

[19] Differences between groups were tested with a χ^2 at $p<0.05$.

Figure 5.3: Proportion of blood lead levels at study follow-up threshold by neighbourhood



***Note:** Neighbourhood zones are aggregates of dissemination areas, based on homogeneity of neighbourhood characteristics related to lead exposure. Peripheral neibourhood zones were cropped to more accurately reflect the location of residential housing.*

5.2 Mean blood lead levels in the study area

The arithmetic and geometric means and confidence limits were calculated for the participants in the study area overall and according to sex and age categories (see Table 5.2). When analysed by sex, male participants had a statistically significant higher mean BLL when compared with female participants.[20] This pattern is consistent with those found in other studies (e.g., Intrinsik Inc. 2010; Niagara Regional Public Health Department 2001). The small differences found among the three age groups were not statistically significant.[21]

Table 5.2: Means and Confidence Limits of Blood Lead Levels in Study Area

GROUP	n	Arithmetic Mean	Arithmetic 95% LCL-UCL	Geometric Mean	Geometric 95% LCL-UCL
Overall	643	0.126	0.120 – 0.133	0.107	0.102-0.112
Sex					
Male	352	0.133	0.123 – 0.142	0.111	0.105 – 0.119
Female	291	0.119	0.110 – 0.128	0.102	0.095 – 0.108
Age Category					
Infant (0m to <18m)	120	0.126	0.108 – 0.144	0.104	0.094 – 0.116
Toddler (18 m to <36m)	154	0.134	0.120 – 0.148	0.113	0.104 – 0.124
Pre-schooler (36m to <84m)	369	0.123	0.114 – 0.132	0.105	0.100 – 0.111

5.3 Comparisons with other jurisdictions

Making valid comparisons between the capillary BLLs obtained among study participants from the City of Hamilton children and children living in other Canadian communities is challenging given the likely differences in sources of potential exposures. Currently, there is no overall national comparison for children under 7 years of age.[22] While a national level survey of BLLs among younger children has not been undertaken in Canada, there has been ongoing monitoring of children's BLLs in the United States, and there have been a number of recent, smaller studies that have been conducted with young children in Canadian communities that would be considered atypically exposed, primarily due to soil lead levels (see Table 5.3).

The United States' National Health and Nutritional Examination Survey (NHANES) (2007-08) in which one age group studied was children between one and five years old reported a geometric mean BLL of 0.073 µmol/L, which is lower than that obtained among children living in the City of Hamilton's study area. The challenge with this comparison is that cultural, regulatory, and environmental differences likely impact the comparability. Similar proportions of children in both studies were found to have BLLs at or above the Health Canada guideline value.

When compared with the BLLs found among similarly aged children in atypically exposed communities elsewhere in Ontario (i.e., Port Colborne, West Carleton), the geometric mean results obtained in the current study are similar, and lower than mean BLLs observed in studies from

[20] Tested with a t-test at $p<0.05$ using log-transformed BLL data.
[21] Tested with a one-way analysis of variance at $p<0.05$ using log-transformed BLL data
[22] The recent Canadian Health Measures Survey (CHMS) collected blood lead levels for children and youth aged 6 to 19 years.

communities outside the province (i.e., Flin Flon, Trail, Belledune, Nunavik). The proportion of children with BLLs at or above the Health Canada guideline value is slightly lower in the Hamilton study compared with these other available data. Caution should be made in making these comparisons, as most of the communities studied are small towns or villages located near lead smelters, compared with the large urban centre characteristic of the current City of Hamilton study area.

Table 5.3: Blood lead concentrations in other communities

Age	Community	Date of Measurement	Exposure Concerns	n	Geometric Mean (µmol/L) (CL)	% at or above Health Canada guideline value (≥ 0.48µmol/L)	Reference
CURRENT NORTH HAMILTON STUDY							
Children 0-6 years old	**North Hamilton**	**2008**	Current Study	**643**	**0.107 (0.102-0.112)**	**0.9%**	**Current Study**
NATIONAL STUDIES*							
Children 1-5 years old	U.S. NHANES (2007-08)	2007-08	General Exposure	817	0.073 (0.068-0.082)	0.9%	U.S. CDC 2011[a]
STUDIES OF ATYPICALLY EXPOSED COMMUNITIES							
Children 0-6 years old	Flin Flon Area, MB (near smelter)	2009	Soil	202	0.133 (0.121-0.142)	2.0%	Intrinsik Inc. 2010[b]
Children 0.5-5 years old	Trail, BC (near smelters)	2007	Soil	132	0.246	—	Trail Health and Environment Committee 2007[c]
Children 3-6 years old	Belledune, NB (near smelter)	2004	Soil	10	0.171	—	Government of New Brunswick 2005[d]
Children 5 years old	Nunavik, QC	2000-2003	Local Food	110	0.256	—	Fraser *et al.*, 2006[e]
Children 0-6 years old	Port Colborne, ON (near smelter)	2001	Soil	42** 56***	0.11 0.10	2.9%**	Regional Niagara Public Health Department 2001[f]
Children 0-6 years old	West Carleton, ON (mine tailings)	2000	Dust	196	0.092	1.7%	Region of Ottawa Carleton 2000[g]

* No Canadian national level data are available for children less than 6 years of age
** East Side Community of Port Colborne
*** Greater Port Colborne
[a] Centre for Disease Control (February 2011) *Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables.* Obtained online at: http://www.cdc.gov/exposurereport/pdf/Updated_Tables.pdf
[b] Intrinsik (2010). *Evaluation of Environmental Contaminant Exposure in Children (under 15) in Flin Flon, Manitoba and Creighton, Saskatchewan – Technical Report*
[c] Trail Health and Environment Committee. (2007). *Annual Fall Blood Lead Testing Results-2007*. Obtained online at: http://thec.ca/?page_id=8/
[d] Government of New Brunswick (2005) *Belledune Area Health Study Summary Report*. Obtained online at: http://www.gnb.ca/0208/pdf/Belledune_Summary_Report-e.pdf
[e] Fraser, S., Muckle, G., and Despres, C. (2006). The relationship between lead exposure, motor function and behaviour in Inuit preschool children. *Neurotoxicology and Teratology* 28, 18-27.
[f] Regional Niagara Public Health Department (2001) *Lead Screening Report*. Obtained online at: http://www.wdghu.org/tytler/docs/Lead%20Screening%20Study%2081401.pdf
[g] Region of Ottawa-Carleton Public Health (2000) *Results of West-Carleton Blood Lead Screening.* Obtained online at: http://www.wdghu.org/tytler/docs/wcarl.pdf

6.0 Public Health Action for Children with Blood Lead Levels Above Study Follow-up Threshold

A secondary objective for the study was (S3): *to evaluate participant compliance with study-recommended clinical follow-up and interest in available public health services as part of study follow-up.* This involved referrals for venous re-testing, referrals to family physicians and study paediatrician, and home visits with public health inspectors.

6.1 Referrals for venous re-testing

Overall, 14% of children who provided a capillary blood sample (101/736) had a level ≥ *0.19 µmol/L*, the *a priori* selected study follow-up threshold level. These 101 children lived in 88 households (88/528 or 17%). The vast majority of children with follow-up threshold levels (96/101 or 95%) lived within the study area, with the remainder living outside the study area but within the city limits.

A HPHS public health nurse was able to contact the parents/guardians of all children with follow-up threshold BLLs. As illustrated in Table 6.1, most parents/guardians agreed with the recommendation of having their child provide a venous blood sample that was tested for blood lead levels, hematocrit and hemoglobin (83/101 children or 82%), although a sizeable proportion did not follow-up with venous re-testing (18/101 or 18%). For these children, HPHS sent their parents/guardians a letter restating the recommendation for a venous re-test and how this could be arranged. Moreover, if they had provided the name of their family physician, a copy of this reminder letter was sent to their family doctor. The mean and median time elapsed between capillary and venous sampling were 33 days and 23 days respectively, ranging from 9 to 84 days.

Table 6.1: Distribution of capillary blood lead levels for those presenting and not presenting for venous re-testing

Capillary Blood Lead Level	Presented for Venous Re-testing	Did Not Present for Venous Re-testing	Row Total
≥ 0.19 to < 0.29 µmol/L	54 (76%)	17 (24%)	71
0.29 to < 0.39 µmol/L	16 (100%)	--	16
0.39 to < 0.48 µmol/L	7 (87%)	1 (13%)	8
≥ 0.48 µmol/L	6 (100%)	--	6
Column Total	83	18	101

6.2 Referrals to family physician and study paediatrician

Based on the results of the venous re-tests:

- 73% of the re-tested children required no further follow-up (61/83);
- 8% of the re-tested children were referred to their family physician for hematocrit and/or hemoglobin values being outside the normal limits (7/83); and
- 18% of the re-tested children were referred to a study paediatrician due to venous blood lead results ≥ 0.19µmol/L (15/83). The referred sub-group had the following distribution of venous blood lead levels:
  - 13% at 0.19 µmol/L (2/15);
  - 53% at > 0.19 to < 0.29 µmol/L (8/15);

- o 13% at 0.29 to < 0.39 µmol/L (2/15);
- o 20% at 0.39 to < 0.48 µmol/L (3/15); and
- o 0% at ≥ 0.48 µmol/L (0/15).

Among the 15 children who were referred to the study paediatrician, 87% (13/15 from 11 households) were subsequently seen and assessed. The mean and median time elapsed between the household referral date and consultation date were 34 days and 32 days respectively; the range was 18 to 59 days. The two children who did not present for a consultation with the study paediatrician were from the same household.

6.3 Home visits by public health inspectors

The parents/guardians of the 15 children (12 households) who were referred to the study paediatrician were offered the opportunity to have a HPHS public health inspector (PHI) conduct a home visit. During the home visit, the PHI offered to perform a home risk assessment, to review the responses parents/guardians had provided to the risk factor survey, and to provide additional resource information regarding mitigating exposure to sources of lead, as well information about the Lead Pipe Service Replacement Program and free water service connection inspection.[23] As well, parents/guardians were offered to participate in the environmental sampling (tap water, dust, soil), if they had not already been selected via the study.

Most households requested a home visit be conducted (11/12). Home visits occurred over a two month period, ranging from mid-December 2008 to early Feb, 2009. Generally, the homes visited were quite old with date of construction ranging from 1870 to 1935 (mean and median = 1902). Approximately one half of homes were noted to have chipped/peeled or worn interior painted surfaces (6/11). A few of the yards (2/11) also had compromised exterior painted surfaces adjacent to the child participant's play area (either own home or adjacent home/garage).

[23] The free inspection service was provided by the PHI at the time of the home assessment if the pipe was visible above ground. If the pipe was not visible above ground, the PHI referred homeowner to contact Public Works Department to request services from the pipe inspection program.

7.0 Exploratory Analysis of Factors Associated With Blood Lead Levels

The overall study objective was to determine the distribution of BLLs and the prevalence of BLLs greater than the current blood lead guidance value (0.48 µmol/L) in a sample of children under 7 years of age who resided in the targeted geographic higher risk area of North Hamilton (Chapter 5.0). While the study was designed to address this primary objective, study implementation gave rise to the opportunity to collect some additional data on potential risk and mitigating factors to address a secondary objective of (S4): *to explore associations between potential lead sources, specific risk and mitigating factors, environmental lead levels and BLLs*. It should be noted that while the study produced solid findings with respect to addressing the primary objective (P1) and the first three secondary objectives (S1-S3), the findings for the remaining secondary objective (S4 - associations) should be considered exploratory given various limitations of the data (outlined in Section 8.0). Had measuring associations been the primary objective, the study would have been designed differently with alternative areas of emphasis related to measurement, sampling, and target populations.

7.1 Hypothesized associations

During the study design phase, the team developed a number of hypotheses as to how sources of lead (both primary and intermediary) could be associated with BLLs in children taking into account numerous potential modifiers, socio-economic and cultural factors, and individual child physiology, behaviours and diet. Table 7.1 presents the main constructs that were included in the study to attempt to understand key associations with BLLs. While measures (either direct or proxy) were attempted for each construct, the validation phase of the study determined that data collected for a few of the measures were not of sufficient quality to be included in the analyses. For example, direct measures of air lead levels for individual properties were not undertaken. The resolution of the MOE-provided air measure (three air lead zones) was deemed to be of too low resolution for inclusion in the association analyses.

Another measurement issue for the assessment of associations was the inability to distinguish between current and historic industrial emissions. Measures of historical emission levels were not available for the study, and given that the more recent air lead levels are below current standards[24], the study team assumed that the primary industrial contributor to current blood lead levels in children would be from historic emissions (i.e., lead in soil from historical emissions). Related to this is the measurement concern with the proxy measure for current and historic emissions of household proximity to industry. This measure was developed by estimating the distance between the centroid of a specific household property and the closest industry (either historic or current). It does not take into account the proximity of other industries besides the closest industry. These and other measurement issues, including the conversion of some variables from continuous measures to categorical measures in the modeling (e.g., proximity to industry, housing construction date), are further discussed in Appendix C.

[24] Current MOE standards and guidelines are (1) a 30-day Ambient Air Quality Criterion (AAQC) of 0.2 µg/m^3 (micrograms per cubic metre of air); (2) a 24-hour AAQC of 0.5 µg/m^3; and (3) a half-hour AAQC of 1.5 µg/m^3.

Table 7.1: Key constructs in hypothesized associations with BLL

Primary Sources	Intermediary Sources	Modifiers			
		Socio-Economic-Cultural Factors	Child Physiological Factors	Behaviours	Environmental Factors
• Objects • Paint • Hobbies • Water pipes • Occupations • Historic industry emissions • Current industry emissions*† • Historic vehicle emissions*	• Dust • Soil • Water • Air*	• Income • Education • Language • Recent immigration • Awareness • Property ownership	• Age • Sex • Diet*	• Home entry factors • Child's personal hygiene • Floor hygiene • Paint ingestion • Time spent in home • Soil ingestion • Soil exposure • Tap water consumption • Tap water flush* • Worker hygiene* • Product recalls*	• Renovations • Season* • Water filters*

** Unmeasured constructs or those with measures deemed to be of insufficient quality (further described in Appendix C).*

† The measure used for industry emissions was residence proximity to closest lead-associated industry. Unfortunately, this measure could not distinguish between current and historic industry emissions. Given the low levels of current emissions (see Section 3.2), the study team assumed that this measure was most indicative of historic industrial emissions.

A detailed concept map is presented in Appendix C (Figure C1). This appendix contains additional information on how each of the constructs was operationalized and measured as well as which variables were dropped from use in analyses. The reader should note that the schema depicted in the concept map in Figure C1 is outlining hypothesized relationships or associations, and is not inferring causal relationships. The determination of causal relationships would require methods and analytic approaches that were not within the scope of the current study.

As illustrated in Figure C1, the relationships between the hypothesized primary sources and BLLs are potentially impacted by various factors including intermediary sources, socio-economic and cultural factors, child physiological factors, and a multitude of other modifiers. During the analysis, the study team explored three sets of relationships:

- The relationships between the individual intermediary sources (i.e., dust, soil, air, water) and BLLs, taking into account various potential modifiers;
- The relationships between the individual primary sources and intermediary sources taking into account various potential modifiers; and
- The relationships between the primary sources and BLLs, once again, taking into account various potential modifiers.

The following sections summarize the findings for each set of relationships. Additional details on the models and scatterplots can be found in Appendix E. Detailed information on derivation of models can be located in the separate technical documents.[25]

[25] *North Hamilton Child Blood Lead Study Technical Documents Volume I-II*

7.2 Relationships between blood lead and dust, soil, and water

Using the environmental sample, the study team initially explored univariate relationships between BLLs and intermediary sources of lead. The direct environmental measures undertaken for a sub-sample of properties included tap water, house dust, and yard soil.

As illustrated in Table 7.2, lead levels in dust, soil and tap water were found to be significant predictors of BLLs in children. Univariate relationships were examined according to a Pearson r correlation statistic using log transformed data, as well as with an analysis of variance using categorized variables. The amount of variance accounted for in BLLs by each of the sources ranged from approximately 3-4% for water, 5-8% for dust, and 3-9% for soil. When examining these relationships, it is important to note that these associations do not take into account the impact of any modifying variables that may be substantially contributing to the association.

Table 7.2: Summary of univariate relationships between BLLs (µmol/L) and direct measures of intermediary sources (environmental sample)

Intermediary Source						
Living room dust lead levels *(environmental sample)*						
			n	**Pearson r**	**P-value**	**r^2**
Correlation with BLLs			281	0.230	< 0.001	0.053
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
≤ 1 µg/ft²	86	0.109	0.059	5.79	< 0.001	0.078
1.1 to 2 µg/ft²	73	0.120	0.091			
2.1 to 4 µg/ft²	54	0.135	0.072			
4.1 to 6 µg/ft²	33	0.145	0.086			
6.1 µg/ft² or higher	34	0.202	0.194			
Yard soil lead levels *(environmental sample)*						
			n	**Pearson r**	**P-value**	**r^2**
Correlation with BLLs			274	0.169	< 0.01	0.029
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
≤ 50µg/g dry	73	0.108	0.054	6.32	< 0.001	0.086
50.1 to 100 µg/g dry	61	0.103	0.059			
100.1 to 200 µg/g dry	88	0.139	0.093			
200.1 to 300 µg/g dry	32	0.196	0.199			
> 300µg/g dry	20	0.156	0.087			
Tap water lead levels *(environmental sample)*						
			n	**Pearson r**	**P-value**	**r^2**
Correlation with BLLs			281	0.190	< 0.01	0.036
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
≤ 1 µg/L	78	0.108	0.058	3.11	< 0.001	0.033
1.1 to 4 µg/L	68	0.122	0.060			
4.1 to 8 µg/L	71	0.148	0.156			
8.1 µg/L or higher	64	0.155	0.094			

Notes: Arithmetic means and standard deviations are presented in this table. Pearson's r statistics and ANOVAs were calculated using log-transformed data.
Interpretation note: The η^2 (eta squared) and r^2 statistics estimate the amount of variance accounted for in the BLL by a specific predictor variable. For example, living room dust levels has an η^2=0.078 and a r^2=0.053 which can be interpreted that dust levels account for approximately 5 to 8% of the variance in BLLs. When interpreting univariate relationships such as this, it is important to remember that this measure does not take into account any overlap or contributions from other variables that may impact the magnitude of the relationship. For example, most of the higher levels of dust lead may be occurring in old houses that also have higher soil lead levels (also significant predictor of BLL). It is then challenging to determine the extent to which it is uniquely the dust lead levels that are related to BLLs.

Once the univariate relationships were assessed, the study team used the findings to develop multivariate regression models to predict BLLs taking into account the shared variance between intermediary sources and other potential contributing factors such as modifying factors, socio-economic and cultural factors and child physiological factors. The summary findings of the individual models are contained in Table 7.3 according to the main multivariate models tested (see Appendix E for more detailed regression results). The summary includes the statistically significant predictors for each model, the standardized regression coefficient, and the estimated percentage change in BLL and demonstration of this change on a population BLL mean, assuming all other variables in the model remained constant.

As illustrated in Table 7.3, for the dust model, the predictors that had a statistically significant association with BLL were living room dust lead levels, lower household income, and male sex. The overall dust model as outlined in the schema accounted for approximately 18% of the variance in BLLs (R^2=0.177). To assist with the interpretation of magnitude of association of these predictors, it was calculated that a *doubling* of household dust lead levels within the population would produce an increase in BLLs of anywhere from 8% to 22% (assuming all other variables were held constant). These findings are as predicted by the original schema, and are consistent with what is found in literature with respect to socio-economic and child physiological factors.

With respect to the yard soil model, the statistically significant predictors of BLL included yard soil levels, lower household income, and male sex. This was similar to the findings for the household dust model. Overall, the soil model accounted for approximately 14% of variance in children's BLLs (R^2=0.143). It was calculated that a *doubling* of yard soil lead levels within the population would produce an increase in BLLs of anywhere from 0% to 12% (assuming all other variables were held constant). In exploratory analyses, the date of clinic visit was also considered in the model and found to be a statistically significant predictor of BLLs, with earlier visits (i.e., early November, late November) being associated with higher BLLs when compared with later visits (i.e., early December). Given that the clinics were held over a compressed time frame of approximately 6 weeks, it is challenging to interpret this finding as an indication of seasonality *per se*.[26] Potentially, it could be a combination of some timing factor combined with an unmeasured parental concern factor given that the children arriving at clinics in the early stages of the study may have been coming from households where concern was greatest. As the study gained momentum and preliminary study results were reported in the media, the attendance at clinics increased substantially.

The water model had similar findings to those of the other two models as water lead levels predicted BLLs along with coming from a home with a lower household income, parents with no post-secondary education, and male sex. Of interest is the finding that being a toddler was a significant predictor of BLL in the water model, but was not found to be significant in the dust or soil model. This is somewhat surprising given the hand-to-mouth behaviour that is generally characteristic of children in this age group, and the common exposure routes for lead in dust and soil among toddlers. A possible interpretation is that the toddler group is associated with another variable that is not included in this particular model, but which may be accounting for some of the variance across age groups (e.g., disproportionate number of toddlers live in older houses). Overall, the water model accounted for approximately 14% of the variance in BLLs (R^2=0.140). It was calculated that a *doubling* of water lead levels within the population would produce an increase in BLLs of anywhere from 4% to 15% (assuming all other variables were held constant).

A regression model developed that included all three environmental media along with the other significant modifiers identified in the individual models highlighted that when combined, lead levels in tap water and household dust were significant predictors of BLLs; however, lead levels in yard

[26] An accurate measure of *seasonality* would likely consist of two to three repeated measures of BLLs within a group of children across different seasons (i.e., spring, summer, fall, winter), not a 6-week period conducted during a warm fall in Southern Ontario.

soil did not significantly predict BLLs (see Table 7.4). Overall, the combined model accounted for approximately 18% of the variance in BLLs (R^2=0.183) with the significant predictors being tap water lead levels, household dust lead levels, male sex, toddlers, and lower income. The non-significance of yard soil lead levels as a direct predictor of BLLs can be explained in part by the findings in the following section (Section 7.3) which indicate that yard soil is likely a strong contributor to household dust lead levels (along with age of housing). This suggests that soil does not appear to be making a substantial unique contribution to BLLs from direct consumption; instead soil lead's contribution may occur primarily via exposure to household dust. This finding should be interpreted with some caution given that it may be specific to the non-random sample used for this study, and/or the distribution of various modifiers within the sample (e.g., toddler, males). Furthermore, the hypothetical modifiers in place for soil lead exposure (as well as dust), reflect how many factors can potentially assist/impede getting dust from the floor or soil to a child's mouth, into the gut and bioavailable for absorption. These are likely considerably more numerous when compared with those factors and modifiers associated with lead in drinking water. As a result, there should be some caution used in interpreting the findings from these models given the amount of shared variance among the environmental measures and modifiers.

Table 7.3: Intermediary sources models: Summary of significant predictors of BLLs (μmol/L)

Model	Statistically significant predictor variables (Beta)	Estimated % change in BLL (95% CI)	Estimated impact on population mean of 0.100 μmol/L
Relationships between the intermediary sources and BLLs			
Household Dust *(environmental sample)*	Dust lead levels (0.25)	doubling dust lead levels: 8.0% to 22.2%	doubling dust lead levels: 0.108 – 0.122 μmol/L
R^2= 0.177	Household income <$60K (0.18) *Baseline:* Income $80K+ *Non-significant categories:* Income $60-<80K	5.2% to 39.6%	0.105 – 0.140 μmol/L
	Males (0.11) *Baseline:* Females	0.0% to 26.6%	0.100 – 0.127 μmol/L
Yard Soil *(environmental sample)*	Yard soil lead levels (0.13)	doubling soil lead levels: 0.3% to 11.7%	doubling soil lead levels: 0.100 – 0.112 μmol/L
R^2= 0.180	Household income <$60K (0.17) *Baseline:* Income $80K+ *Non-significant categories:* Income $60-<80K	3.9% to 38.7%	0.104 – 0.139 μmol/L
	Males (0.12) *Baseline:* Females	0.3% to 27.3%	0.100 – 0.127 μmol/L
Tap Water *(environmental sample)*	Water lead levels (0.21)	doubling water lead levels 4.4% to 14.6%	doubling water lead levels 0.104 – 0.115 μmol/L
R^2= 0.140	Household income <$60K (0.18) *Baseline:* Income $80K+ *Non-significant categories:* Income $60-<80K	5.1% to 40.3%	0.105 – 0.140 μmol/L
	Parents have no post- secondary education (PSE) (0.14) *Baseline:* Parents have PSE	2.6% to 41.4%	0.103 – 0.141 μmol/L
	Toddlers (0.17) *Baseline:* Preschoolers *Non-significant categories:* Infants	4.5% to 44.5%	0.105 – 0.144 μmol/L
	Males (0.11) *Baseline:* Females	1.1% to 27.7%	0.101 – 0.128 μmol/L

Interpretation note 1: Estimating from a model how much change in BLL can result from changing a specific predictor (while holding all other predictors constant) can be derived from converting regression coefficients into proportions of change which is demonstrated in columns 4 and 5 in the table. For example, for the dust model, if we were to double the dust lead level in a community, we would estimate that this would result in a corresponding 8% to 22% increase in BLLs (assuming all other variables remained constant). If a population mean BLL was 0.100 μmol/L prior to doubling dust levels, then it would likely rise to somewhere between 0.108 μmol/L and 0.122 μmol/L after dust levels were raised. Ranges are reported to take into account a 95% confidence interval around the original regression coefficient. Larger ranges indicate less certainty (higher standard errors) compared with smaller ranges.

Table 7.4: Intermediary sources combined model: Summary of significant predictors of BLLs (µmol/L)

Model	Statistically significant predictor variables (Beta)	Estimated % change in BLL (95% CI)	Estimated impact on population mean of 0.100 µmol/L
Relationships between the intermediary sources and BLLs			
Combined Environmental Media *(environmental sample)* $R^2 = 0.183$	Dust lead levels (0.20)	doubling dust lead levels: 4.7% to 18.9%	doubling dust lead levels: 0.105 – 0.119 µmol/L
	Water lead levels (0.18)	doubling water lead levels 2.9% to 13.1%	doubling water lead levels 0.103 – 0.113 µmol/L
	Males (0.13) *Baseline:* Females	2.1% to 27.9%	0.102 – 0.128 µmol/L
	Toddlers (0.15) *Baseline:* Preschoolers *Non-significant categories:* Infants	0.9% to 40.1%	0.101 – 0.140 µmol/L
	Household income <$60K (0.17) *Baseline:* Income $80K+ *Non-significant categories:* Income $60-<80K	3.9% to 37.3%	0.104 – 0.137 µmol/L

Interpretation note 1: Estimating from a model how much change in BLL can result from changing a specific predictor (while holding all other predictors constant) can be derived from converting regression coefficients into proportions of change which is demonstrated in columns 4 and 5 in the table. For example, if we were to double the dust lead level in a community, we would estimate that this would result in a corresponding 5% to 19% increase in BLLs (assuming all other variables remained constant). If a population mean BLL was 0.100 µmol/L prior to doubling dust levels, then it would likely rise to somewhere between 0.105 µmol/L and 0.119 µmol/L after dust levels were raised. Ranges are reported to take into account a 95% confidence interval around the original regression coefficient. Larger ranges indicate less certainty (higher standard errors) compared with smaller ranges.

In addition to the main models used to predict BLLs, the study team developed logistic regression models to explore which variables predicted BLLs at the study follow-up threshold of 0.19 µmol/L.[27] As illustrated in Table 7.5, the findings for the household dust and water models were similar to the main BLL models with these environmental media being significant predictors of BLL for the study follow-up threshold group.

For the soil model, yard soil lead levels were not found to be a significant predictor of BLLs in the 0.19 µmol/L or above range. Similar to the main soil model, in exploratory analyses, the clinic visit date was a significant predictor for which it is challenging to accurately interpret what unmeasured factors are potentially contributing to this association.

When all environmental media measures were combined within one model along with modifiers, the only significant predictor was tap water lead levels. The relationship with water is relatively independent and shares little variance with the various modifiers; however, the modifiers do tend to overlap considerably in variance with dust and soil. When just the three environmental measures (water, dust, soil) were included in the model, both water and dust lead levels were significant. When modifiers were added into the model, the unique variance associated with water remained almost the same, while the variance uniquely accounted for by dust is considerably reduced. This may be explained in part by the numerous modifiers hypothesized for dust and soil that are reflective of the many factors can potentially assist/impede getting dust from the floor to a child's mouth, into the gut and then bioavailable for absorption. These are likely more numerous when compared with those factors and modifiers associated with lead in drinking water. As a result,

[27] These models could not be developed for the Health Canada guideline value of 0.48 µmol/L given the small proportion of children in the study (0.9%) with BLLs at this level.

there should be some caution used in interpreting the findings from these models given the amount of shared variance among the environmental measures and modifiers.

Table 7.5: Intermediary sources model: Summary of significant predictors of study follow-up threshold BLLs (≥ 0.19 µmol/L)

Model	Statistically significant predictor variables (B)	Odds Ratio (95% CI)
Relationships between the intermediary sources and study follow-up threshold BLLs		
Household Dust *(environmental sample)*	Living room dust levels (0.54)	1.72 (1.21 – 2.46)
	Vacuuming floors as primary method of cleaning (-0.99) *Baseline:* Vacuuming not primary method of cleaning floors	0.37 (0.15 – 0.90)
Yard Soil *(environmental sample)*	*None statistically significant*	*N/A*
Tap Water *(environmental sample)*	Tap water lead levels (0.52)	1.67 (1.23 – 2.27)
Combined Environmental Media *(environmental sample)*	Tap water lead levels (0.63)	1.88 (1.23 – 2.27)

Interpretation Dust – A one log unit increase in dust lead levels increases the odds of being in the high blood lead category by approximately 72%. The median dust lead level is 1.80 ug/ft2 (ln=0.58). If this is increased by one log unit which is equivalent to a dust lead level of 4.90 ug/ft2 (ln=1.58), then there is 72% increase in odds of being in the high blood lead category, all other factors being held constant.
Interpretation Water – A one log unit increase in the water lead levels increases the odds of being in the high blood lead category by approximately 67%. The median water lead level is 4.00 ug/L (ln=1.38). If this is increased by one log unit which is equivalent to a water lead level of 10.8 ug/L (ln=2.38), then there is 67% increase in odds of being in the high blood lead category, all other factors being held constant.

7.3 Relationships between primary sources and dust, soil, and water

The second set of models developed from the schema (Appendix C, Figure C1) were used to determine what significant relationships existed between the identified primary sources and the lead levels found in the various environmental media (intermediary sources).

As illustrated in Table 7.6, the primary sources of lead that were found to significantly predict levels of lead in dust, soil and water were consistent with the overall schema. The significant predictors of lead levels in household dust collected in the living room were found to be yard soil lead levels and the date the house was constructed with higher dust lead levels found in housing built prior to 1945. The model accounted for approximately 19% of the variance found in household dust lead levels. The main predictor of soil lead levels was proximity to current and historic industry as would be expected.[28] Given the limitations with the data and measures available for the study (as discussed in Section 7.1), it was not possible to accurately assess the current and/or historic emissions from industry, so proximity to industry was used a proxy measure.[29] This model accounted for approximately 8% of variance in yard soil lead levels. Similar to the dust lead levels, water lead levels were predicted by the period in which the house was constructed, with the model accounting for approximately 13% of the variance in tap water lead levels.

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[28] Testing of the model using proximity to industry as a categorical and continuous variable concluded that the categorical method produced a better fit for the model. Categories were determined by examining the distribution of BLLs within various 500m segments.
[29] The most recent air lead level data available for the study area (2008) indicated that all air lead measures were below current MOE guidelines and standards.

Table 7.6: Summary of significant predictors of intermediary sources

Model	Predicted Variable	Statistically significant predictor variables (Beta)
Relationships between the primary sources and the intermediary sources		
Household Dust *(environmental sample)* *R^2= 0.194*	Living room dust lead levels	Soil lead levels (0.20)
		House construction date prior to 1920 (0.45) *Baseline:* House construction date post 1944
		House construction date between 1920-44 (0.27) *Baseline:* House construction date post 1944
Yard Soil *(environmental sample)* *R^2= 0.079*	Yard soil lead levels	Proximity to historic industry 0-500m (0.15) *Baseline:* Proximity to industry greater than 2500m
		Proximity to historic industry 501-1000m (0.25) *Baseline:* Proximity to industry greater than 2500m
		Proximity to historic industry 1001-2500m (0.20) *Baseline:* Proximity to industry greater than 2500m
Tap Water *(environmental sample)* *R^2= 0.130*	Kitchen tap lead levels	House construction date prior to 1920 (0.47) *Baseline:* House construction date post 1944
		House construction date between 1920-44 (0.40) *Baseline:* House construction date post 1944

7.4 Relationships between primary sources and blood lead

The final set of models analysed was developed to determine the extent to which primary sources were predictors of BLLs taking into account various modifiers, but not the intermediary variables of dust, water, and soil. Unlike the previous models which were restricted to the approximately 200 households that participated in the environmental sampling, this model used the larger sample of over 400 households that participated in the survey on risk factors.

Similar to the analysis of relationships between BLLs and intermediary sources, the study team initially explored univariate relationships between BLLs and primary sources. As illustrated in Table 7.7, there were a number of statistically significant relationships identified between BLLs and various primary factors. As with all univariate statistics, when examining these relationships it is important to note that these associations do not take into account the impact of any modifying variables that may actually be contributing significantly to the association.

The primary sources which were found to be significantly related to BLLs at the univariate levels were housing construction date (which was used as a proxy for pipes and paint), proximity to current and historic lead-emitting industry (used as a proxy for industry emissions), and the child's parent/guardian in a lead-associated occupation. As demonstrated by the η^2 statistic, the amount of variance in BLLs accounted for by any one of these relationships, not taking into account overlap or shared variance with other variables, ranged from approximately 1% (parent/guardian occupation) to 3% (housing construction date; living near the old recycling plant) to 6% (proximity to industry).

Table 7.7: Summary of univariate relationships between BLLs (μmol/L) and primary sources (interview sample)

Primary Source						
Pipes/Paint (*proxy is house construction date*)						
			n	**Pearson r**	**P-value**	**r^2**
Correlation with BLLs			580	-0.173	< 0.001	0.029
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
Construction date prior to 1920	290	0.143	0.108	10.21	< 0.001	0.034
Construction date 1920 to 1944	202	0.115	0.065			
Construction date 1945+	88	0.102	0.054			
Lead-associated hobby						
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
Family member with lead-associated hobby	127	0.130	0.117	0.21	0.646	0.000
No family member with lead-associated hobby	453	0.126	0.080			
Objects						
Toys/jewelry purchased outside Canada						
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
Contact with toys/jewelry	204	0.124	0.099	0.52	0.473	0.001
No contact	376	0.129	0.084			
Makeup/cosmetics purchased outside Canada						
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
Contact with makeup/cosmetics purchased outside Canada	37	0.105	0.052	1.97	0.161	0.003
No contact	543	0.128	0.091			
Industry emissions[30] (*two proxy measures*)						
Proximity to any known current or historic lead-emitting industry						
			n	**Pearson r**	**P-value**	**r^2**
Correlation with BLLs			580	-0.214	< 0.001	0.046
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
0 to 500m	16	0.267	0.255	12.67	< 0.001	0.062
501 to 1000m	82	0.142	0.082			
1001 to 2500m	383	0.125	0.081			
2500m+	99	0.098	0.045			
Proximity to former lead recycling plant only						
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
In proximity to former plant	9	0.339	0.324	15.66	< 0.001	0.026
Not in proximity to former plant	571	0.123	0.077			
Occupation						
ANOVA	**n**	**Mean BLL**	**SD**	**F-ratio**	**P-value**	**η^2**
Parent/guardian in a lead-associated occupation	114	0.138	0.071	5.82	0.016	0.010
No parent/guardian in a lead-associated occupation	466	0.124	0.093			

Notes: Arithmetic means and standard deviations are presented in this table. ANOVAs and correlations were calculated using log-transformed data for BLLs.
Interpretation note: The η^2 (eta squared) and r^2 statistics estimate the amount of variance accounted for in the BLL by a specific predictor variable. For example, construction date of house has an η^2=0.034 and an r^2=0.029 which can be interpreted that construction date of house accounts for approximately 3.4% to 2.9% of the variance in BLLs. When interpreting univariate relationships such as this, it is important to remember that this measure does not take into account any overlap or contributions from other variables that may impact the magnitude of the relationship. For example, most of the older houses may be located in a zone that is in close proximity to current or historic lead-emitting industry (also a significant predictor of BLL). It is then challenging to determine whether it is older housing or proximity to current or historic lead-emitting industry that is uniquely related to BLLs.

[30] In the hypothesized associations, vehicle emissions were included along with industry emissions; however, the study did not include a direct or proxy measure for vehicle emissions.

Once the univariate relationships were analysed, the study team used the findings to iteratively develop a number of multivariate regression models that explored the various associations between primary sources and modifiers with BLLs until a relatively parsimonious regression model was achieved. The summary findings of the overall final model are presented in Table 7.8. The summary includes an overview of what the model is designed to predict, the statistically significant predictors for each model, the standardized regression coefficient, and the estimated percentage change in BLL and demonstration of this change on a population BLL mean, assuming all other variables in the model remained constant. The more detailed results from this model are contained in Appendix E.

As illustrated in Table 7.8, the model accounted for approximately 14% of the variance in BLLs (R^2=0.136). The primary sources that were significant predictors of BLLs were housing construction date pre-1920 (proxy for pipes and paint), and proximity to industry of 0-500m (proxy for current and historic industry emissions). The other primary sources (objects, occupation and hobbies) were not found to be significantly associated with BLLs. The only socio-economic and cultural variable that was found to predict BLLs was being from a home with a lower household income, which is consistent with the schema and the findings from most of the other models tested. The child physiological factor that was a significant predictor was male sex, again consistent with the schema and the findings from many of the other models. The only modifying variable that was found to be a significant predictor was the home floor hygiene factor. Children who came from households in which parents reported cleaning floors 2 to 3 times per week were positively associated with higher blood lead levels when compared to households with reported daily cleaning of floors, or weekly/monthly cleaning of floors. This finding is challenging to interpret given that the expectation would be that those households with less frequent floor cleaning (e.g., weekly or monthly) would also be associated with higher BLLs. Possible reasons for this finding could be that it does not take into account the cleaning method (e.g., wet mopping vs. sweeping or vacuuming), and there may be an unmeasured social desirability bias present as would be predicted with many questions pertaining to hygiene.

Similar to the soil model described in Section 7.2, exploratory analyses undertaken for the primary sources model also found that the timing of the clinic visit was a significant predictor of children's BLLs with earlier visits being associated with higher BLLs when compared with later visits. As stated earlier, this finding is challenging to interpret given that the clinics were held over a compressed time frame of approximately 6 weeks and is likely not an accurate indication of seasonality, but more likely a combination of some timing factor combined with an unmeasured parental concern factor.

Other exploratory analyses included examining a number of potential interactions for the models. No interactions were found to be significant in the models.

Table 7.8: Primary source model: Summary of significant predictors of BLL (µmol/L)

Model	Statistically significant predictor variables (Beta)	Estimated % change in BLL (95% CI)	Estimated impact on population mean of 0.100 µmol/L
Relationships between the primary sources and BLLs			
Primary Sources *(interview sample)* *R^2= 0.136*	Housing construction date pre 1920 (0.15) *Baseline:* House construction date post 1944 *Non-significant categories:* House construction date 1920-44	0.3% to 33.0%	0.100 – 0.133 µmol/L
	Proximity to historic industry 0-500m (0.17) *Baseline:* Proximity to historic industry <2500m *Non-significant categories:* Proximity to historic industry 501-1000m Proximity to historic industry 1001-2500m	30.1% to 92.9%	0.130 – 0.193 µmol/L
	Household income <$60K (0.14) *Baseline:* Income $80K+ *Non-significant categories:* Income $60-<80K	5.3% to 28.9%	0.105 – 0.129 µmol/L
	Males (0.09) *Baseline:* Females	1.3% to 19.3%	0.101 – 0.119 µmol/L
	Clean floors 2-3 times per week (0.13) *Baseline:* Clean floors daily *Non-significant categories:* Clean floors weekly Clean floors less than weekly	1.9% to 29.7%	0.102 – 0.130 µmol/L

Interpretation note: Estimating from a model how much change in BLL can result from changing a specific predictor (while holding all other predictors constant) can be derived from converting regression coefficients into proportions of change which is demonstrated in columns 4 and 5 in the table. For example, if everyone was to move into housing that was constructed pre 1920, we would estimate that this would result in a corresponding 0.3% to 33.0% increase in BLLs (assuming all other variables remained constant). If a population mean BLL was 0.100 µmol/L prior to everyone moving, then it would likely rise to somewhere between 0.100 µmol/L and 0.133 µmol/L after everyone had moved. Ranges are reported to take into account a 95% confidence interval around the original regression coefficient. Larger ranges indicate less certainty (higher standard errors) compared with smaller ranges.

Similar to the process used to assess relationships between intermediary sources and BLLs, for the primary source model, the study team developed logistic regression models to determine which variables could predict BLLs at the study follow-up threshold of 0.19 µmol/L.[31] As illustrated in Table 7.9, there were some similarities and some differences between the logistic regression model when compared with the overall regression model. Proximity to industry (proxy for current or historic industry emissions) was a significant predictor of BLLs at or above 0.19 µmol/L). It should be noted that the primary source factor of year of house construction was not found to be a significant predictor in this model. A modifying variable that was a significant predictor in the logistic regression but not in the overall regression model was home renovations within the previous six months.

[31] These models could not be developed for the Health Canada guideline value of 0.48 µmol/L given the small proportion of children in the study (0.9%) with BLLs at this level.

Table 7.9: Primary source model: Summary of significant predictors of study follow-up threshold BLLs (≥ 0.19 µmol/L or greater)

Model	Statistically significant predictor variables (B)	Odds Ratio (95% CI)
Relationships between the primary sources and study follow-up threshold BLLs		
Primary Sources *(interview sample)*	Proximity to historic industry 0-500m (2.99) *Baseline:* Proximity to historic industry <2500m	19.93 (4.16 – 95.41)
	*Proximity to historic industry** *501-1000m *not significant p=0.084* *(1.12)* *Baseline: Proximity to historic industry <2500m*	*3.06* *(0.86 – 10.86)*
	Proximity to industry 1001-2500m (1.15) *Baseline:* Proximity to historic industry <2500m	3.17 (1.03 – 9.73)
	Home renovations in previous six months (0.56) *Baseline:* No home renovations	1.77 (1.08 – 2.92)

**This middle category of proximity to plant (501-1000m) produced similar B and odds ratio, but was not found to be significant. This may be due to a smaller number of observations in this category.*
Interpretation note: The odds ration can be interpreted as the increase in odds of being in the high blood lead category, all other factors being held constant. For example, for those having implemented home renovations in the previous six months, there is a 77% increase in odds of being in the high blood lead category, all other factors being held constant.

8.0 Study Limitations and Lessons Learned

As with most studies, there are a number of limitations of which the reader should be aware when reviewing the findings and conclusions. As well, there are a number of considerations and factors related to conducting this type of study that have been noted by the study research team throughout the course of the design and implementation phases of the study. These are presented as lessons learned which may be useful for other health units or similar organizations considering a study of this nature.

8.1 Study limitations

The main study limitations identified included the following:

Non-random samples – The original study design incorporated a random process for selection of child participants according to the DA in which they lived within the study area. Despite extensive communication and invitations to participate focused on the randomly selected DAs, within the first few weeks of operating the community clinics, it was determined that participation would not be sufficient from the selected DAs to implement the original study design. As a result, the study design was converted to a self-selected sample design in which participants were accepted into the study as long as they met the criteria of having lived in the study area for at least three months and were under 7 years old. As well, the sub-sample that agreed to have environmental samples collected from their households (i.e., dust, soil, water) were quota sampled from the self-selected overall sample. As a result, the environmental sampling cannot be considered a random sample.

Sample not representative of study area – As was demonstrated in Section 3.0, neither the overall sample nor the environmental sub-sample can be considered representative of the population of the families in the North Hamilton study area. The sample achieved were more likely to come from the neighbourhoods in the study area that had higher median incomes, higher rates of home ownership, higher levels of post-secondary education, more likely to speak an official language at home, and had fewer recent immigrants. In addition, families living in closest proximity to industry were less likely to participate in the study.

Sample size – While the overall sample achieved was relatively large for a community study of this nature (n=643) allowing for reasonable levels of precision in measures that included the overall sample, the environmental measures were only available from 196 households which included less than one-half of the overall sample (n=281). This smaller sample size was the result of the decision to focus resources on addressing the primary objective, with lesser emphasis and resources on the secondary objectives. For descriptive purposes, the sample size is sufficient; however, for the multivariate analyses used to assess associations between BLLs and risk factors, this sample size was inadequate for some of the variables used. As a result, the findings from the multivariate analyses of associations of risk and mitigating factors with BLLs should be interpreted by the reader with some caution.

***Timing for environmental measures*-** In addition to the limited number, the environmental samples were not taken concurrently with the blood samples with an average delay of approximately two weeks for dust and water sampling and approximately six months for soil sampling. For this reason, some households had an opportunity to make changes to their environment between capillary blood and environmental sample collection (e.g. adding filters to tap water plumbing, changing cleaning habits, addressing deteriorating paint conditions etc).

Capillary versus venous blood samples – Although capillary blood sampling to assess lead levels has been determined as suitable for screening and large scale community studies, the "gold standard" would remain venous blood samples. Collection of venous blood samples was reserved for the follow-up procedures given that implementing venous blood draws with young children in a mobile clinic setting was not practical and would likely have significantly impacted on participation rates.

Limit of detection for blood lead analyses – The limit of detection for lead in whole blood for the laboratory used for the study was 0.05µmol/L. This resulted in a small proportion of samples with levels below detection limits (8.8%).

Comparison of children's BLLs with other communities – The study design did not incorporate a comparison group recruited from a comparable community. Rather, the study relied on making comparisons with previous studies that have been conducted in Canada in various communities. None of the communities is directly comparable to a large, urban centre such as North Hamilton, so additional resources such as NHANES from the general population in the US were also used as comparisons.

Reliance on recall measures versus actual observations – Efforts were made to collect direct measures or observations where possible for potential risk factors. For some measures this was not practical, so parents/guardians of children were asked to recall information and/or provide estimates. This included variables such as the flushing water lines for a full 5 minutes before drinking water is used in the morning, time children spent playing outdoors, hours spent in the home, etc. There was likely some level of error introduced into the recall measures that would be less present in observed measures. During the validation process, if the data for these variables appeared to be invalid, the measures were removed from the analyses.

Missing data – Overall, the level of missing data was minimal with the exception of a few variables for which information was collected via a telephone interview with parents and guardians. Missing data was a result of either interviewer error (in the case of worker hygiene for parents/guardians employed in lead-related industries, floor cleaning practices) or respondents not able to answer the question (e.g., type of water pipes in house). Through the validation process, these variables were identified and removed from the analyses when warranted.

Poor quality of some measures – The validation process determined that some of the measures implemented were not quality measures. The main variable presenting this challenge included a standardized question on food security, responses to government recalls, and presence of filters on tap. The questions on food security and government recalls appeared to elicit a socially desirable response from guardians and parents. The question on tap filters was not specific enough with respect to the types of filter being used. The data from these questions were removed from the analyses.

Direct measures of exposure to intermediate sources - Although there were measures taken of lead levels in the intermediate sources (i.e., tap water, living room dust, yard soil) for a sub-sample of households, individual, direct measures of child exposure to these sources were not taken. For example, parents/guardians were asked if a child drank tap water, but there were no measures of actual consumption. Similarly, there was a general question about playing in unsodded areas, and hours spent at home, but these are relatively general questions that cannot be used as substitutes for direct measures of exposure to intermediate lead sources.

8.2 Lessons learned

There were a number of lessons learned as a result of designing and implementing a study of this nature and scale within a public health unit. These may be of use for other organizations or health units that are considering a large scale lead exposure study within a community setting. The main lessons learned from the study included the following:

Public health unit implementation of large research studies – The public health unit structure, mandate, and funding presents challenges to the administration, design, implementation and analysis of a large research study. Challenges were experienced in balancing public health staff and resource commitments to fulfill their regular public health mandate with those required by the study. This resulted in study delays and heavy workloads for key public health staff (e.g., project manager, epidemiologists) as they were required to respond to various public health issues such as the H1N1 pandemic, outbreaks, and regular tasks while administering, implementing and guiding the analysis and reporting for this large research study. Likely the greater involvement and collaboration with organizations designed to conduct research, such as the local university, would have addressed some of the challenges encountered by the health unit without major changes of emphasis on the research questions and study objectives.

Choose objectives conservatively – The primary objective of the study was to determine the distribution of BLLs, and the prevalence of BLLs greater than the current blood lead guidance value (0.48 µmol/L) in a sample of children under 7 years of age who resided in the targeted geographic higher risk area of North Hamilton. The bulk of the resources that were spent in cleaning the data, analysis, interpretation and report writing were spent primarily on the *secondary* objectives. The study design to meet these objectives was not ideal. For example, a study focused on risk and mitigation factors as a primary objective would likely have placed more emphasis and resources on measuring direct levels of lead in environmental media, as well as relying on direct measures rather than the various proxy measures that were used for the current study (e.g., age of housing as a proxy for lead paint, etc). Similarly, there would have been an increased attempt to design the study area to obtain greater variation within the community and/or include a comparison community that did not have the same level of risk and mitigation factors. The present study design has the problem that many of the environmental sources and risk factors fall in the same geographic area (e.g. low socio-economic neighbourhoods in old houses located near current and historic lead-emitting industry) making delineations between risk and mitigation factors and environmental sources difficult. In retrospect, these secondary objectives could potentially have been more efficiently addressed through a review of existing literature along with good descriptive information of the potential risk and mitigation factors present in the study area.

Time and resources required for ethics review process – The local university research ethics review board agreed to review the study to ensure it met ethical standards and guidelines for research with children. The process for preparing an ethics review submission, making revisions and receiving approval took approximately four months, and must be planned for accordingly. Given that the study had a small window for data collection based on the seasonality of lead exposure, and no communications or recruitment for the study could begin until final ethics approval had been received, the study had to be carried out rapidly. As well, the timing of the study required that study implementation only occur once schools were open, and parents/children were back from summer vacation and into their regular family routine.

Outline potential contingencies and alternatives for study design and implementation during the planning stage – A study of this size will evolve as implementation proceeds. By outlining potential contingencies and alternatives at the planning stage, the research team was able to be flexible and quickly adapt to challenges encountered. For example, the decision to move from a random-sample design to a self-selection sample was made quickly so that the communication strategy could be adapted and implemented, clinics changed accordingly, and selection procedures for households to participate in environmental sampling adjusted. This was all completed within a seasonal sampling window that was already very tight given the timeframe required to complete the ethics approval process.

Importance of community communications – One main success factor for the study was the recruitment of participants. Although the random sampling design was not possible, the study was successful in recruiting a relatively large number of children within the study area. The success in recruitment was largely attributable to the communications that were developed to explain the purpose of the study, what participation involved, and the benefits for the individual, family and community. Considerable work was involved in engaging the media, having appropriate spokespeople (e.g., Medical Officer of Health), and working with community organizations and networks to publicize the study.

Effective use of recruitment resources – For this study, aggressive recruitment procedures were used in the randomly selected DAs (e.g. letters distributed through schools, direct telephone contact of households). Despite these measures, only 7.4% (141/1894) of children from these selected neighbourhoods participated in the study as compared to 7.1% (502/7028) from neighbourhoods in which only general communications were used to recruit participants. A contributor to this recruitment failure may have been challenges encountered with the telephone notification campaign. A large number of households in the randomly selected DAs were contacted during the initial stage of the study to encourage families to participate in the clinics and to address any questions about the study. Given that the phone lists were not targeted (i.e., lists of families with children under 7 years of age), a large number of phone calls were required in order to contact those families with children who were part of the target population. This combined with many people's use of caller ID to screen calls resulted in a very small percentage of successful contacts making this approach inefficient as well as ineffective in this study.

Benefits of having various data sources – The study benefited from having access to various data sources. These contributions strengthened the study findings and were particularly helpful in defining the study area population, understanding the relevant resident and environment characteristics in the study area, and providing proxy measures for variables and constructs that would replace more expensive direct measures that were not feasible to obtain under the current study. These data sources included municipal water and water infrastructure data, property registry including housing construction dates, data from air monitoring stations and derived air zones, and the 2006 Census profiles for the study area and City of Hamilton.

Importance of having public health team and medical referral structure in place a priori to follow-up with clinically actionable values – One component of the study that was assessed as successful was the implementation of the referral system for the children who had BLLs at or above the study follow-up threshold level. The follow-up threshold value was decided *a priori* along with all of the algorithms and decisions points so that there was limited delay in referring children for follow-up. The clinic staff receiving the capillary BLLs coordinated regularly with the contact for the HPHS referral team so that parents/guardians of children requiring follow-up were identified and informed of results by phone generally within a few days of the receipt by the referral team of their capillary BLL results. The referral structure in place was composed of a public health nurse, the child's family physician and study paediatrician. The family of the referred child also received public health support and transportation to the laboratory for testing, along with assistance to those who may not have had health insurance. Also a benefit was routing all of the children to a single laboratory for venous retesting which created efficiencies and identical laboratory diagnostics.

Training of public health staff to collect environmental samples – Training of the public health and clinic staff in collecting the dust and water samples was completed relatively quickly in order to limit the length of time between the collection of the capillary blood samples and the environmental samples. There was not sufficient time to have the staff practice in real life settings prior to data collection until they received 100% null results on control samples. This lack of training may have resulted in some contamination of samples.

Benefits of having multiple stakeholders involved in the study – The public health team put forth a considerable effort in engaging and collaborating with multiple stakeholders for the study. While HPHS led the study, many other groups were involved and contributed. This effort benefited the study by enriching the available data sources, and providing resources to the study. The diverse groups involved in the study included the following:

- Provincial Ministry of Environment (air monitoring data, soil sampling and analysis, historical industrial information);
- Provincial Ministry of Health and Community Care (provincial laboratory provided analyses for capillary blood lead);
- University (ethics review, study paediatricians);
- Public and Catholic School Boards (distribution of communications);
- Various municipal departments (mapping, housing data, water data, clinic space);
- Community organizations and networks (communications, clinic space);
- Public health front line staff (assisting with environmental sample collection); and
- Professional/Expert Reviewers (report writing, analysis).

Time and effort required to validate measures – Once the data had been collected and preliminary analyses undertaken, there was considerable time and effort expended in validating the various measures that had been designed for potential risk factors. Having secondary data sources available to validate measures developed from primary measures assisted in this process. Also helpful would have been the introduction of a few redundant or highly correlated measures to validate some of the key measures collected via interviews with parents/guardians. The validation process resulted in some measures being removed, resulting in some gaps. However, the analysis team determined that stronger findings result from their removal rather than having poor measures mislead the analyses.

Housing infrastructure questions challenging for parents/guardians to answer – Questions about housing infrastructure are likely better answered with direct observation and inspection techniques rather than asking residents questions such as types of water pipes, housing age, etc. This gap in knowledge is even more pronounced in areas with high proportions of people renting their homes.

Avoid questions that evoke socially desirable answers –Some of the variables that had lower validity were based on questions that had relatively high levels of social desirability attached to the question. For example, questions of personal or household hygiene, response to recalls, etc., are likely to be associated with high levels of social desirability. Where possible these questions should likely be addressed using observation variables, or having people provide examples.

9.0 Discussion and Conclusions

This study benefited from the large sample size (n=643), and among the participants there was a range of environmental risk factors and responses to the questionnaire for most study variables. For the most part, results were internally consistent and in line with expectations from the literature. Also, an analysis (using post hoc weights) based on neighbourhood characteristics had minimal impact on the outcome estimates of blood lead levels. Despite the limitation that the sample was self-selected, the findings are believed to be generally reflective of the BLLs of the study population. The lower participation rates from the more at-risk groups may have resulted in a slightly lower estimate of overall BLLs.

The distribution of BLLs in the study area was highly positively skewed. Despite small differences between male and female children and the different age groups examined, none of these were statistically significant. However, BLLs varied across the study area to some extent. The distribution of BLLs in the study area followed a similar pattern found in other jurisdictions, although it is challenging to make direct comparisons as there are no suitably comparable Canadian data on young children's BLLs available at this time. Despite the identification of medium-risk exposure levels in the study population, the study sample is similar to data from a US national study for children 1 to 5 years of age, with a slightly higher geometric mean (0.107 µmol/L North Hamilton vs. 0.073 µmol/L US population), but very similar proportions of children (0.9%) at or above the current Health Canada guideline of 0.48 µmol/L. The mean and proportion above the guideline within this study is lower than some studies involving point-source exposures.

It is important to note that while there is a Health Canada guideline, there is no threshold for safe effects of lead exposure in children. Commonly accepted practice is to place efforts to control or eliminate lead in children's environments before they become exposed. Population studies have confirmed that lead exposure is a risk for negative effects on neurocognitive development in children, demonstrating that such changes can be observed in an exposed population of children in the absence of individual, clearly measurable clinical effects. A population approach is part of an overall strategy to limit exposure as much as possible through the use of emissions controls, waste disposal, food residue limits, drinking water guidelines and consumer product regulation, as well as an individual approach through awareness and education. Targeted approaches are also helpful in reaching identified populations at increased risk of lead exposure.

It appears that the participants were moderately aware of available services promoted in the "Get the Lead Out" campaign as one half of participant households within the highest risk area of the City of Hamilton were aware of the free water service pipe inspection. This suggests that there remains a substantial audience for public health educational and promotional materials. The levels of awareness were somewhat lower among those with low household incomes, tenants in rented accommodations, those who did not speak either English or French at home, and households where no adults had a post-secondary education. Similar patterns were also found among levels of awareness of steps to reduce children's exposure to lead from tap water, and awareness that older homes may be serviced with lead water service pipes. This further supports consideration of targeted public health approaches.

The simple evaluation of uptake and compliance with the follow-up study component (i.e., recommendations for venous retesting, referral for medical follow-up, and home visit by a public health inspector) demonstrated a high degree of interest and willingness to comply. Anecdotal evidence from the staff conducting interviews, public health nurse follow-up conversations, and health inspector home visits suggested participants appreciated the services provided. On the other hand, a meaningful proportion did not follow-up with venous re-testing (18%) despite considerable efforts made by the HPHS (e.g., offers to provide public health support, transportation to the laboratory for re-testing, coverage of costs for those who may not have had health insurance).

Secondary research objectives included the description of the presence in the North Hamilton area of potential lead sources and specific risk and mitigating factors, as well as, to explore associations between these and measured environmental lead levels and BLLs. The overall model of associating primary sources and various other risk/mitigating factors with children's BLLs found that only a small proportion of variance in BLLs could be accounted for by these factors (14%). While statistically significant, this means that a large proportion of variance in BLLs cannot be reliably predicted by these factors. The factors that were found to be significant predictors of children's BLLs are consistent with other research (e.g., older housing, industrial emissions, household income, male sex). These analyses were exploratory, and the findings should be interpreted with caution given that the study was not designed to collect data for these types of analyses.

Similarly, the models developed to measure associations between BLLs and intermediary sources of environmental lead were also statistically significant, but still explained relatively small proportions of the variance in BLLs. This lack of variance explanation is likely in part the result of having BLLs in the sample that were relatively consistent (e.g., 85% below study follow-up threshold of 0.19 µmol/L), lack of variability in many of the predictors (e.g., most children lived in older housing, similar socio-economic status, all in relative proximity to industry). Regression models developed that included all three environmental media along with the other modifiers highlighted that when combined, lead levels in tap water and household dust were significant predictors of BLLs; however, lead levels in yard soil were not. In this study, yard soil appears to be a strong contributor to household dust lead levels (along with age of housing), but does not appear to make much of a unique contribution to BLLs beyond dust. The relationship with water is relatively independent and shares little variance with the various modifiers; however, the modifiers do tend to overlap considerably in variance with dust and soil. This may be due to the hypothetical modifiers in place for dust and soil which reflect how many factors can potentially assist/impede getting dust from the floor to a child's mouth, into the gut and bioavailable for absorption. These are likely more numerous when compared with those factors and modifiers associated with lead in drinking water.

Research demonstrates that elevated BLLs are usually found among lower socioeconomic groups and minorities who are more likely to live in older housing that require repair. This is supported by this study's finding of a positive association between low household income and BLL. In addition, these communities have fewer resources to remove or counteract the hazards of lead exposure. In this study, participation was low among neighbourhoods characterized by low income, new immigrants and households speaking non-official languages. This suggests that more targeted efforts by public health may be required to reach such high-need communities. The study area is also comprised of a substantial number of rental dwellings and a meaningful proportion of participants lived in rental dwellings. These participants are challenging to reach and often have less control over the home environment. These findings are relevant in the planning of public health efforts and for developing policies that may impact these communities.

Older housing is a main characteristic of the study area's population with the vast majority of families living in housing constructed prior to 1945, a period during which paints typically contained substantial amounts of lead and water delivery systems may also have contained lead. In this study, housing constructed prior to 1920 was positively associated with BLLs, as well, home renovations in the previous six months was associated with being over the study follow-up threshold for BLLs. A significant proportion of the sample households reported that there were interior painted surfaces in the home that were deteriorating or flaking and almost 40% reported having renovated their home in the previous 6 months. These high proportions indicate that awareness of lead exposure risks from home renovations in older housing stock is an important component for consideration in public health lead exposure interventions.

There are modifiable behaviours that influence the uptake of lead. There were few modifiable behaviours that showed statistically significant associations in this study, however, there are associations reported in the literature. A surprising majority of households reported that members removed their shoes before home entry, children mostly washed their hands before eating, and that they cleaned their floors once a week or more (with a wet mop) – an encouraging finding, suggesting many families in the study area are already engaged in mitigating practices. This finding should be interpreted with caution given the potential for socially desirable responses to hygiene practice questions. A comprehensive education strategy would benefit from continued emphasis on the importance of mitigating behaviours.

The findings show the geographic distribution of environmental lead sources across the study area is uneven and there are some neighbourhoods characterized by relatively higher risks of multiple lead sources. In particular, the areas defined in the study as being proximal to lead-associated industry are also those that are long-established built environments retaining historic risks from emissions from lead-based gasoline, lead-based paint, lead piping, and known and unknown industrial sources. In addition, many of these areas are also characterized by low-socio-economic status. In the analyses of association, these potential predictors of BLLs were intertwined to the extent that it was challenging to disentangle contributions to BLLs and intermediary sources. For example, the modeling could not determine the extent to which older housing contributed to tap water lead levels versus dust lead levels, or how proximity to industry was also related to housing age and socio-economic factors. This study's measure of industry emissions was a proxy measure that may reflect long-established, urban neighbourhoods that are also adjacent to long-established lead-emitting industry with unmeasured risk from multiple sources. This factor demonstrated a significant and strong association with BLLs. Such areas are therefore of particular importance to public health lead exposure reduction strategies.

9.1 Conclusions

The study's primary objective was to determine the distribution of BLLs, and the prevalence of BLLs greater than the current blood lead guidance value (0.48 μmol/L) in a sample of children under 7 years of age who resided in the targeted geographic higher risk area of North Hamilton. Within the stated limitations, the study concluded that Hamilton children are experiencing levels of lead exposure that are likely consistent with other populations residing in long-established urban communities, and there is a small proportion of children who are being exposed at levels that would require interventions at an individual, clinical level.

The results suggest that there is a substantial audience for public health promotional materials about reducing lead exposure, and that promotional activities may be improved by targeting specific groups within the population. Overall, the compliance with recommendations and willingness to participate in home remediation education suggest that public health lead-exposure reduction services will be well received in this community and there will be significant interest and uptake of programming. However, we expect there will be a segment of the population that will not seek to benefit from available public health services.

The factors that were found to be significant predictors of children's BLLs were consistent with other research (see Appendix A). These included older housing stock, proximity to historical and current industry, household income, recent renovations, and male sex. As well, intermediary sources of environmental lead such as yard soil, tap water, and household dust were also statistically significant predictors of BLLs. These risk factors and sources as well as others from the literature such as recent immigration, rental housing, and an unofficial language spoken at home were found to be characteristic of the study area in North Hamilton. There was some evidence that many families in the study area were already engaged in mitigating practices; however promotional activities should continue to encourage behaviours that can mitigate the potential risks, such as proper renovation techniques, wet mopping, and household entry and individual hygiene practices. Long-established, urban neighbourhoods with risks from multiple sources that are also adjacent to long-established lead-emitting industry are particularly important to target by public health in lead-exposure reduction strategies.

The results of this study may be used to inform and refine ongoing public health efforts and initiatives to reduce lead exposure among North Hamilton children and families. Recommendations resulting from the study findings and conclusions will be developed and presented in a separate report submitted to the City of Hamilton Board of Health.

Appendix A: Overview of Research Literature Reviewed

During the developmental phases of the study, HPHS undertook a review of relevant literature to identify key constructs to include, approaches to measurement, and overall considerations to take into account for study design. This literature review contributed to the overall study design and study conceptualization including main hypotheses as outlined in the risk factor concept map (see Appendix C). The findings from the literature are presented below.

Ample information exists about population exposures to lead in environmental and occupational settings; especially among infants and children, as they along with pregnant women are the most susceptible groups in the population. Most of this information comes from the USA whose experience with children's exposures has been well documented. In contrast, Canada has not produced as much information on children's exposure to lead especially among 'ordinary children'. With few exceptions, Canadian studies include children at risk of point source lead emissions or contaminated sites. We have no evidence as to how lead in drinking water or other media in Hamilton contribute to lead exposure. Hamilton residents, namely young children living in high risk areas, are a particular focus of concern. The impact of current guidelines on children's blood lead levels (and hence exposure) has never been evaluated. New ones are being proposed, including emission guidelines (standards) in Ontario that are meant to modify exposures at a population level. Without available baseline information, there is no basis to evaluate the impact of these population level interventions.

In 1994, a Federal Provincial Working Group (based on sparse data) estimated that 5-10% of urban Canadian children had BLLs above 0.48 micromoles per liter (µmol/L), the level at which primary care physicians are recommended to take clinical action as well as the collection of an exposure history.[32] The Working Group recommended community interventions when the percentage of children in that community with values above 0.48 µmol/L is double that seen in the general population.[33] After a review of recent observational studies, researchers estimate the prevalence in general population to be 1%. [34-35-36]

Lead is a heavy metal that occurs naturally in the environment; however, most lead found in high levels in the environment is the result of human activity.[37] Rarely found in its natural metallic state, lead is most often found combined with other elements to form lead compounds. Lead can be combined with other metals to form lead alloys which are commonly found in pipes, solder, batteries, ammunition, cable covers and radiation shields. Inorganic lead compounds are often used in the manufacture of dyes, paints, insecticides, ceramic glazes, and rubber compounds. In Canada, organic lead compounds were used as additives in gasoline until their prohibition in 1990, however, the once airborne lead may still be present in soil even today.

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[32] Sanborn, M.D., Abselsohn, A., Campbell, M. Weir, E. (2002). *Identifying and managing adverse environmental health effects: 3. Lead exposure.* CMAJ. 166 (10). P-1287-1292.
[33] Federal-Provincial Committee on Environmental and Occupational Health. Update of Evidence for Low-Level Effects of Lead and Blood Lead Intervention Levels and Strategies – Final Report of the Working Group. Environmental Health Directorate, Health Canada. 1994.
[34] Region of Ottawa-Carleton (2000). Results of West Carleton Blood Lead Screening. Region of Ottawa-Carleton Health Department
[35] Decou, ML, Williams, R, Ellis, E. (2001). Lead Screening Report Eastside Community, Port Colborne, April- June, 2001. Retrieved November 20, 2007 from http://www.wdghu.org/tytler/docs/Lead%20Screening%20Study%2081401.pdf
[36] Nova Scotia Department of Health and the Cape Breton District Health Authority. (2001) *Lead and Arsenic Biological Testing Program In Residential Areas Near the Coke Ovens Site.*
[37] Agency for Toxic Substances and Disease Registry (ATSDR). (2005). Public Health Statement on Lead (CAS#: 7439-92-1). U.S. Department of Health and Human Services. Retrieved November 20, 2007 from: http://www.atsdr.cdc.gov/toxprofiles/phs13.html

Health Risks of Lead Exposure

Humans can be exposed to lead or its various compounds in both indoor and outdoor environments. Lead can be found in soil, dust, air, drinking water, food and consumer products. The human body may absorb lead through inhalation, ingestion, dermal contact and via the placenta in the fetus. Once lead enters the body, it circulates in the bloodstream and either accumulates in tissues or is excreted. Short-term exposure to high lead levels can cause vomiting, diarrhea, convulsions, coma and death. Chronic exposure to lead in adults is associated with impaired red cell production and kidney and nervous system function. In addition, lead has been identified as a probable carcinogen by the International Agency for Research on Cancer (IARC).[38] Children are more at risk of harmful health effects from lead exposure than adults because their bodies and nervous systems are still developing and they absorb and retain a larger percentage of ingested lead per unit of body weight than adults which increases toxic effects.[39] Low levels of lead exposure have been shown to impair the physical and mental development of children. High levels of exposure among children may cause anemia, kidney damage, muscle weakness, colic, and brain damage, which can ultimately lead to death. Fetuses exposed to lead in the womb, because their mothers had significant amounts of lead in their bodies, may be born prematurely, have lower birth weights, and may also experience slowed mental development and consequentially lowered intelligence later in childhood.[40]

Measuring and Monitoring Blood Lead Levels

A blood lead level (BLL) is a measure of the amount of lead circulating in a person's blood. A BLL reflects the equilibrium between absorption, excretion and deposition in tissues and does not show either the current or cumulative effects of lead on a person's body. A BLL is used to assess lead exposure, as rapid changes in lead intake are generally considered to show a linear relationship with exposure.[41] A BLL is reported by Ontario's Central Public Health Laboratory in micromoles per liter (μmol/L).

Capillary blood lead samples (as opposed to venous blood samples) can be used for population screening because it is convenient and because previous studies indicate that this is an appropriate approach for population screening blood lead levels in children.[42,43,44,45]

In 1991, the U.S. Centers for Disease Control and Prevention (CDC) recommended activities such as taking an environmental exposure history, educating parents about lead and conducting follow-up blood lead monitoring for children with BLLs greater or equal to the SI unit of 0.48μmol/liter or

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38 International Agency for Research on Cancer (IARC). (2006). *Inorganic and Organic Lead Compounds*. IARC Monograph Vol.87. Retrieved November 29, 2007 from: http://monographs.iarc.fr/ENG/Monographs/vol87/volume87.pdf .
39 Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre. (1995). *Why Barns Are Red: Health Risks from Lead and Their Prevention. A Resource Manual to Promote Public Awareness*. Metropolitan Toronto, Ontario.
40 Agency for Toxic Substances and Disease Registry (ATSDR). (2005). Public Health Statement on Lead (CAS#: 7439-92-1). U.S. Department of Health and Human Services. Retrieved November 20, 2007 from: http://www.atsdr.cdc.gov/toxprofiles/phs13.html
41 *Ibid*
42 Parsons, P.J.; Reilly, A.A.; Esernio-Jenssen D. (1997). Screening children exposed to lead: an assessment of the capillary blood lead fingerstick test. Clinical Chemistry. 43:2, pp 302-311.
43 Sargent JD, Dalton MA. (1996). *Rethinking the threshold for an abnormal capillary blood lead screening test.* Pediatri Adolesc Med. Oct; 150(10):1084-8
44 Schonfeld DJ, Cullen MR, Rainey PM, Berg AT, Brown DR, Hogan JC Jr, Turk DS, Rude CS, Cicchetti DV. (1994). *Screening for lead poisoning in an urban pediatric clinic using samples obtained by fingerstick.* Paediatrics. Aug. (2Pt 1):174-9.
45 Schlenker TL, Fritz CJ, Mar D, Layde M, Linke G, Murphy A, Matte T. (1994*). Screening for pediatric lead poisoning. Comparability of simultaneously drawn capillary and venous blood samples*. May 4;271(17):1346-8.

10µg/dl.[46] It is widely understood that there is no evidence for a threshold below which lead has no adverse effects. Despite a number of studies since 1991 that indicate additional evidence exists of adverse health effects in children at BLLs under 0.48µmol/liter or 10µg/dl, the CDC maintains that there are valid reasons not to lower the level of concern.[47]

In 1994, a Federal Provincial Working Group (based on sparse data) estimated that 5-10% of urban Canadian children had a BLL above 0.48 µmol/L – the current level at which an intervention is required.[48] The report indicated 'at risk populations of children' to have the following risk factors:

- living near point-source emissions of lead (smelters, metal refineries)
- living near soil contaminated by lead from mine tailings, etc;
- living in houses painted internally or externally with paint containing lead.

The National Health and Nutrition Examination Surveys (NHANES), conducted by CDC's national Center for Health Statistics, have been tracking BLLs in the USA since the 1970s (NHANES). These national surveys are designed to estimate BLLs at the national level only and not at the state or local levels. NHANES have documented a substantial decrease in BLLs among young children. BLLs ≥ 0.48 µmol/L were estimated for 2.2% of children aged 1-5 years according to NHANES 1999-2000.[49]

In addition, the Centers for Disease Control and Prevention (CDC) Lead Poisoning Prevention Branch (LPPB) compiles state surveillance data for children age < 72 months (< 6 years) who were tested for lead at least once between January 1, 1997 and December 31, 2006. Many participating states target their screening resources to children considered to be at highest risk. State surveillance therefore does not necessarily produce data representative of all children aged 1-5 years. Nationally, the prevalence of clinically actionable BLLs in the USA (biased towards high risk children) since 1997 has steadily declined from 7.61% to 1.21% in 2006.[50] Based on 1996-1998 state surveillance data from 19 states, the county-specific proportions of children with clinically actionable BLLs ranged from 0.5%- 27.3%.[51]

In the past decade, two blood lead surveys have been conducted in Ontario, one in Nova Scotia and a pilot blood lead survey in New Brunswick. In 2000, the Region of Ottawa-Carleton Health Department conducted finger-prick blood lead screening in West Carleton near a mine site (point-source) following test results of mine tailings obtained in 1999 that had a high lead content and which had been used (since the mine closure) for local driveways, roads, fill and landscaping[52]. The study involved a convenience sample of 688 individuals of which 196 lived in the target area and were under the age of 7 years or were pregnant. Anyone with clinically actionable BLLs upon initial screening underwent venous blood lead re-testing. In addition, drinking water lead testing was offered to all area residents. Results indicated there was no evidence of lead poisoning

[46] Système International
[47] Centers for Disease Control and Prevention. (2005). *Preventing Lead Poisoning in Young Children.* Atlanta, U.S.A.
[48] Federal-Provincial Committee on Environmental and Occupational Health. Update of Evidence for Low-Level Effects of Lead and Blood Lead Intervention Levels and Strategies – Final Report of the Working Group. Environmental Health Directorate, Health Canada. 1994.
[49] Centers for Disease Control and Prevention. National Centre for Environmental Health. Retrieved January 14, 2008 from http://www.cdc.gov/nceh/lead/research/kidsBLL.htm
[50] Centers for Disease Control and Prevention. National Centre for Environmental Health. Lead Poisoning Prevention Branch. CDC Surveillance Data , 1997-2006. Last updated: 11/29/2007. Retrieved January 14, 2008 from http://www.cdc.gov/nceh/lead/surv/stats.htm
[51] Centers for Disease Control and Prevention. Morbidity and Mortality Weekly Report . Blood Lead Levels in Young Children – United States and Selected States, 1996-1999. Retrieved January 30, 2008 from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4950a3.htm
[52] Region of Ottawa-Carleton (2000). Results of West Carleton Blood Lead Screening. Region of Ottawa-Carleton Health Department

among all those tested. Repeat blood lead testing of all children under age 7 years and pregnant women living or frequently spending time in the target area was deemed not to be required.

In 2001, the Regional Niagara Public Health Department conducted a similar blood lead screening survey in the Eastside Community of Port Colborne, situated near a defunct nickel refinery (point-source).[53] The study involved a convenience sample of 1,065 individuals of which 24% were younger than age 15 years. Of the 1,065 study participants, 30 (2.8%) were found to have clinically actionable BLLs on the initial finger-prick lead screening test of which 6 (0.6%) were confirmed to be elevated on repeat venous blood lead testing. Based on the results of the blood lead screening program, no immediate intervention was deemed to be required regarding lead soil based on the results of the 'at risk' population who had participated in the survey.

In the summer of 2001, a biological testing program for lead and arsenic was conducted in Sydney Nova Scotia, near a point-source emission (near Coke Ovens Site).[54] Testing was offered to all children age 1 to 5 years and all pregnant women in neighbourhoods around the Coke Ovens Site. In addition, all residents in the area north of the Coke Ovens (NOCO) were offered testing. In total, 372 people in the target area were tested for lead including 186 children age 1 to 5 years. Blood lead levels averaged 1.86 ug/dL for all ages tested and 1.86 ug/dL for children. This is well below the level of 10 ug/dL designated as the level at which follow up would be done. Two adults had a level above 10 ug/dL. No children were above this level.

In 2004, the New Brunswick Department of Health and Wellness undertook a pilot survey of children in the vicinity of the lead-zinc smelter located in the Belledune industrial park.[55] A total of 23 children between the ages of 3 years and 15 years currently residing in either of two selected neighbourhoods were recruited in the survey. Two of the 23 children (9%) had clinically actionable BLLs . Based on this pilot survey, researchers highly recommended an expanded blood lead survey be conducted of a representative sample from the other communities within the Greater Belledune Area.

Sources of Lead Exposure

Air

Lead released from industrial emissions into the atmosphere can be a major source of environmental contamination, especially near "point sources" such as smelters or refineries.[56] Lead in air was primarily due to the use of organic lead as an additive to gasoline to prevent engine knock. Unleaded gasoline was introduced to the Canadian market in 1975 and leaded gasoline for cars was completely banned in 1990. Since then, lead levels in the air of most Canadian cities have dramatically decreased to well below regulated levels. In Hamilton, 22 local companies comprise the Hamilton Air Monitoring Network. This cooperative network provides ongoing surveillance of several indicators of air quality in Hamilton including lead. Although lead concentrations in Hamilton may be found to be below the accepted standard set out by the Ontario Ministry of the Environment, airborne lead eventually settles and has the potential to accumulate in

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[53] Decou, ML, Williams, R, Ellis, E. (2001). Lead Screening Report Eastside Community, Port Colborne, April- June, 2001. Retrieved November 20, 2007 from http://www.wdghu.org/tytler/docs/Lead%20Screening%20Study%2081401.pdf

[54] Nova Scotia Department of Health and the Cape Breton District Health Authority. (2001) *Lead and Arsenic Biological Testing Program In Residential Areas Near the Coke Ovens Site.*

[55] Department of Health and Wellness, Government of New Brunswick, (2005). Belledune Area Health Study. Appendix E – Pilot Lead Survey Results. Retrieved November 20,. 2007 from http://www.gnb.ca/0208/pdf/AppendixE_PDF_version.pdf

[56] Health Canada. (2007). *Lead and Health*. Retrieved November 20, 2007 from http://www.pollutionprobe.org/Reports/CH%20NPC/Lead%20Health%20Canada%20Fact%20Sheet%20Jan%2022%202007.pdf

dust, soil and surface water. Moreover, airborne lead has exposure implications for a much larger number of children than those potentially at risk from a specific point source.

Dust and Soil
Dust and soil are the most likely sources of environmental lead exposure among children due to the mouthing of hands, surfaces and objects on which dust or soil containing lead is deposited.[57] Lead in soil can be deposited from the air or from erosion of lead-bearing rock. Once lead falls onto soil, it sticks strongly to soil particles and remains in the upper layer of the soil.[58] The amount of lead in soil has particular significance for young children who, through their outdoor play activities frequently come into contact with soil in yards and playgrounds.

Historic uses of lead in products such as gasoline, house paint, and pesticides are important contributors to the amount of lead found in soil. Dust found in the home can also contain lead, especially in older homes that have a history of using lead-based paints. Lead was commonly used as an additive to paint until the 1960's, and in 1976, the Canadian Federal Government began to place limits on the amount of lead used in interior paint. The use of lead paint in homes built prior to 1960 is believed to contribute to elevated lead levels in dust found in those homes.[59] Health Canada is planning to release results in 2010 of a "Canadian House Dust Study", of which lead was one of the many environmental toxins that were assessed in house dust. Regular home cleaning, accompanied by parental education, has been found to be a safe and partially effective intervention to reduce lead-dust exposure to children for whom lead-safe housing is not an option.[60]

Water
Naturally occurring lead in drinking water in Canada is very low[61]. Lead present in drinking water usually comes from any combination of three sources: lead pipes or connections (including service connections to buildings and homes); lead-containing solder used to join pipes; or brass materials such as valves, fittings and fixtures. In May, 2007, the Ontario Ministry of the Environment ordered all municipalities in Ontario to test their potable water systems for lead concentrations. Tests conducted in Hamilton found that roughly 10% of samples voluntarily submitted by local residents were higher than the maximum acceptable concentration for lead. Lead sampling surveys of drinking water at private and public sampling points in Hamilton were conducted in late 2007 to further assess the extent of elevated lead levels in drinking water.

Lead levels in tap water increases with the amount of time water stands in the pipes. It is commonly recommended to flush water lines for a period of time prior to using any water for consumption in order to potentially lower the level of lead. Although tap water generally represents a small proportion of total lead exposure to children, lead in water is readily absorbed, and is especially available for children who are anemic. The prevalence of iron deficiency anemia in

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[57] Centers for Disease Control and Prevention. (2005). *Preventing Lead Poisoning in Young Children.* Atlanta, U.S.A.
[58] Agency for Toxic Substances and Disease Registry (ATSDR). (2005). Public Health Statement on Lead (CAS#: 7439-92-1). U.S. Department of Health and Human Services. Retrieved November 20, 2007 from: http://www.atsdr.cdc.gov/toxprofiles/phs13.html
[59] Ontario Public Health Association. (2004). *Childhood Lead Exposure and Housing Sources: Does a Problem Exist in Ontario?* Toronto, Ontario.
[60] Rhoads G.G., *et al*. **1999**. *The Effect of Dust Lead Control on Blood Lead in Toddlers: A Randomized Trial*. Pediatrics, 103(3): 551-555.
[61] Health Canada. (2007). *Lead and Health*. Retrieved November 20, 2007 from http://www.pollutionprobe.org/Reports/CH%20NPC/Lead%20Health%20Canada%20Fact%20Sheet%20Jan%2022%202007.pdf

Canadian children is reported to be between 3.5 % and 10.5 % in the general population and approximately 18% among Aboriginal children.[62-63]

Monitoring Blood Lead Levels in Other Jurisdictions

There are currently no public health recommendations or guidelines for the routine screening of young children for BLLs in Ontario. A Canadian review found that, because clinical lead poisoning is very rare in Canada, screening of all children is not considered cost effective unless there are potential sources of lead and circumstances that make children bear more risk [64].

The Center for Disease Control (CDC) in the USA. has also developed recommendations on Preventing Lead Poisoning in Young Children – 2005.[65] The CDC's recommendations are based on scientific evidence and practical considerations. The report promotes the primary prevention of two main exposure sources of children in the U.S.A: i) lead-paint contaminated houses and ii) non-essential uses of lead in products made or decorated with lead such as toys, eating and drinking utensils, cosmetics and traditional medicines. They recommend to local, state and federal decision makers, policies and legislative changes that include:

- Comprehensive early childhood lead screening policies
- Advocacy for lead-safe affordable housing
- Testing of non-essential products for possible health hazard from lead
- Monitor and enforce regulations controlling lead content of various environmental media, including air, water and soil.

On a national level in the USA, the U.S. Department of Housing and Urban Development (HUD) has Guidelines for the Evaluation and Control of Lead-Based Paint Hazards that provide detailed, comprehensive, technical information on how to identify lead-based paint hazards in housing and how to control such hazards safely and efficiently[66]. The guidelines address lead hazards posed by paint, dust and soil in the residential environment. HUD's suggested BLLs that are health hazards for young children are the same as those for New York State.

New York State public health regulations require all health care providers to test all children for blood lead levels at age one year and again at age two years [67]. More frequent testing may be done if the child is at high risk. When BLLs are found to be greater or equal to 0.48 μmol/L or 10μg/dl, the physician is directed to provide guidance on lead poisoning prevention, risk reduction and nutritional counselling to the child's parent or caregiver. In cases where the BLL is >20 μg/dl, a public health worker inspects the child's home and possible actions may be taken against landlords or homeowners to ensure the home is "lead-safe" through compliance with safety guidelines. It

[62] Christofides, A., Schauer, C., Zlotkin, S. (2005). *Iron deficiency anemia among children: Addressing a global public health problem within a Canadian context*. Can J Public Health. Jul-Aug; 96 (4):304-7
[63] Willows, N.D., Gray-Donald, K. (2004). *Infection and anemia in Canadian aboriginal infants.* Can J Diet Pract Res. 65(4):180-2.
[64] Federal-Provincial Committee on Environmental and Occupational Health. Update of Evidence for Low-Level Effects of Lead and Blood Lead Intervention Levels and Strategies – Final Report of the Working Group. Environmental Health Directorate, Health Canada. 1994.
[65] Centers for Disease Control and Prevention. (2005). *Preventing Lead Poisoning in Young Children.* Atlanta, U.S.A.
[66] U.S. Department of Housing and Urban Development. (1996). *The HUD Guidelines for the Evaluation and Control of Lead-Based Paint in Housing.* Washington, D.C., USA.
[67] New York State Department of Health. Retrieved January 29, 2008 from http://www.health.state.ny.us/environmental/lead/

should be noted that housing stock, and lead paint dust, in say Buffalo, might also occur in similar Ontario cities such as Hamilton or Toronto.

Appendix B: Map Data Sources

Data item	Data source
Child care facilities *(Figure 2.1)*	Data provided by Inform Hamilton (www.inform.hamilton.ca). Inform Hamilton is a free online database of human services that is a collaboration among three community information centres in Hamilton: Community Information Hamilton, Dundas Community Services/Information Dundas, Flamborough Information and Community Services. Child Care Information Hamilton is also a partner and data contributor. The partners of Inform Hamilton are committed to provide a database that is accurate, up-to-date and comprehensive. However, we are unable to assume any liability resulting from errors or omissions. Inclusion or omission of a program or service is neither a recommendation nor a comment on its quality.
Schools *(Figure 2.1)*	Data provided by the City of Hamilton Corporate Services department, GIS database, 2008.
Ontario Early Years Centres *(Figure 2.1)*	Data provided by the City of Hamilton Public Health Services department, 2008.
Downtown Area *(Figure 2.1)*	Data provided by the City of Hamilton Economic Development and Planning department, Oracle database, 2010. **Downtown Area (name in database: Downtown Secondary Plan Area)** was queried from the Oracle featureclass named GISDBA.PED_SEC_PLAN_BNDRY. It is a Polygon Featureclass that shows the outline of each Secondary Plan area. The Downtown Secondary Plan Area approved in 2001.
Dissemination area boundary files *(Figures 2.1, 3.6, 5.2)*	Boundary files were obtained from Statistics Canada (www.statcan.gc.ca). The boundaries displayed on the map portray the dissemination area boundaries for which 2006 Census data are disseminated. A dissemination area is a small area composed of one or more neighbouring blocks and is the smallest standard geographic area for which all census data are disseminated. A reference guide is available for the 2006 Boundary Files (Statistics Canada Catalogue no. 92-160-GWE). Statistics Canada. 2007. *Dissemination Areas, Hamilton CMA, 2006 Census* (cartographic boundary file, gda_035b06a_e.zip). Statistics Canada Catalogue no. 92-169-XWE2006007. February 14. ARC/INFO shapefile format.
Dissemination area census profile data – age and sex (2006) *(Figures 2.1, 3.6)*	Age and sex profile data were obtained from Statistics Canada (www.statcan.gc.ca). A dissemination area is a small area composed of one or more neighbouring blocks and is the smallest standard geographic area for which all census data are disseminated. The 2006 profile data was extracted from the file authored by 2006 Census Statistics Canada, POB94581002. In order to achieve an expected number of children aged 0-6 in each dissemination area, 40% of the population from the total (male and female) 5-9 age group was added to the total for the 0-4 age group.
Dissemination area census profile data – Income, Education, Language, Immigration, Home Ownership (2006) *(Figure 3.6)*	Statistics Canada. 2007. *Profile for Canada, Provinces, Territories, Census Divisions, Census Subdivisions and Dissemination Areas, 2006 Census File* (ProfileCanada2006_HamiltonDA.IVT). 2006 Electronic Profiles. *Data Quality Note: - The overall quality of the 'Highest certificate, diploma or degree' variable from the 2006 Census is acceptable. However, users of the 'University certificate or diploma below the bachelor level' category should know that an unexpected growth in this category was noted compared to the 2001 Census. In fact, in the 2001 Census, 2.5% of respondents aged 15 years or over declared such a diploma, compared to 4.4% in 2006, representing 89% growth. This phenomenon was not found in other sources*

Data item	Data source
Average age of residential housing *(Figure 3.2)*	Based on data from the Municipal Property Assessment Corporation (MPAC) 2008, combined with parcel fabric from Teranet Land Information Services Inc. and its licensors, 2008, and aggregated by Statistics Canada 2006 Dissemination Block boundaries via property centroid.
Residential housing *(Figures 3.2, 3.4)*	Data housed in City of Hamilton Corporate Services department, GIS database, GISDBA.PED_LANDUSE feature, 2008. This feature is maintained by the City of Hamilton Planning and Economic Development department and is an aggregation of parcel fabric from Teranet Land Information Services Inc. and its licensors, 2008 and property assessment data from the Municipal Property Assessment Corporation (MPAC), 2008. Residential housing was selected out of the feature based on the following definition: LUC1 = 110, 115, 120, 130, 140, 150 OR LUC2 = 110, 115, 120, 130, 140, 150. The definitions of LUC1 and LUC2 are based on a document created by Hamilton's Planning and Economic Development Department (**Metadata_PED_LANDUSE.doc**), whereby LUC1 represents the acronym for the Land Use Code 1. This is a 3-digit alphanumeric value that describes the predominant general land use classification of the parcel. These codes were initially populated by group classification of assessment property codes defined by consultants and planners. For a complete list of these land use codes refer to "Recommendations for the Creation and Maintenance of Land Use System for the City of Hamilton", March 2002, BPPI Partners located on .Information Planning\Data\Land Use\Documentation\Draft Recommendations - Hamilton Land Use - Rev Apr 16.doc. These codes were further validated through survey site visits that that took place in the summer of 2003. LUC2 represents the acronym for the Land Use Code 2. This is a 3-digit alphanumeric value that describes the second most predominant detailed land use classification of the parcel. A complete list can be found in the above specified document. The definitions regarding how LUC is related to Property Code can be found in the document, **Land_Use_Code_2008_DDC.pdf**. Property codes are also defined on MPAC's website (http://www.mpac.ca/pages_english/property_owners/property_code_inventory.asp#300).
Dissemination block boundary files *(Figure 3.2)*	Boundary files, available as digital boundary files or cartographic boundary files, portray the dissemination block boundaries for which 2006 Census data are disseminated. A dissemination block is an area bounded on all sides by roads and/or boundaries of standard geographic areas and is the smallest geographic area for which population and dwelling count data are disseminated. A reference guide is available for the 2006 Boundary Files (Statistics Canada Catalogue no. 92-160-GWE). Statistics Canada. 2007. *Dissemination Blocks, Hamilton CMA, 2006 Census* (cartographic boundary file, gdb_035b06a_e.zip). Statistics Canada Catalogue no. 92-163-XWE2006007. February 14. ARC/INFO shapefile format.
Lead-associated industries *(Figures 3.4, 3.5)*	Data was extracted from the National Pollutant Release Inventory (NPRI) database located on Environment Canada's website, www.ec.gc.ca/npri (December 10, 2007). The search found industries associated with Lead (and its compounds) in Hamilton for the 2006 reporting year. Reporting to the NPRI (National Pollutant Release Inventory) is a legal requirement and mandatory under Canadian Law.
Lead-associated metal recycling plants *(Figure 3.4)*	Data was extracted from the Canadian Metals and Minerals Recycling Database resulting from a search for lead recyclers in Hamilton (September 26, 2007). Natural Resources Canada houses this database on their website, www.recycle.nrcan.gc.ca. The website retains, "The information in the database has been entered by the companies in the language of their choice. No editing or modifications have been made by NRCan and the department assumes no responsibility for its accuracy."

Data item	Data source
Air monitoring stations *(Figure 3.5)*	The locations and data associated with the air monitoring stations were provided by the Ontario Ministry of the Environment, 2009.
Air lead zone *(Figure 3.5)*	Data were provided by the Ontario Ministry of the Environment, 2009 *(STATIONUTM08HAMreport.xls)* The strata drawn by an MOE analyst were a pair of contours of common concentration that could reasonably be drawn through the geographic distribution of 2006 lead geometric means for the 7 TSP stations where there were data. As such they were mostly defined by measurements. In the southeast corner the analyst had to estimate because there was no station but based estimates on historical knowledge of what previous contours looked like when there were more stations. These are not strata of high, moderate and low. They are all low, all well below standards and guidelines. There is a slight gradient from the northeast industrial area but ambient levels of lead are typical of any urban area. The data lent themselves to the contours of .005 and .010 but there is no particular significance to those numbers.
Water mains *(Figure 3.3)*	Data provided by the City of Hamilton Public Works department, Hansen database, 2007. **Water mains** are pipes or conduits for conveying water (as defined by the Merriam-Webster online dictionary, www.merriam-webster.com/dictionary/water%20main). These pipes carry pressurized and treated fresh water to buildings (as part of a municipal water system), as well as inside the building (http://en.wikipedia.org/wiki/Water_pipe).

Appendix C: Study Schema and Construct Operationalization

Figure C1: North Hamilton Child Blood Lead Study Framework

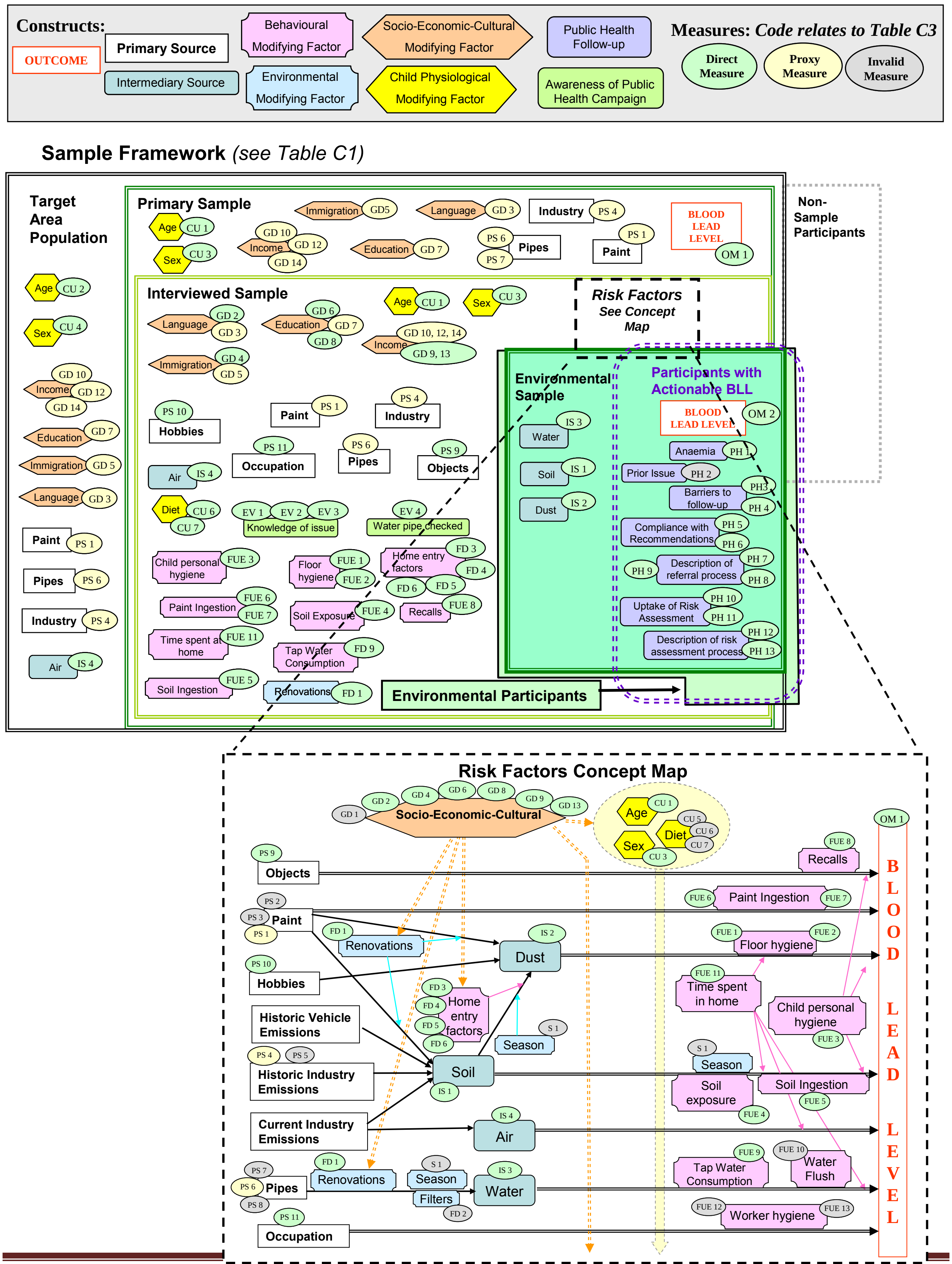


Table C1: Overview of Study Samples

Name	Type of Sample	Description of Sample	Sample Size
Target Area Population	Target Population	Population of children aged 6 years or younger (less than 84 months) who at the time of the study resided in the **Target Area** within the City of Hamilton, located east of the 403 Highway, south of the mountain brow (escarpment), west of Parkdale Avenue and south of the Hamilton Harbour	8922 in 233 Dissemination Areas
Target Area Households		Population of households containing children under 7 years of age (less than 84 months) who at the time of the study resided **'at that address**' in the **Target Area** within the City of Hamilton, located east of the 403 Highway, south of the mountain brow (escarpment), west of Parkdale Avenue and south of the Hamilton Harbour	7630 in 233 Dissemination Areas 7572
Study Household	N/A	The single residential household of a **Study Participant**	528
Study Participant		Any child who participated in the study for whom there is a record in the database.	755
Capillary BLL Participants		**Study Participants** for whom there is a valid capillary blood lead value.	736
Non-Sample Participants		**Study Participants** for whom valid capillary blood lead values were obtained who: (*i*) at the time of the study resided in the **Target Area** within the City of Hamilton however did NOT reside **'at that address**' at the time of the study and for at least 3 months prior or (*ii*) were NOT members of the **Target Area Population**	93
Primary Household Sample	Self-Selected Sample	Households in which at least 1 child resides under 7 years of age (less than 84 months) who has a valid capillary blood lead value and has resided in that same household for at least 3 months prior to the date of their capillary blood sample, and that their household belongs to the **Target Area Households**	453
Primary Sample		Children under 7 years of age (less than 84 months) with valid capillary blood lead values who are members of the **Target Area Population** who at the time of the study and for at least 3 months prior, resided in the targeted '**Target Area'** within the City of Hamilton, located east of the 403 Highway, south of the mountain brow (escarpment), west of Parkdale Avenue and south of the Hamilton Harbour	643
Non Interviewed Sample		Children who are members of the **Primary Sample** whose parents/guardians did not complete a telephone interview for risk factors	63
Interviewed Household Sample	Self-Selected Sample	Households belonging to the **Primary Household Sample** for which a telephone interview for risk factors was completed	406

Name	Type of Sample	Description of Sample	Sample Size		
Interviewed Sample		Children who are members of the **Primary Sample** whose parents/guardians completed a telephone interview for risk factors	580		
Environmental Households	N/A	**Study Households** for which there is at least 1 valid environmental sample	209		
Environmental Participants	N/A	**Study Participant** for whom there is at least 1 valid environmental sample.	302		
Environmental Sample	Quota Sample	Children who are members of the **Interviewed Sample** selected based on the quota sampling process who at the time of environmental sampling, resided **'at that address'** for at least 3 months prior to capillary blood lead sampling and for whom there is at least 1 valid environmental sample. Quota groups consists of houses built prior to 1950 (Old Housing) and houses built 1950 + (New Housing) whose property is assigned to an air lead zone (i.e. High Air Lead – HAL, Medium Air Lead – MAL, Low Air Lead – LAL or Old Recycling Plant area – ORP)	281	New Housing =40	ORP=0
					LAL=19
					MAL=20
					HAL=1
				Old Housing =241	ORP=9
					LAL=117
					MAL=67
					HAL=48
Participants with BLLs at or above the study follow-up threshold	N/A	**Study Participants** having a capillary blood lead value at or above the study follow-up threshold (≥ 0.19 µmol/L)	101		
Environmental Household Sample	Quota Sample	Households arising from the **Interviewed Household Sample** which were selected and categorized based on the quota sampling process and there is at least 1 valid environmental sample. Furthermore, at the time of environmental sampling, household members resided **'at that address'** for at least 3 months prior to capillary blood lead sampling. Quota groups consists of houses built prior to 1950 (Old Housing) and houses built 1950 + (New Housing) whose property is assigned to an air lead zone (i.e. High Air Lead – HAL, Medium Air Lead – MAL, Low Air Lead – LAL or Old Recycling Plant area – ORP) Note: The map displays only include old housing categories. Contrary to the naming convention of the strata for air lead zones (i.e. high, medium and low), all gradient levels of ambient air lead are all well below the regulatory limit..	196	New Housing =28	ORP=0
					LAL=12
					MAL=15
					HAL=1
				Old Housing =168	ORP=6
					LAL=81
					MAL=46
					HAL=35

Table C2: Overview of Issues and Decisions on Exclusions, Weighting and Data Analyses

Category	Issues	Decisions / Data Details
Exclusion of Outliers	Consideration was given as to whether or not one record should be excluded from all analyses (records were associated with a parent having a white lead hobby). The environmental measures and BLL outcome were examined to determine if they were outliers (likely due to hobby) Investigated record associated with extremely high kitchen dust level (109µg/ft^2). This result was a significant extreme value. In comparison, nearly two thirds of samples collected (65%) were under 2.5 µg/ft^2. This extreme value was nearly three times higher than the next highest value (40 µg/ft^2). Survey data and other enviro sampling data for this record were reviewed to determine if there was a possible rationale for this high level. Kitchen and bedroom dust samples collected were under 10µg/ft^2 . Lead measured in soil was within the top 25% of the distribution. There had not been any reported recent renovations, peeling paint, etc.	Outcome: Decision was to retain the household and child record, as it was not an outlier upon further investigation. Extreme living room dust level to be removed from analyses and map displays involving dust lead. Overall record to be retained for all other analyses.
Control Dust Samples with measurable lead values	It is believed that the control samples were incorrectly collected, but unlikely to have impacted the collection of other dust samples given the process that was used for collection.	Control sample values will be considered invalid.
Post-weighting	Self – selected sample is not representative of North Hamilton Area. Weighted primary sample by "neighbourhood" and age group (0-4yrs; 5 & 6 yrs) to evaluate impact on estimate of BLL. For the individual census DAs were aggregated up to 17 geographically contiguous neighbourhoods by professional judgment based on survey stratification categories, census derived SES indicators, proximity to industry, age of housing stock, and participation rate to maximize homogeneity within boundaries. Used as a proxy measure for many constructs in conjunction with direct measures, in order to achieve the 'best possible' measure of the construct (most effect with fewest variables). The assessment of the impact of post-weighting determined that while the weighting appeared to adjust the sample characteristics to more closely resemble the population, the actual impact of weighting on the outcome variable (BLLs) was minimal.	Decision was to use unweighted data in all analyses.
Seasonal Adjustment	A true measure of seasonality was not possible given the timeframes for the study (i.e., late fall). If seasonality of BLLs was to be accurately measured, this would involve collecting BLLs over three or four time periods within 12 months. The timeframe for the study involved approximately 6 weeks of data collection.	Decision was made to drop this variable from multivariate analyses given that it is an inaccurate measure of seasonality, and is unclear what it may actually be measuring.

Category	Issues	Decisions / Data Details
Quota Sampling Adjustment	The environmental sub-sample was quota sampled using 4 geographic zones according to 3 air lead levels and one historical industrial setting (i.e., Industry-Adjacent Zone; Middle Zone; Escarpment Adjacent Zone and Old Recycling Plant). The DA within which the residential property falls was categorized into these geographic zones based on the centroid of the DA. Within the geographic zones, the sample was stratified and quota sampled according to the age of housing (prior to 1950 and 1950 or later). Analyses performed on the environmental subsample should consider the limitations associated with the stratified quota sampling methodology employed.	The quota variables were not used as analytic variables. More refined variables were used (actual housing age) and property centroid.
Neighbourhoods for Environmental Mapping	There were issues in how best to display the environmental sampling results in map form taking into consideration the quota sampling areas and limited number of new houses.	In order to display the environmental results in map form, the 4 geographic quota sampling areas (described above) were divided further into 12 display zones based on visual homogeneity of socio-economic-cultural determinant constructs (such as education, recent immigration etc - see Table C3 below). In order to account for the age of housing quota sampling, new houses were excluded from the display map given that the vast majority of housing is old in the various areas, and the new housing achieved with the sample were generally clustered in one sub area of one of the zones (i.e., there was no or very limited new housing in most zones).
Household Clustering	As the sampling was not based on a simple random sample, there was some clustering in certain neighbourhoods (as noted above) and also within households when two or more siblings were brought to the clinics. Several different statistical procedures were utilized to test the sensitivity of the findings to these sampling issues including jackknifing procedures. Generally there were only minor differences between the different analytic approaches.	For reporting and interpretation purposes, the final descriptive and modeling analysis used unweighted data given these minor differences.
Unknown Values	In most cases records with 'unknown' values are excluded from proportions and univariate analyses unless specified in the table below. For the multivariate analyses, the inclusion/exclusion of missing or unknown values was determined on a per variable basis. The majority of those with small numbers of missing data were excluded unless there was a strong theoretical argument to retain them (which is detailed in the table below) Individual records were examined to determine if there was a high percentage of missing data in any one household of for a particular participant (e.g., terminated interview early; did not answer any of the socio demographic questions, etc.).	As identified in the table below, there were some variables resulting from the validation exercise that were removed from analysis due to being assessed as poor quality measures in part because of large proportions of missing data (e.g., respondent does not know answer such as type of water pipes in house). The variable in the multivariate analyses for which missing/unknown values were included were household income. Once examined, there were no individual records that were determined to have large portions of systematic missing data. No records were removed as a result.

Table C3: Overview of Study Constructs, Measurement and Validation Notes

Schema Code	Construct	Measurement	Validity/Notes
Outcome Measures			
OM 1	**Blood Lead Level**	Capillary blood lead level – lower detection limit 0.05µmol/L 1. Continuous variable (µmol/L) 2. Categorical—control: Under 0.19µmol/L; case >= 0.19 µmol/L 3. Categorical— toxicity over 0.48 µmol/L	Consensus reached not to include the comparison analyses (capillary compared with venous) in the report due to concerns about comparability between the two measures (i.e. different laboratories, different laboratory testing methods, two points in time for two different samples etc).
OM 2		Venous blood lead level – lower detection limit of 0.01 µmol/L Continuous variable (µmol/L) **Dropped**	
Public Health Follow-up			
PH 1	**Anemia**	Hemoglobin or Hematocrit outside of parameters Categorical - (yes/no)	
PH 2	**History of Lead Exposure Investigation**	Previous blood lead test Categorical Yes; No **Dropped**	Refer to this in public health report only in narrative form
PH 3	**Barriers to Follow-up:** • **Transportation** • **Health Care Insurance**	Use of taxi chit Categorical Yes; No; Unknown; N/A	
PH 4		Insurance coverage available Categorical Yes; No; Unknown; N/A	
PH 5	**Compliance with Recommendations:** • **Venous sample** • **Paediatric MD followup**	Venous blood lead sample was collected as was recommended. Categorical Yes; No; N/A	
PH 6		Had consultation with paediatrician as recommended Categorical Yes; No; N/A	
PH 7	**Description of Referral Process:** • **Efficiency in Referral Process** • **Successful referral to Paediatric MD** • **Successful referral to GP**	Days between date of telephone referral made to parents and date of consultation visit Continuous: Days	Days between Date Telephone Referral was made to Paediatrician and Date of Consultation Visit
PH 8		Referral to study paediatrician office Categorical: Yes; No; N/A	Date of Telephoned Referral to Study Paediatrician office– when is not null, used as a flag to indicate a referral was made.
PH 9		Referral to family physician office Categorical: Yes; No; N/A	Date of Telephoned referral to Family Physician office – when is not null, used as a flag to indicate a referral was made.
PH 10	**Uptake of Public Health Home Visit**	Home risk assessment conducted Categorical Yes; No; Unknown; N/A	

Schema Code	Construct	Measurement	Validity/Notes
PH 11	• **Risk Assessment** • **Review of Survey Tool**	Review of risk factor questionnaire Categorical Yes; No; Unknown; N/A	
PH 12	**Description of Risk Assessment Process**	Date home visit completed	
PH 13		Descriptive narrative summarizing comments.	Used free text in comments field from hard copy records of 'Home Risk Assessment Visit' forms.
Awareness of Public Health Campaign			
EV 1	**Knowledge of Issue:** • **Awareness of risk of lead service pipes**	Prior awareness of large number of older homes in City may be serviced with lead water service pipes Categorical: Yes; No; Don't Know	
EV 2	• **Awareness of steps to reduce exposure to lead in water**	Prior awareness of steps to reduce children's exposure to lead from tap water. Categorical: Yes; No	Second variable (H12A) was used to assess validity of response (i.e. mention of at least one valid step was required to validate response)
EV 3	• **Awareness of free water pipe inspection**	Prior awareness about free water service pipe inspection Categorical: Yes; No; Don't Know	
EV 4	**Water pipes checked**	Had water service pipe checked to see if made of lead Categorical: Yes; No; Don't Know	
Socio-economic-cultural Factors			
GD 1	**Mobility of the study population**	Length of time child at current residence **Dropped**	This variable was used as a selection criterion in sample flag; any other mobility is not relevant in this time frame
GD 2	**Language barriers**	**Direct Measure**: Language spoken most often at home Categorical—English; French/Other	
GD 3		**Neighbourhood Measure**: (by census DA) Proportion of neighbourhood of residence for which the language spoken most often at home is non-English. Continuous: percentage Categorical: 0-<5%, 5-<20%, 20%+	The categories were chosen by using cut points that approximate the lower and upper quartiles of the data distribution.
GD 4	**Cultural Barriers (Recent immigration)**	**Direct Measure:** Recent immigration to Canada (past 5 years) Categorical—Yes, No	
GD 5		**Neighbourhood Measure** (by census DA): Proportion of people in the neighbourhood of residence that are recent immigrants Continuous: percentage Categorical: 0 to <5%, 5% +	Many DAs had value of 0; rounding error (to 1%) in Census data thereby influencing choice of categories. 75% of the DA have less than 4.3% recent immigrant.

Schema Code	Construct	Measurement	Validity/Notes
GD 6	Education Level of Household	**Direct Measure:** Highest level of education of any adult in your household Categorical—No secondary education (some high school/high school graduate/<2 yrs college or university); Community college diploma; More than 2 yrs univ/bachelors/graduate	Educ_highschool: [No certificate diploma or degree]+[High School certificate or equivalent]+[Apprenticeship or trades certificate or diploma] College: [College CEGEP or other non-university certificate or diploma] University: [University certificate diploma or degree subtotal]
GD 7		**Neighbourhood Measure** (by census DA): Proportion of individuals 25 to 64 years in neighbourhood of residence who have no post-secondary education. Categorical—<50%, 50-<75%; 75%+	The categories were chosen by using cut points that approximate the lower and upper quartiles of the data distribution.
GD 8		**Direct Measure:** Prior awareness of steps to reduce children's exposure to lead from tap water. Categorical: Yes; No	Second variable (H12A) was used to assess validity of response (i.e. mention of at least one valid step was required to validate response)
GD 9	Income status	**Direct Measure:** Total Household income Mock continuous— 1=<$20,000; 2=$20,000-<$40,000; 3= $40,000-<$60,000; 4= $60,000-<$80,000; 5=$80,000+ Further categorized into: 1=<$60,000; 2=$60,000-<$80,000; 3=$80,000+	Tested underlying assumption that it is a linear relationship. Tested using mock continuous variable against categorical variable in a model to see what difference it makes to the variance. Decision was made to use a limited number of categories in multivariate models.
GD 10		**Neighbourhood Measure:** Average Household income in the neighbourhood of residence. Derived Categorical variable — 1: <$40,000; 2: $40,000-$60,000; 3: >$60,000	The categories were chosen by using cut points that approximate the lower and upper quartiles of the data distribution.
GD 11		**Direct Measure**: Calculate Low Income Cut off (LICO) for our sample: For family size 3+, the LICO is <$20,000; For family size 6 or more or 7 or more, LICO is $40,000 to $60,000 **Dropped**	For consideration in the event that further analysis take place.
GD 12		**Neighbourhood Measure:** Proportion of low income economic families before tax in the year 2005 in neighbourhood (DA) of residence. Categorical <15%; 15% - <30%; 30%+	The categories were chosen by using cut points that approximate the lower and upper quartiles of the data distribution.
GD 13	Property Ownership	**Direct Measure**: Ownership Status: Owned vs. rented house Categorical—owner; rental; public housing	

Schema Code	Construct	Measurement	Validity/Notes
GD 14		**Neighbourhood Measure:** Proportion of rented property among occupied private dwelling in neighbourhood Categorical: <20%; 20%-<65%; 65%+	The categories were chosen by using cut points that approximate the lower and upper quartiles of the data distribution. Refers to whether some member of the household owns or rents the dwelling.
Child Physiological Modifying Factors			
CU 1	**Age**	**Direct Measure:** Age at capillary sample 1. Categorical—Infants = 0 to < 18 mos; Toddlers = 18 mos to < 36 mos; Preschool = 36 mos to < 84 mos 2. Categorical— 0-4 yrs = < 60 mos; 5-6 yrs = 60 mos to < 84 mos (for assessing representativeness)	
CU 2		**Neighbourhood Measure:** Aggregate count for neighbourhood (census DA) Categorical: 0-4years, 5-6 years of age	
CU 3	**Gender (Sex)**	**Direct Measure:** Sex Categorical—Male, Female	
CU 4		**Neighbourhood Measure:** Aggregate count for neighbourhood (census DA) Categorical: Male, Female	
CU 5	**Diet** • **Food security** • **Calcium supplement use** • **Iron supplement use**	Food Security **Dropped**	Not well understood by respondents.
CU 6		Calcium supplement use	A relatively low proportion of children take these supplements. Decision was to include this measure in the descriptive section of the report, but not to include in the section pertaining to association given very small proportions taking these supplements (2%).
CU 7		Iron Supplement use	
Primary Sources of Lead in the Environment			

Schema Code	Construct	Measurement	Validity/Notes
PS 1	**Lead from Paint (Age of house)** • **Individual Residence** • **Neighbourhood of Residence**	Age of house – MPAC data 1. Continuous variable (years) 2. Categorical—pre 1900; 1900 to 1919; 1920 to 1944; 1945-1974; 1975+ 3. Categorical—OH - Pre 1950; NH –1950 + (variable created to identify quota sample to exclude new housing [NH] for purposes of displaying environmental sample in map only) Alone and with paint quality: Deteriorated interior painted surfaces Categorical—Yes; No; Don't Know	House Age for older housing has bias due to digit preference to 5-year categories
PS 2		Age of Neighbourhood Categorical – Lives in neighbourhood developed pre-1950; Lives in neighbourhood developed 1950 + **Dropped**	Reviewed the historical land use for the Target Area and found only one neighbourhood developed after 1950
PS 3		Dwelling Type **Dropped**	We know dwelling type is associated but we do not think that this factor is a contributor to lead in paint independent from age of dwelling, nor a better measure of socio-economic status than rented versus owned.
PS 4	**Lead from Industry Sources (Proximity to Lead Emitting Sources)**	Distance to nearest lead emitter (current and historical) 1. Continuous variable (m) 2. Categorical proximity zone (display)—0-<1200 meters (zone 1); 1200-<1800 (zone 2); 1800-<2400 (zone 3); 2400+ (zone 4) 3. Categorical proximity zone (analysis)— 0 to 500 m (n=16); 501m to 1000 m (n=145); 1001 to 2500m (n=383) and more than 2500m (n=99). Distance to a particular recycling plant (historical) 3. Continuous variable (m) Alone and with closest industry source: • Categorical—industries A to K Closest industry source **Dropped**	The proximity data were tested in the models as both a continuous variable and as a categorical variable. The conclusion was that there was a better fit with the data used as a categorical variable. The categories were selected by looking at the apparent 'clustering' of BLLs within categories of 500m segments. Given the historical importance of a particular decommissioned recycling plant, a proximity measure for this specific site was developed. Name of industry sources was required only for the purposes of developing the distance variable to nearest emitter.
PS 5	**Vehicle Emissions**	Do not have a measure for vehicle emissions	

Schema Code	Construct	Measurement	Validity/Notes
PS 6	**Lead from Water Pipes (Age of house)**	Age of house – MPAC data 1. Continuous variable (years) 2. Categorical—pre 1900; 1900 to 1919; 1920 to 1944; 1945-1974; 1975+ 3. Categorical—OH - Pre 1950; NH – Post 1950 Excluding "bottled-water only" responders in relationship with BLL Alone and with Dwelling Type: Categorical—House; Apt; Other Neighbourhood effect of lead service pipes: **Dropped**	An attempt was made to determine If a better variable for lead service pipe could be obtained; however, the data were too sparse for use so we elected to use only the 'Age of Housing' variable. Water main data were also explored as a possible basis for defining neighbourhoods in terms of lead service piping; however this was unsuccessful. Analysis of these data by FSA had found differences, but it had not accounted for the stratified quoting sampling methodology for the tap water samples – therefore was not able to be used.
PS 7		Type of water pipes in house **Dropped**	Responses to questions about the 'Type of water pipes in house' and 'year lead pipe replacement' occurred seemed inconsistent and were consequently considered invalid. Multiple households reported upgrades in 1990 or later however also stated their housing pipes were made of lead or didn't know if the water pipes were lead or copper or a mixture, or that they were a mixture of lead and copper pipes. General Note: We found that the responses to all of the survey questions pertaining to plumbing were suspect and therefore the decision was made to drop these data from all analyses.
PS 8		Lead pipe replacement - If yes, what year? **Dropped**	
PS 9	**Lead from Objects/Products**	Toys/jewelry purchased outside Canada Categorical Yes – often or sometimes; No – never Makeup, cosmetics made outside Canada Categorical Yes – often or sometimes; No – never Toys/jewelry over 50 years old Categorical Yes – often or sometimes; No – never Toys/jewelry/face paints/cosmetics purchased outside Canada or Toys/jewelry over 50 years old Categorical Yes – often or sometimes to any; No – never to all (excludes D/K to any)	

Schema Code	Construct	Measurement	Validity/Notes
PS 10	**Lead from Materials (Hobbies)**	Family member with lead associated hobby Categorical – Yes (yes to any); No (no to all) Type of hobby 8 variables all categorical—yes; no **Dropped**	Type of hobby – data too sparse.
PS 11	**Lead from Occupation of Household members**	Household has at least one person with current occupation is lead associated. such that if the occupation is not among the 21 listed, it is considered a 'non-lead occupation' Categorical – Yes * (yes to at least one adult with lead associated occupation); No * Includes NOC Codes: 711; 712; 721; 2234; 2241; 2242; 2275; 5136; 6261; 7213; 7215; 7219; 7241; 7245; 7264; 7265; 7271; 7292; 7311; 7321; 7322; 7381; 7611; 9221; 9411; 9421; 9422; 9423; 9482; 9496; 90711; 90712	Only one household had 2 adults with lead related occupation. Occupation and modifying behavior was the same for both adults. Assumed not to be a double exposure
Intermediate Sources of Lead in the Environment			
IS 1	**Soil Lead**	Soil Lead Level –lower detection limit of 5 µg/g Continuous (µg/g dry) Alone and with areas of exposed soil: Are there any areas on your property where there is or has been exposed dirt in the last 3 months. Categorical—Yes; No	Measure of soil lead level potentially influenced by sampling procedure. Soil samples were not collected if the residents had moved, the home does not have a large enough area of exposed soil or lawn, or if the lawn had just been re-sodded prior to sampling. This occurred for 20 households. The resulting number of samples was n=176 rather than n=196.

Schema Code	Construct	Measurement	Validity/Notes
IS 2	**Household Dust Lead**	Living Room Dust Lead Level – lower detection limit of 1 μg/ft^2 Continuous μg/ft^2	Control sample issue – Consensus was reached to include households for which control samples were above 0. Literature is scant for dust collection using swipe method. Concern: There are approx 21-25 children for which the child-associated bedroom dust samples are unusable. For any multi-variate analyses using dust we would need to drop these child records from the multivariate analyses. Our assumption is that this disadvantage (decreasing the sample size) outweighs the advantage gained from using bedroom dust (for which we have individual measurements for each child as opposed to repeated household measurements for each child). This concern disregards the behavior-based reason for choosing bedroom dust over living room/kitchen dust. The behavior-based reasoning is unclear and we could argue convincingly on either side – for example, we could argue that waking hours when hand to mouth behavior is most likely to occur would be in common areas vs. most hours spent in house are spent in bedroom. Given that there is not strong evidence one way or the other, we should probably attribute less weight to this argument. The strongest argument then likely becomes statistical advantage. This will require that we consider both the sample size advantage, but also the strength of relationship advantage (which type of dust correlates most with BLL). Consensus is that using bedroom dust levels will introduce systematic bias (i.e. removing larger families with younger children), therefore living room dust will be used as the household measure.
IS 3	**Tap Water Lead**	Water Lead Level – limit of detection 0.5μg/L Continuous (μg/L) Exclude individuals/households who drink only bottled water from analyses exploring water to BLL relationship	We have some concerns about the validity of the water samples as the mapping shows that the median water lead level is highest in the ORP zone. This is the highest area for soil (as might be expected given the location of a decommissioned recycling plant) and we are concerned about some possible water sample cross-contamination from dust sampling during sample collection.
IS 4	**Air Lead**	Air Lead Zone Categorical—Industry Adjacent Zone (HAL); Middle Zone (MAL); Escarpment Adjacent (LAL) Air Lead Zones were provided by the Ministry of the Environment. Variable was based on where centroid of the property fell into a given Air Lead Zone.	Tested some underlying assumptions (to be included in Technical Appendices and outlined in PH Report). The air lead measure is based on property location within general zones outlined by the MOE. Unlike the other environmental measures (water, soil, dust), the air lead is not a direct measure of that household. As a result, given the lack of specificity, the air lead zone measure was not used in multivariate analyses.
Seasonality			

Schema Code	Construct	Measurement	Validity/Notes
S 1	**Seasonality**	Date of Capillary Blood Lead Collection Continuous variable: Date **Dropped**	The data collected during the study (date of clinic visit over a 6-week period) is likely not a good measure of seasonality, and may be confounded with other factors related to time. Dropped from analyses.
Factors that Influence the Uptake of Lead from the Environment			
FUE 1	**Floor Hygiene** **Type of cleaning** **Vacuuming with Hepa filter vacuum**	How are your floors usually cleaned? 1. Wet mop floors: Categorical—Yes; No 2. Dry sweep floors: Categorical—Yes; No 3. Vacuum floors: Categorical—Yes; No (these variables are NOT mutually exclusive) Type of vacuum: **Dropped**	Responses for 'type of vacuum' are unusable as we did not categorize as 'hepa-filter and non hepa-filter vacuums).
FUE 2		How often would you say you floors are cleaned this way? Categorical or Mock Continuous: 1—Once a month; 2 -Once a week; 3 - Every 2/3 days; 4 - Once a day	There was an error in the execution of the telephone questionnaire in that there was only one frequency question asked instead of 3 type-specific questions. As there is only one response, the assumption was made that the response to question 4.3 (frequency of way floors are cleaned) is attributed by the respondent to the way in which the respondent most often clean their floors. One aspect of the analysis was to determine the impact that using this variable as a mock continuous vs. a categorical variable would have on the modeling. It was determined that the optimal variable was as a categorical variable.
FUE 3	**Child Personal Hygiene**	How often does child wash hands before eating? Categorical – 75 to 100%; 50%-75%; <50%	Consider the 'desirability' of response bias.
FUE 4	**Frequency of Exposure to soil**	Frequency of child exposure to dirt/unsodded grass Categorical—Often; Sometimes/Rarely	In analyses, stratified by age group and interaction tested.
FUE 5	**Soil Ingestion**	Eating soil Categorical Yes; No	In analyses, stratified by age group and interaction tested.
FUE 6	**Paint Ingestion**	Peeling/picking at paint chips Categorical Yes; No	In analyses, stratified by age group and interaction tested. Investigated to check if eating paint chips is subset of picking at paint; considered only one variable in the analyses. Both considered within iterative models.
FUE 7		Eating paint chips. Categorical Yes; No	

Schema Code	Construct	Measurement	Validity/Notes
FUE 8	**Parental / guardian risk reduction behavior (measured by response to government recalls)**	Frequency of response to government recalls Categorical: Every time; most; Rarely/Never/Don't Hear about recall **Dropped**	It was noted that the 8 respondents who reported "don't know" to this question had a high mean blood lead. The data for this group were explored further on an individual basis, and it was determined that there was nothing consistent among them as a group of 8 that could explain this level. It was also noted that there were significant differences between those who responded "every time" and "most" that did not make sense. Variable was assessed as likely measuring something other than desired factor (risk reduction behavior) so variable was dropped from analyses.
FUE 9	**Tap Water Consumption**	Type of drinking/cooking water used Categorical–Tap water only; Tap water and bottled water; bottled water only	Bottle water only children (4.3% of children) were included as a separate category in multivariate analyses
FUE 10	**Flushing Tap Water System**	Cold water 5-minute flush Categorical—Always; Often; Rarely/Never **Dropped**	Running the tap for 5 minutes is self reported. Expert Opinion: 5 minutes is a very long time. Consumers run the tap for <1-2 minutes depending on the flow rate and the system configuration, short term flushing may actually increase lead exposure if a lead service line is present.. Pattern in our table was inconsistent.
FUE 11	**Time spent in risk environment**	Exposure location by time Daytime hours spent at home per week: Continuous (hour)	Note: This question was broken up as is for the sole purposes of assisting clients with the provision of the most accurate answer.
		Eve/Nighttime hours spent at home per week: **Dropped**	Given children's primary activity during these hours are sleeping at which point lead exposure is expected to be minimal, this variable has been dropped and day time hours where children are more active has been maintained.
FUE 12	**Worker hygiene**	Frequency of removal of protective clothing before entering home. Categorical 75 to 100%; 50%-75%; <50% **Dropped**	There was only one household with 2 adults with occupational exposures and their responses to these questions were identical Use a single adult to represent household Data quality considered to be poor as many records had missing data – major gaps.
FUE 13		Frequency of showering at workplace or immediately after returning home from work? To be used as a measure of the modifier 'worker hygiene'. Categorical – 75 to 100%; 50%-75%; <50% **Dropped**	Data quality considered to be poor as many records had missing data – major gaps.
Factors that Influence the Deposition of Lead from Primary to Intermediate Sources			

Schema Code	Construct	Measurement	Validity/Notes
FD 1	**Home Renovations**	Home renovation past 6 months • Categorical Yes; No	Protective to soil but might reverse if proximity variable is added to the model.
FD 2	**Filters on Tap Water Line**	Presence of filter devices on drinking water pipe **Dropped**	The measure for the water filter question does not behave as expected (we expect that having a water filter on the drinking water tap should be protective – it should lower water lead levels) but instead, the relationship is reversed. We think it either means: (1) having a water filter is a better marker for lead piping in the house/service line than the age and type of house or (2) the respondents either don't understand the question or don't really know whether their drinking water tap/line has a filter on it or not, or they aren't using/maintaining a water filter properly on their drinking water tap. General Note: We found that the responses to all of the survey questions pertaining to plumbing were suspect and therefore the decision was made to drop these data from all analyses.
FD 3	**Home Entry Factors** • **Removal of shoes** • **Indoor/Outdoor Pets** • **Dwelling Type** • **Exposed Soil**	Removal of shoes before entering home Categorical 75 to 100%; 50%-75%; <50%	
FD 4		Indoor / outdoor pets Categorical Yes; No	
FD5		Dwelling Type: Categorical: House; Apt; Other	
FD6		Are there any areas on your property where there is or has been exposed dirt in the last 3 months. Categorical—Yes; No	

Appendix D: Algorithm for Participant Follow-up

BLL = Blood Lead Levels
ET = Environmental Testing
GP = General Practice Physician
Hct/Hgb = Hematocrit / Hemoglobin
MOH = Medical Officer of Health
PHS = Public Health Services
P/LG = Parent/Legal Guardian
RFQ = Risk Factor Questionnaire

Eligible child undergoes capillary BLL testing at study clinic location

Capillary BLL < 0.19 μmol/L

CLINIC STAFF WILL:

(a) send MOH notification letter of child capillary BLL results (Appendix S) to parents/legal guardians
(b) include in mail-out to P/LG, general education about how to reduce environmental lead exposure
(c) mail copy of MOH notification letter to child's GP (if GP name was provided on consent form)

Capillary BLL ≥ 0.19 μmol/L

PUBLIC HEALTH SERVICES WILL:

(a) f anotify P/LG by telephone of capillary BLL result
(b) recommend child undergo venous BLL re-testing and testing for anaemia (hemoglobin and hematocrit)
(c) provide counselling as needed to parent/legal guardian regarding initial capillary BLL result
(d) drop off lab requisition to home and provide location of central laboratory **OR** of other nearby labs who can perform venous blood collection for children under 7 years of age

Venous BLL < 0.19 μmol/L (< 4ug/dl) **HGB and/or HCT WITHIN NORMAL RANGE**

PUBLIC HEALTH SERVICES WILL:
(a) notify P/LG by telephone of venous BLL and anaemia test results
(b) provide counseling as needed to P/LG regarding test results
(c) inform P/LG that they will receive notification letter by MOH of test results by mail as well as a copy of their child's signed consent form.
(d) following PHS phone call, send MOH notification letter of child venous BLL result and anaemia test results to P/LG
(e) include a copy of their child's signed consent form
(f) include in mail-out to P/LG, general education about how to reduce environmental lead exposure
(d) mail copy of above MOH notification letter to child's GP (if GP name provided on consent form)

Venous BLL < 0.19 μmol/L (< 4 ug/dl) **HGB and/or HCT OUTSIDE NORMAL RANGE**

PUBLIC HEALTH SERVICES WILL:
(a) notify P/LG by telephone of venous BLL and anaemia test results
(b) provide counseling as needed to P/LG regarding test results
(c) inform P/LG of MOH referral either to child's family GP or study paediatrician (if no family GP)
(d) inform P/LG that they will receive notification letter by MOH of test results by mail following PHS phone call
(e) following PHS phone call, send MOH notification letter of child venous BLL result and anaemia test results to P/LG
(f) include copy of child's signed consent form
(g) include in mail-out to P/LG, general education about how to reduce environmental lead exposure
(h) mail copy of above MOH notification letter to child's GP (if GP name provided on consent form)
(i) if child has no GP, send referral letter to study paediatrician

STUDY PAEDIATRIANS WILL:
(j) contact P/LG of children with no family GP and arrange for a follow-up appointment
(k) send copy of consult note to MOH

Venous BLL ≥ 0.19 μmol/L (≥ 4 ug/dl) Regardless of Hgb and/or Hct results, **BLL= AT OR ABOVE STUDY FOLLOW-UP THRESHOLD**

PUBLIC HEALTH SERVICES WILL:
(a) notify P/LG by telephone of venous BLL and anaemia test results
(b) provide counseling as needed to P/LG regarding test results
(c) recommend to P/LG that they participate in a telephone-administered RFQ and ET
(d) inform P/LG of MOH referral to study paediatrician
(e) inform P/LG that they will receive notification letter by MOH of venous test results by mail as well as ET results (as the latter become available)
(f) coordinate RFQ via contracted firm (if not already done as part of the research study protocol)
(g) coordinate ET (if not already done as part of the research study protocol)
(h) mail copy of above MOH notification letter to child's GP (if GP name provided on consent form)
(i) send referral letter to study paediatrician and include a copy of child's completed RFQ and ET results (as the latter become available)
(j) following phone call to P/LG, send MOH notification letter of child venous BLL result and anaemia test results to P/LG
(k) include in mail-out to P/LG, general education about how to reduce environmental lead exposure
(l) Offer P/LG to conduct a home visit to review the information provided in RFQ and perform a home risk assessment
(m) upon receipt of ET results, call P/LG to discuss these results and send MOH notification letter of ET to P/LG

CLINIC STAFF WILL:
(n) administer telephone RFQ (if not already completed as part of research study protocol)

STUDY PAEDIATRICIANS WILL:
(o) contact P/LG of children and arrange for a follow-up appointment
(p) send copy of consult note to MOH and child's family GP (if GP name provided on consent form)

Note: In cases where the P/LG has not followed through with study recommendations for capillary or venous BLL at or above study follow-up threshold, PHS will follow-up with a phone call, then a home visit to facilitate study recommendations. If P/LG unwilling to follow-up with study recommendations, research coordinator will bring child's record forward for case review by MOH.

Appendix E: Detailed Regression Model Results and Scatterplots

DETAILS FOR TABLE 7.3

Model Summary for Household Dust Predicting BLLs

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.421	.177	.114	.54966	.177	2.791	20	259	.000

Coefficients for Household Dust Predicting BLLs

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.470	.232		-10.639	.000
	Dust	.151	.036	.247	4.241	.000
	household_income_less_than_60K	.224	.088	.181	2.537	.012
	household_income_60K_to_less_than_80K	.055	.090	.041	.615	.539
	household_income_DKNR	.186	.145	.078	1.286	.200
	no_post_secondary	.105	.102	.067	1.029	.304
	not_english_spoken_most_often_at_home	-.278	.149	-.123	-1.866	.063
	immigrated_in_past_five_years	.197	.145	.083	1.358	.176
	Toddler	.164	.101	.117	1.622	.106
	pre_schooler	.103	.089	.088	1.157	.248
	male_dummy Gender of child	.133	.068	.114	1.975	.049
	daytime_hrs_per_day_at_home_weekday_plus_weekend_5_to_8	-.104	.178	-.078	-.585	.559
	daytime_hrs_per_day_at_home_weekday_plus_weekend_9_to_12	-.021	.173	-.018	-.121	.904
	daytime_hrs_per_day_at_home_weekday_plus_weekend_13_to_16	-.072	.179	-.054	-.399	.690
	daytime_hrs_per_day_at_home_weekday_plus_weekend_missing	-.058	.283	-.014	-.204	.839
	floors_usually_cleaned_by_sweeping	-.109	.073	-.089	-1.487	.138
	floors_usually_cleaned_by_vacuuming	-.167	.087	-.134	-1.923	.056
	floors_usually_cleaned_by_mopping	.086	.088	.058	.977	.329
	frequency_floors_are_cleaned_2_to_3_days	.090	.090	.075	.991	.323
	vacuuming_by_frequency_cleaning_interaction_once_a_week	.091	.108	.069	.838	.403
	frequency_floors_are_cleaned_once_a_month	-.054	.129	-.028	-.416	.678

Model Summary for Yard Soil Predicting BLLs

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.378	.143	.082	.55743	.143	2.357	18	255	.002

Coefficients for Yard Soil Predicting BLLs

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.798	.231		-12.134	.000
	Yard Soil	.060	.029	.128	2.087	.038
	household_income_less_than_60K	.213	.089	.171	2.378	.018
	household_income_60K_to_less_than_80K	.089	.090	.066	.989	.324
	household_income_DKNR	.151	.149	.063	1.008	.314
	no_post_secondary	.143	.104	.088	1.377	.170
	not_english_spoken_most_often_at_home	-.041	.158	-.017	-.261	.794
	immigrated_in_past_five_years	-.007	.158	-.003	-.045	.964
	Toddler	.173	.107	.123	1.611	.108
	pre_schooler	.120	.100	.102	1.195	.233
	male_dummy Gender of child	.138	.069	.119	1.993	.047
	daytime_hrs_per_day_at_home_weekday_plus_weekend_5_to_8	-.112	.183	-.083	-.609	.543
	daytime_hrs_per_day_at_home_weekday_plus_weekend_9_to_12	-.028	.179	-.024	-.159	.874
	daytime_hrs_per_day_at_home_weekday_plus_weekend_13_to_16	-.025	.183	-.019	-.134	.894
	daytime_hrs_per_day_at_home_weekday_plus_weekend_missing	.053	.285	.013	.187	.852
	seen_child_eating_soil_in_lastyr	.153	.099	.106	1.554	.121
	areas_on_property_with_exposed_dirt_last_3months	.045	.087	.032	.523	.601
	child_often_plays_in_soil_not_covered_by_grass	.108	.111	.071	.970	.333
	child_sometimes_plays_in_soil_not_covered_by_grass	-.086	.089	-.066	-.971	.332

Model Summary for Tap Water Predicting BLLs

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.374[a]	.140	.088	.55697	.140	2.683	16	264	.001

Coefficients for Tap Water Predicting BLLs

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.779	.245		-11.327	.000
	LN_rAd_Water_Pb	.095	.026	.211	3.593	.000
	household_income_less_than_60K	.227	.090	.184	2.521	.012
	household_income_60K_to_less_than_80K	.059	.093	.044	.639	.524
	household_income_DKNR	.137	.146	.058	.935	.351
	no_post_secondary	.220	.099	.140	2.210	.028
	not_english_spoken_most_often_at_home	-.159	.147	-.070	-1.085	.279
	immigrated_in_past_five_years	.069	.147	.029	.467	.641
	Toddler	.245	.102	.174	2.389	.018
	pre_schooler	.164	.092	.140	1.785	.075
	male_dummy Gender of child	.144	.068	.123	2.112	.036
	daytime_hrs_per_day_at_home_weekday_plus_weekend_5_to_8	-.015	.177	-.011	-.085	.933
	daytime_hrs_per_day_at_home_weekday_plus_weekend_9_to_12	.047	.172	.040	.274	.784
	daytime_hrs_per_day_at_home_weekday_plus_weekend_13_to_16	.068	.179	.051	.379	.705
	daytime_hrs_per_day_at_home_weekday_plus_weekend_missing	.035	.286	.009	.124	.901
	for_cooking_drinking_at_home_mostly_use_tap_water	.129	.170	.107	.757	.450
	for_cooking_drinking_at_home_mostly_use_tap_and_bottled_water	.043	.176	.035	.243	.809

DETAILS FOR TABLE 7.4

Model Summary for Combined Environmental Media Predicting BLLs

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1 – Dust	.270[a]	.073	.069	.56202	.073	21.263	1	271	.000
2 – Dust & Soil	.289[b]	.084	.077	.55976	.011	3.195	1	270	.075
3 – Dust, Soil, Water and modifiers	.428[c]	.183	.145	.53865	.099	3.158	10	260	.001

Coefficients for Combined Environmental Media Predicting BLLs

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.332	.042		-55.580	.000
	DUST	.163	.035	.270	4.611	.000
2	(Constant)	-2.543	.125		-20.281	.000
	DUST	.148	.036	.245	4.079	.000
	SOIL	.051	.028	.107	1.788	.075
3	(Constant)	-2.886	.145		-19.842	.000
	DUST	.118	.036	.195	3.257	.001
	SOIL	.047	.028	.100	1.715	.087
	WATER	.080	.026	.176	3.030	.003
	household_income_less_than_60K	.206	.085	.166	2.415	.016
	household_income_60K_to_less_than_80K	.071	.086	.052	.819	.414
	household_income_DKNR	.173	.143	.072	1.207	.228
	no_post_secondary	.147	.098	.090	1.503	.134
	not_english_spoken_most_often_at_home	-.214	.151	-.089	-1.423	.156
	immigrated_in_past_five_years	.036	.152	.014	.239	.811
	Toddler	.205	.100	.146	2.054	.041
	pre_schooler	.116	.083	.099	1.391	.165
	male_dummy Gender of child	.150	.066	.129	2.277	.024

DETAILS FOR TABLE 7.5

Summary Logistic Regression Model for Dust Predicting BLLs at Study Follow-up Levels

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	32.123	20	.042
	Block	32.123	20	.042
	Model	32.123	20	.042

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	224.438[a]	.108	.181

		B	S.E.	Wald	df	Sig.	Exp (B)
1	Dust	.544	.182	8.930	1	.003	1.723
	household_income_less_than_60K	.742	.473	2.459	1	.117	2.100
	household_income_60K_to_less_than_80K	.240	.502	.229	1	.632	1.271
	household_income_DKNR	.226	.860	.069	1	.793	1.253
	no_post_secondary	.218	.480	.206	1	.650	1.244
	not_english_spoken_most_often_at_home	-.606	.667	.823	1	.364	.546
	immigrated_in_past_five_years	1.053	.653	2.601	1	.107	2.865
	Toddler	.226	.516	.191	1	.662	1.253
	pre_schooler	-.202	.481	.177	1	.674	.817
	male_dummy	.618	.366	2.857	1	.091	1.856
	daytime_hrs_per_day_at_home_weekday_plus_weekend_5_to_8	-.519	.840	.381	1	.537	.595
	daytime_hrs_per_day_at_home_weekday_plus_weekend_9_to_12	-.513	.803	.407	1	.523	.599
	daytime_hrs_per_day_at_home_weekday_plus_weekend_13_to_16	-1.221	.860	2.015	1	.156	.295
	daytime_hrs_per_day_at_home_weekday_plus_weekend_missing	1.132	1.201	.887	1	.346	3.101
	floors_usually_cleaned_by_sweeping	-.325	.375	.752	1	.386	.722
	floors_usually_cleaned_by_vacuuming	-.998	.457	4.775	1	.029	.369
	floors_usually_cleaned_by_mopping	-.061	.443	.019	1	.891	.941
	frequency_floors_are_cleaned_2_to_3_days	.693	.475	2.129	1	.145	2.000
	vacuuming_by_frequency_cleaning_interaction_once_a_week	.876	.615	2.032	1	.154	2.401
	frequency_floors_are_cleaned_once_a_month	.275	.713	.149	1	.699	1.317
	Constant	-1.833	1.134	2.615	1	.106	.160

Summary Logistic Regression Model for Soil Predicting BLLs at Study Follow-up Levels
Omnibus Tests of Model Coefficients

		Chi-square	Df	Sig.
Step 1	Step	29.509	18	.043
	Block	29.509	18	.043
	Model	29.509	18	.043

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	211.960[a]	.102	.174

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
1	Yard soil	.235	.162	2.102	1	.147	1.265	.921	1.738
	household_income_less_than_60K	.552	.476	1.342	1	.247	1.736	.683	4.416
	household_income_60K_to_less_than_80K	.428	.502	.725	1	.394	1.534	.573	4.105
	household_income_DKNR	-.494	1.121	.194	1	.660	.610	.068	5.491
	no_post_secondary	.204	.499	.167	1	.683	1.226	.461	3.261
	not_english_spoken_most_often_at_home	.425	.752	.320	1	.571	1.530	.351	6.676
	immigrated_in_past_five_years	.059	.785	.006	1	.940	1.061	.228	4.936
	Toddler	.292	.536	.295	1	.587	1.338	.468	3.830
	pre_schooler	-.186	.535	.120	1	.729	.831	.291	2.370
	male_dummy	.743	.383	3.759	1	.053	2.103	.992	4.459
	daytime_hrs_per_day_at_home_weekday_plus_weekend_5_to_8	-.720	.852	.713	1	.399	.487	.092	2.589
	daytime_hrs_per_day_at_home_weekday_plus_weekend_9_to_12	-.722	.814	.788	1	.375	.486	.099	2.392
	daytime_hrs_per_day_at_home_weekday_plus_weekend_13_to_16	-1.046	.848	1.523	1	.217	.351	.067	1.850
	daytime_hrs_per_day_at_home_weekday_plus_weekend_missing	1.241	1.144	1.178	1	.278	3.460	.368	32.564
	seen_child_eating_soil_in_lastyr	.199	.500	.159	1	.691	1.220	.458	3.252
	areas_on_property_with_exposed_dirt_last_3 months	.260	.466	.310	1	.577	1.297	.520	3.235
	child_often_plays_in_soil_not_covered_by_grass	.520	.522	.993	1	.319	1.682	.605	4.681
	child_sometimes_plays_in_soil_not_covered_by_grass	-1.001	.560	3.203	1	.074	.367	.123	1.100
	Constant	-2.984	1.168	6.530	1	.011	.051		

Summary Logistic Regression Model for Water Predicting BLLs at Study Follow-up Levels

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	30.800	16	.014
	Block	30.800	16	.014
	Model	30.800	16	.014

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	226.136[a]	.104	.173

		B	S.E.	Wald	df	Sig.	Exp (B)
1	LN_rAd_Water_Pb	.515	.156	10.932	1	.001	1.674
	household_income_less_than_60K	.695	.469	2.193	1	.139	2.004
	household_income_60K_to_less_than_80K	.237	.503	.222	1	.637	1.268
	household_income_DKNR	-.014	.855	.000	1	.987	.986
	no_post_secondary	.649	.456	2.028	1	.154	1.913
	not_english_spoken_most_often_at_home	-.249	.663	.141	1	.708	.780
	immigrated_in_past_five_years	.583	.670	.757	1	.384	1.792
	Toddler	.531	.516	1.059	1	.303	1.701
	pre_schooler	-.021	.488	.002	1	.966	.980
	male_dummy	.695	.363	3.668	1	.055	2.003
	daytime_hrs_per_day_at_home_weekday_plus_weekend_5_to_8	-.099	.794	.015	1	.901	.906
	daytime_hrs_per_day_at_home_weekday_plus_weekend_9_to_12	-.301	.763	.155	1	.694	.740
	daytime_hrs_per_day_at_home_weekday_plus_weekend_13_to_16	-.540	.807	.447	1	.504	.583
	daytime_hrs_per_day_at_home_weekday_plus_weekend_missing	1.644	1.205	1.861	1	.172	5.175
	for_cooking_drinking_at_home_mostly_use_tap_water	.985	1.014	.942	1	.332	2.677
	for_cooking_drinking_at_home_mostly_use_tap_and_bottled_water	.820	1.029	.635	1	.426	2.271
	Constant	-3.895	1.338	8.477	1	.004	.020

Summary Logistic Regression Model for Combined Intermediate Sources Predicting BLLs at Study Follow-up Levels

Omnibus Tests of Model Coefficients

		Chi-square	Df	Sig.
Step 1	Step	24.954	10	.005
	Block	24.954	10	.005
	Model	34.806	12	.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	206.313[a]	.120	.204

		B	S.E.	Wald	df	Sig.	Exp (B)	95% C.I.for EXP(B)	
								Lower	Upper
1	DUST	.308	.191	2.601	1	.107	1.360	.936	1.977
	SOIL	.125	.143	.761	1	.383	1.133	.856	1.498
	WATER	.633	.183	11.936	1	.001	1.883	1.315	2.695
	household_income_less_than_60K	.506	.461	1.207	1	.272	1.659	.672	4.094
	household_income_60K_to_less_than_80K	.156	.480	.106	1	.745	1.169	.456	2.997
	household_income_DKNR	-.695	1.119	.386	1	.534	.499	.056	4.475
	no_post_secondary	.292	.481	.368	1	.544	1.339	.521	3.441
	not_english_spoken_most_often_at_home	-.424	.750	.319	1	.572	.655	.151	2.845
	immigrated_in_past_five_years	.134	.808	.028	1	.868	1.144	.235	5.569
	Toddler	.642	.530	1.467	1	.226	1.901	.672	5.377
	pre_schooler	.115	.468	.060	1	.806	1.122	.448	2.809
	male_dummy	.717	.378	3.592	1	.058	2.049	.976	4.302
	Constant	-4.214	.861	23.953	1	.000	.015		

DETAILS FOR TABLE 7.6

Model Summary for Primary and Modifiers Predicting Dust

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.440	.194	.157	.91011	.194	5.221	12	261	.000

Coefficients for Primary and Modifiers Predicting Dust

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.911	.264		-3.450	.001
	age_house_pre_1920	.889	.174	.448	5.113	.000
	age_house_1920_1944	.590	.183	.273	3.224	.001
	home_renovated_in_past_six_months	.207	.114	.102	1.823	.069
	family_member_with_lead_associated_hobby	-.027	.137	-.011	-.198	.843
	LN_rad_MOE_Pb_µg_per_g_dry	.159	.047	.198	3.379	.001
	Clinic_visit_in_first_half_of_Nov	-.013	.188	-.005	-.068	.946
	Clinic_visit_in_last_half_of_Nov	.153	.139	.075	1.101	.272
	family_removes_shoes_before_walking_into_home_sometimes	.097	.385	.014	.252	.802
	family_removes_shoes_before_walking_into_home_rarely	.092	.170	.031	.541	.589
	dwelling_type_apt	.261	.281	.054	.932	.352
	dwelling_type_duplex_row_other	.367	.244	.087	1.504	.134
	have_a_pet_that_can_go_in_and_out	.130	.120	.064	1.082	.280

Model Summary for Primary and Modifiers Predicting Soil

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.281	.079	.058	1.19616	.079	3.825	6	267	.001

Coefficients for Primary and Modifiers Predicting Soil

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.636	.220		16.508	.000
	age_house_pre_1920	.368	.235	.149	1.570	.118
	age_house_1920_1944	.384	.236	.143	1.630	.104
	home_renovated_in_past_six_months	-.165	.149	-.065	-1.104	.271
	Nearest_Plant_Distance_0_500m	.806	.379	.149	2.125	.034
	Nearest_Plant_Distance_501_1000m	.815	.272	.254	2.996	.003
	Nearest_Plant_Distance_1001_2500m	.512	.222	.204	2.307	.022

Model Summary for Primary and Modifiers Predicting Water

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.360	.130	.114	1.22527	.130	8.183	5	275	.000

Coefficients for Primary and Modifiers Predicting Water

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.287	.227		1.265	.207
	age_house_pre_1920	1.217	.208	.467	5.843	.000
	age_house_1920_1944	1.149	.227	.402	5.060	.000
	home_renovated_in_past_six_months	-.271	.151	-.101	-1.796	.074
	Clinic_visit_in_first_half_of_Nov	-.068	.246	-.019	-.277	.782
	Clinic_visit_in_last_half_of_Nov	-.291	.185	-.109	-1.575	.116

DETAILS FOR TABLE 7.8

Model Summary for Primary and Modifiers Predicting BLLs

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.369	.136	.109	.55102	.026	5.530	3	561	.001

Coefficients for Primary and Modifiers Predicting BLLs

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.793	.103		-27.103	.000
	home_renovated_in_past_six_months	.082	.048	.069	1.709	.088
	interior_peeling_paint_surfaces	.073	.047	.063	1.570	.117
	seen_child_eating_paint_chips_in_lastyr	.294	.151	.077	1.953	.051
	frequency_floors_are_cleaned_once_a_month	.118	.096	.060	1.230	.219
	frequency_floors_are_cleaned_once_a_week	.107	.070	.090	1.514	.131
	frequency_floors_are_cleaned_2_to_3_days	.158	.071	.128	2.213	.027
	family_removes_shoes_before_walking_into_home_some	.176	.107	.066	1.645	.101
	family_removes_shoes_before_walking_into_home_rarely	.124	.072	.068	1.705	.089
	family_member_with_lead_associated_occupation	.113	.060	.077	1.887	.060
	household_income_less_than_60K	.171	.060	.140	2.874	.004
	household_income_60K_to_less_than_80K	.013	.067	.008	.186	.852
	household_income_DKNR	.040	.083	.021	.483	.629
	male_dummy Gender of child	.103	.046	.088	2.228	.026
	age_house_pre_1920	.179	.077	.153	2.312	.021
	age_house_1920_1944	.046	.075	.038	.614	.539
	Nearest_Plant_Distance_0_500m	.615	.160	.173	3.853	.000
	Nearest_Plant_Distance_501_1000m	.185	.096	.111	1.937	.053
	Nearest_Plant_Distance_1001_2500m	.079	.071	.064	1.107	.269

DETAILS FOR TABLE 7.9

Summary Logistic Regression Model for Primary and Modifiers Predicting BLLs at Study Follow-up Levels
Omnibus Tests of Model Coefficients

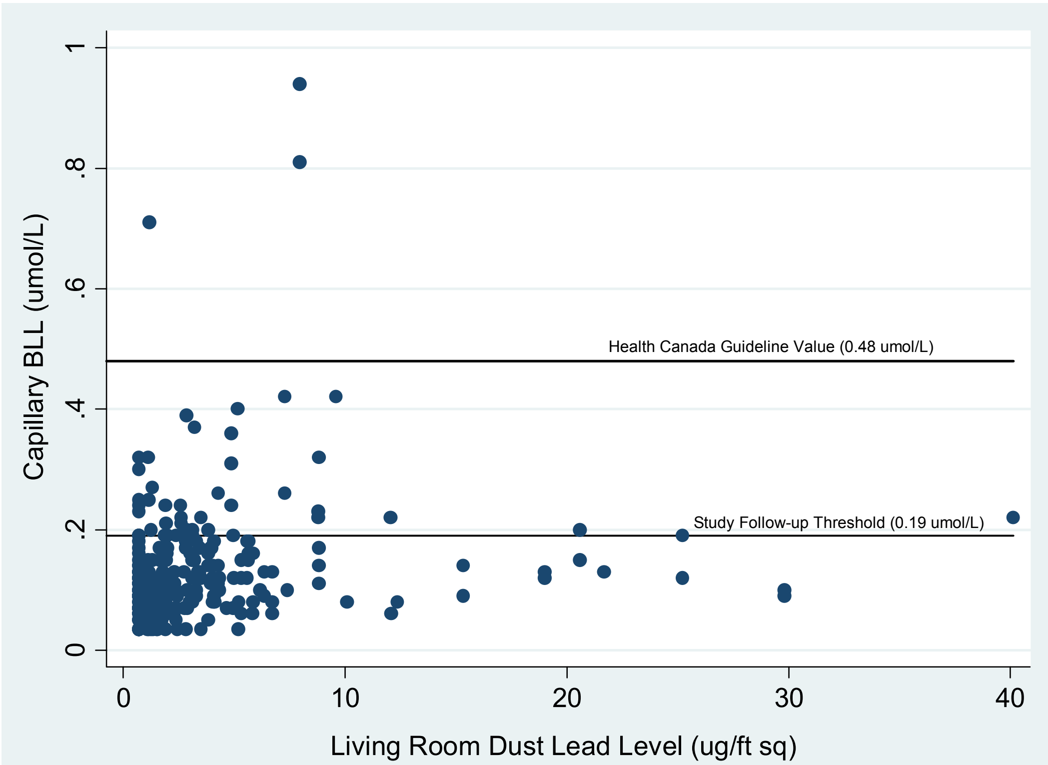
		Chi-square	Df	Sig.
Step 1	Step	15.750	3	.001
	Block	15.750	3	.001
	Model	57.916	18	.000

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	442.714	.095	.164

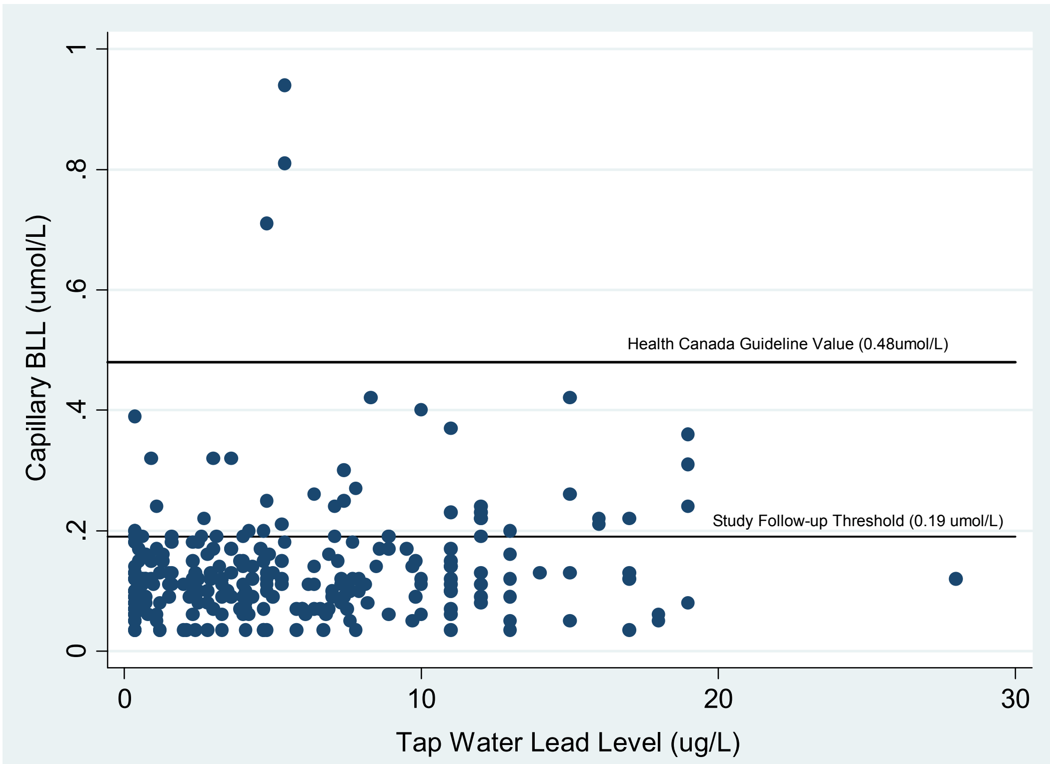
Model Summary

		B	S.E.	Wald	df	Sig.	Exp (B)	95% C.I.for EXP(B)	
								Lower	Upper
1	home_renovated_in_past_six_months	.571	.254	5.045	1	.025	1.771	1.075	2.915
	interior_peeling_paint_surfaces	.184	.249	.545	1	.460	1.202	.738	1.957
	seen_child_eating_paint_chips_in_lastyr	1.011	.653	2.399	1	.121	2.748	.765	9.877
	frequency_floors_are_cleaned_once_a_month	.426	.486	.769	1	.381	1.531	.591	3.970
	frequency_floors_are_cleaned_once_a_week	-.037	.381	.009	1	.923	.964	.457	2.034
	frequency_floors_are_cleaned_2_to_3_days	.343	.372	.851	1	.356	1.410	.680	2.925
	family_removes_shoes_before_walking_into_home_sometimes	.814	.484	2.835	1	.092	2.258	.875	5.826
	family_removes_shoes_before_walking_into_home_rarely	.470	.340	1.910	1	.167	1.600	.822	3.116
	family_member_with_lead_associated_occupation	.390	.294	1.768	1	.184	1.478	.831	2.627
	household_income_less_than_60K	.435	.318	1.878	1	.171	1.546	.829	2.881
	household_income_60K_to_less_than_80K	.065	.374	.030	1	.862	1.067	.513	2.219
	household_income_DKNR	-.313	.523	.358	1	.549	.731	.262	2.038
	male_dummy	.430	.252	2.908	1	.088	1.537	.938	2.520
	age_house_pre_1920	.629	.469	1.797	1	.180	1.875	.748	4.700
	age_house_1920_1944	.041	.494	.007	1	.933	1.042	.396	2.744
	Nearest_Plant_Distance_0_500m	2.992	.799	14.028	1	.000	19.932	4.164	95.414
	Nearest_Plant_Distance_501_1000m	1.117	.647	2.985	1	.084	3.057	.861	10.858
	Nearest_Plant_Distance_1001_2500m	1.154	.572	4.073	1	.044	3.172	1.034	9.730
	Constant	-4.317	.733	34.652	1	.000	.013		

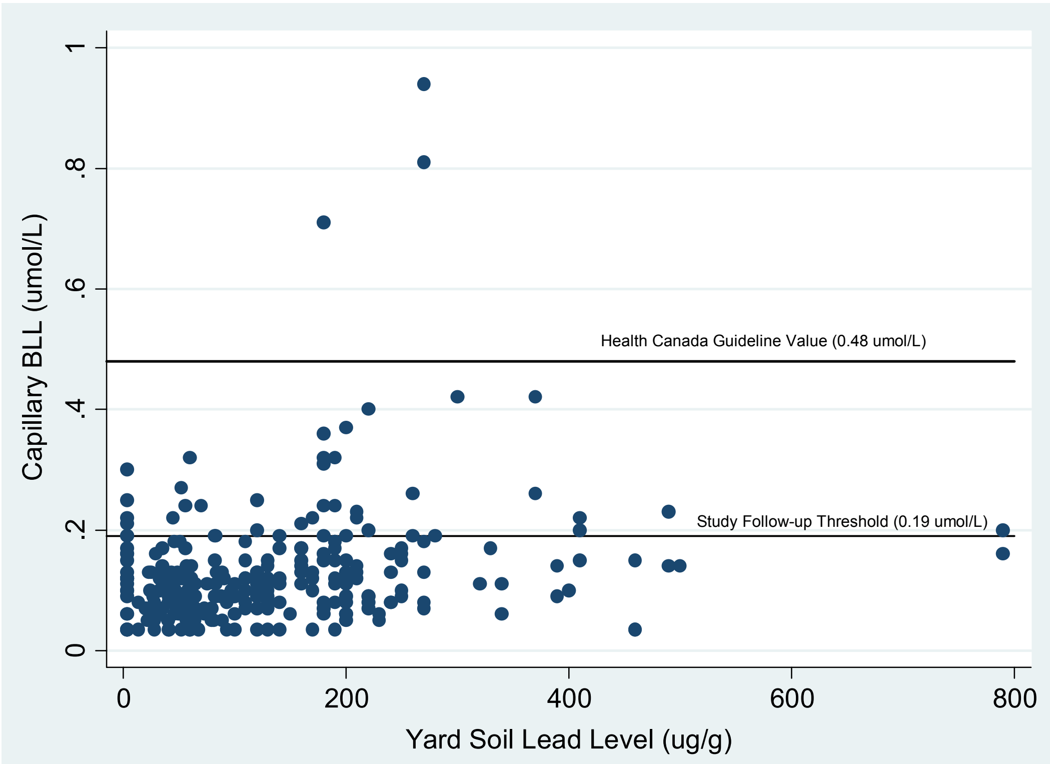
Scatterplot 1: Capillary Blood Lead Levels and Household Dust Lead Levels (n=281)



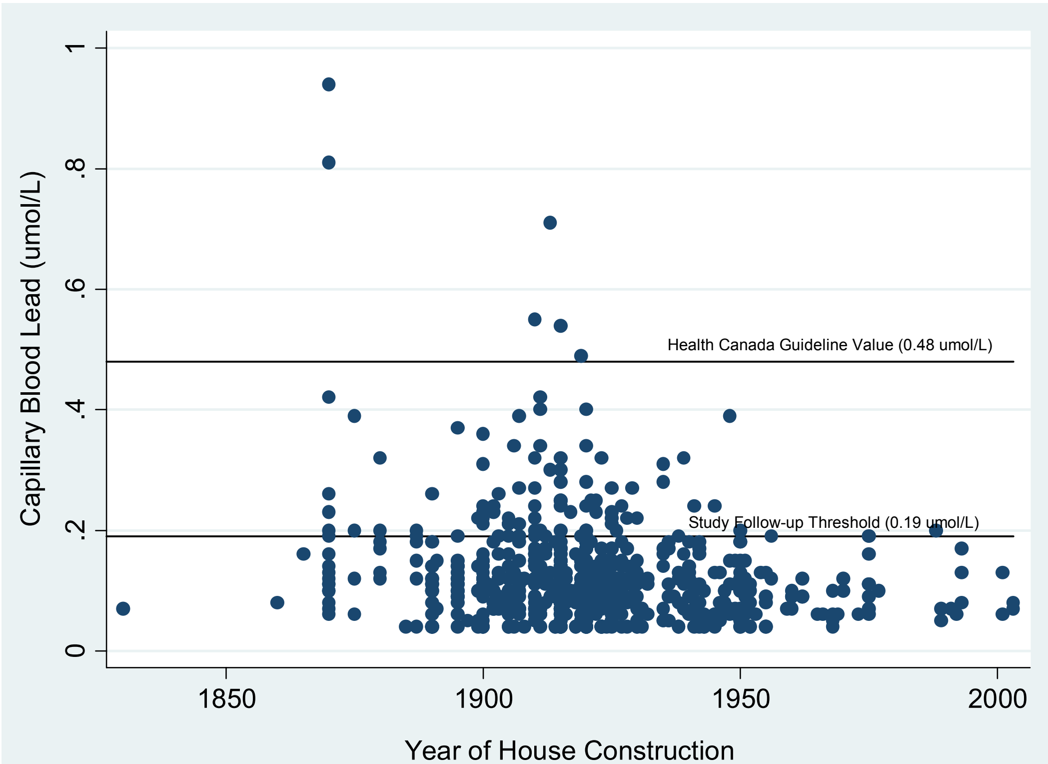
Scatterplot 2: Capillary Blood Lead Levels and Tap Water Lead Levels (n=281)



Scatterplot 3: Capillary Blood Lead Levels and Yard Soil Lead Levels (n=281)



Scatterplot 4: Capillary Blood Lead Levels and Housing Year of Construction (n=643)



Scatterplot 5: Capillary Blood Lead Levels and Proximity to Industry (n=643)