Follow-up Evaluation of Lead Exposure in Children (under 7) in Flin Flon, Manitoba and Creighton, Saskatchewan

April 23, 2013
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OVERVIEW

Hudson Bay Mining and Smelting Co., Limited (HBMS) established a fully-functional mine and base metal smelting complex in Flin Flon, Manitoba in the 1930’s. As a result of historical activities at the HBMS facility, government agencies and independent researchers have completed numerous studies considering the content of smelter-related metals in the environment. In August 2006, Manitoba Conservation conducted soil sampling to determine the concentration and potential distribution of metals and other elements in the surface soils of Flin Flon, Manitoba and Creighton, Saskatchewan. The Manitoba Conservation report “Concentrations of Metals and Other Elements in Surface Soils of Flin Flon, Manitoba and Creighton, Saskatchewan, 2006” was published in July 2007 (Manitoba Conservation, 2007). This report recommended further study to better understand potential health risks for people living in the Flin Flon Area related to the HBMS smelter emissions. The Flin Flon Soils Study was the result of this recommendation.

The Flin Flon Soils Study was initiated by HBMS in July 2007 to better understand the nature of facility emissions and soil conditions in the Flin Flon Area, and to determine if exposure to these metals and elements pose an increased health risk to residents and visitors. The Flin Flon Soils Study was composed of several individual components that have addressed human health considerations for the Flin Flon Area using different approaches. The Study included supplemental environmental data collection (residential soil, indoor dust, drinking water, ambient air, fish, surface water, sediment, blueberries, snow), an extensive Human Health Risk Assessment (HHRA) conducted during 2008 and an evaluation of children’s exposure (biomonitoring) to lead, inorganic arsenic, and inorganic mercury conducted during Fall 2009. An overview of the Flin Flon Soils Study is available in Appendix A.

The overall conclusion of the Flin Flon Soils Study was that the likelihood of adverse health effects among area residents from exposure to the metals evaluated was negligible to low. Overall, the findings from these studies were reassuring, but some low level risks were identified from some metals.

Based on the findings from the HHRA and the evaluation of exposure, recommendations were made in 2010 to undertake efforts to reduce children’s exposure to lead. The main efforts undertaken included a public health awareness campaign that targeted parents and children to improve the frequency and quality of handwashing among children. Other efforts included continuation of an HBMS program of progressive remediation and re-vegetation of the area in and around the Flin Flon Metallurgical Complex, as well as a sustained effort by HBMS to continue with operating practices and procedures aimed at minimizing dust emissions from the Flin Flon Metallurgical Complex in areas such as the metallurgical operations, tailings facility, etc. HBMS also continued other environmental improvements within its operations such as the paving of in-plant roads and material handling upgrades to help improve ambient air quality. In addition, there have been some operational changes in the three years since the original exposure study including the closing of the Copper Smelter in 2010. This follow-up blood lead monitoring program is intended to determine the extent to which the community blood lead levels of children living in the Flin Flon Area have changed since the original exposure study.
INTRODUCTION

The purpose of this document is to present the results of a follow-up evaluation of lead exposure among children (under 7) in Flin Flon, Manitoba and Creighton, Saskatchewan, conducted in Fall 2012. This study is a follow-up component to a Human Health Risk Assessment (HHRA) and exposure study completed in 2009. The study was commissioned by Hudson Bay Mining and Smelting Co., Ltd. (HBMS), and was overseen by a Technical Advisory Committee (TAC) and Community Advisory Committee (CAC). The TAC was engaged to provide technical guidance. The TAC is comprised of representatives of HBMS, Health Canada, Saskatchewan Environment, Saskatchewan Health, Manitoba Conservation, Manitoba Health, and includes two public observers. The CAC was engaged to obtain input and comments from members of the public. Overall, the TAC and CAC provided input into study research methods, were updated on study progress on a regular basis, and assisted with interpretation of findings, where appropriate.

The study team was composed of three research firms working as a consortium (Intrinsik Environmental Sciences Inc., Goss Gilroy Inc., and Habitat Health Impact Consulting Corp.)

This document provides a technical description of the methods and the analyses undertaken, as well as the detailed results. It is intended for a scientific audience. A plain language summary document suitable for a general audience is available under separate cover.

The main sections of this report are:

- Introduction
- Section 1.0 – Rationale and objectives
- Section 2.0 – Approach and methods
- Section 3.0 – Characteristics of sample
- Section 4.0 – Current levels of internal exposure
- Section 5.0 – Lead Levels in environmental media
- Section 6.0 – Factors associated with exposure levels
- Section 7.0 – Study limitations
- Section 8.0 – Summary and conclusions

The appendices attached to this report are:

Appendix A - Overview of The Flin Flon Soils Study
Appendix B - Rationale for focus evaluation of exposure on children
Appendix C - Consent forms
Appendix D - Landlord Consent forms
Appendix E - Household Survey Instrument
Appendix F - Capillary blood sample collection protocols
Appendix G - Capillary blood storage and shipping protocols
Appendix H - Laboratory Analysis Plan
Appendix I - Yard Soil Collection Protocol
Appendix J - Household Dust Collection Protocol
Appendix K - Tap Water Collection Protocol
Appendix L - Lead Paint Analysis Protocol
Appendix M - Notification of individual results templates
Appendix N - Notification of environmental results template
Appendix O - Comparison to National and Community Surveys
Appendix P - Regression Model of BLL and Household Data
Appendix Q - Awareness of Public Health Messages
Appendix R - Summary of Recent Scientific Literature and Policy on Blood Lead Levels
1.0 RATIONALE AND OBJECTIVES

1.1 What is an evaluation of exposure?

An evaluation of exposure is a study that examines the levels of people’s internal exposure to selected chemicals that they encounter. These types of studies are sometimes described as biomonitoring studies because they focus on measuring exposure of humans to chemicals by measuring the amount of chemicals that are in people’s biological fluids or tissues (e.g., blood, urine, hair).

1.2 Rationale: Why conduct this follow-up evaluation of exposure?

An extensive Human Health Risk Assessment (HHRA) was conducted during 2008-2010 to address the potential human health risks associated with exposure to smelter-related metals in soils and other environmental media in the Flin Flon Area. The term “Flin Flon Area” refers to Flin Flon, Manitoba; Channing, Manitoba; Flin Flon, Saskatchewan; and Creighton, Saskatchewan. Linked to the HHRA was an evaluation of children’s exposure to lead, inorganic arsenic, and inorganic mercury conducted during Fall 2009. For additional information and background on the communities of Flin Flon and Creighton, contamination issues, and HHRA findings including evaluation of exposure findings, please refer to Appendix A.

Based on the findings from the HHRA and the evaluation of exposure, recommendations were made in 2010 to undertake efforts to reduce children’s exposure to lead. The main efforts undertaken to date have included a public health awareness campaign (Mighty Bubble) that targets parents and children to improve the frequency and quality of hand-washing among children. Other efforts have included continuation of an HBMS program of progressive remediation and re-vegetation of the area in and around the Flin Flon Metallurgical Complex, as well as a sustained effort by HBMS to continue with operating practices and procedures aimed at minimizing any dust emissions from the Flin Flon Metallurgical Complex in areas such as the metallurgical operations, tailings facility, etc. HBMS will also continue with other environmental improvements within its operations such as the paving of in-plant roads and material handling upgrades that will help improve ambient air quality further. In addition, there have been some operational changes during this three year time period which may have had an impact on exposure levels in the community. The closing of the Flin Flon Copper Smelter in 2010 has significantly reduced concentrations of lead in ambient air and the deposition of lead-containing particulates to the environment to which the community may be exposed. The purpose for this follow-up evaluation was to determine if the community blood lead levels of children living in the Flin Flon Area changed significantly over a three year period.

1.3 Objectives: What questions was study designed to answer?

This follow-up study was designed to determine the size and direction of change in community levels of lead exposure among Flin Flon Area children. The study was designed to determine whether or not there were statistically significant differences between children’s average blood lead levels in 2009 compared to 2012. It should be noted that a statistically significant difference refers to the likelihood that a difference between the two time periods is not due to chance. The factors that determine whether a difference is statistically significant include aspects such as the number of children participating in the study, variability in participants’ blood lead levels, and overall size or magnitude of difference. As a result, study results may indicate that a difference is statistically significant because it is assessing probability, but the actual difference may not be significant from a clinical or community perspective. As a result, it remains important to interpret...
statistically significant differences with other considerations to ensure that observed differences are meaningful.

Given that the goal was to make comparisons across two time periods, the current study closely replicated the methods and approaches used in the 2009 evaluation. As a result, the study design attempted to collect and analyse blood lead levels from a cross-sectional sample of approximately 250 children under the age of 7 (0-83 months) residing in the Flin Flon Area with a distribution according to age, gender and geographic area that was similar to that obtained in the 2009 evaluation. The rationale for the focus on children is included in Appendix B.

The following three questions were used to guide the development of the overall approach, and the specific methods:

1. What is the current level of internal exposure to lead in the child population residing in the Flin Flon Area?
2. Compared to the lead exposure levels measured in 2009, have levels in Flin Flon Area children increased, decreased, or remained the same in 2012?
3. Are the personal factors associated with children’s lead exposure measured in 2009 (e.g., place of residence, age, gender) similar in 2012?

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1 An overview of the 2009 Flin Flon Soils Study is located in Appendix A.
2.0 APPROACH AND METHODS

2.1 Overall approach

The study followed a nearly identical approach to that employed in the 2009 study. The one additional component was the collection of some environmental samples (i.e., household dust, yard soil, tap water, and paint assessment) for most of the households in which children providing blood samples lived. As illustrated in Figure 2-1, the cross-sectional study consisted of four main components which included the collection of blood samples from children under 7 years of age, collection of environmental samples (household dust, tap water, yard soil, lead paint), household surveys and observation for household features that may contain lead (e.g. old pipes, old paint, etc.). The overall study was conducted in four phases. Throughout each phase, there was a heavy emphasis on community consultations and communications.
PHASE ONE:
Methodology Development and Community Engagement

- Develop Overall Study Objectives and Approach
- Develop Detailed Study Protocols
- Implementation of Communications Strategy
- Review by Study Advisory Committees
- Research Ethics Board Review

Timeline: March to July 2012

PHASE TWO:
Sample Collection and Survey Implementation

- Develop Sampling Frame and Sample Participants
- Recruit Participants
- Household Interview
- Collect Environmental Samples
- Collect Blood Sample
- Community Updates

Timeline: August to October 2012

PHASE THREE:
Laboratory and Survey Analyses

- Analyses of environmental samples
- Blood analyses for lead
- Analyses of survey data
- Comparative analyses with 2009 study

Timeline: November 2012 to February 2013

PHASE FOUR:
Summary Reporting and Reporting Individual Results

- Reporting of Individual Results
- Follow-up and Referrals
- Technical Scientific Reporting
- Community Reporting

Timeline: December 2012 to May 2013

Figure 2-1 Overall approach for study
2.2 Sampling and Recruitment

Sampling plan

Selection of geographical areas and age groups

The sampling plan was developed based on stratification by: 1) geographical area; and 2) age. The selection of geographical areas was identical to the areas selected for the 2009 exposure study, which were based on the information that had been derived from the HHRA. According to results from the HHRA, the location of different communities within the Flin Flon Area relative to the HBMS complex has had a significant influence on the potential exposure of its residents. The proximity of the community to the smelter and the location relative to predominant wind direction determined the level of particulate in ambient air and the amount that is available for deposition. In the HHRA, the Flin Flon Area was divided into four sub-communities:

1. East Flin Flon (designated as the area east and northeast of Ross Lake);
2. West Flin Flon (designated as the area west of Ross Lake);
3. Channing; and,
4. Creighton.

The four sub-communities formed the geographic areas that were sampled in the present study. Maintaining these strata offered a number of advantages: 1) it allowed for direct comparison with HHRA estimates and 2009 exposure study results; and 2) internal comparisons could be conducted with the lowest sub-community used as a referent group. The relative geographical locations of the strata are shown in Figure 2-2.

![Figure 2-2 Relative geographical locations of East Flin Flon, West Flin Flon, Channing, and Creighton](image-url)
Sampling frame, plan and strategy

The registries of residential tax properties in Flin Flon and Creighton were used as sampling frames. Each household was assigned an identification number to be used for random selection. According to Statistics Canada, in 2006 there were 3,460 households in Flin Flon and Creighton. The tax rolls provided complete information for 3,493 residential addresses. The primary sampling unit used was the household.

To be able to make the strongest comparisons, the sample would have ideally been similar in size to the 2009 sample size of n=202. The original goal was to obtain a sample size of approximately 250 children in order to have some flexibility in matching the distributions according to age and geographic location across the two time periods. A stratified random sampling approach was employed to recruit study participants. Households were sampled at random until the required number of children in each age group and geographic area were enrolled. Given the size of the communities, all West Flin Flon households were invited to participate in the study, while a random sample of those from the other geographic areas was invited in order to fulfill sample size requirements. To ensure sufficient participation, the randomized approach was followed to the point that all households were provided the opportunity to participate.

Recruitment of participants

Sampled households received an information letter and a visit from a study team member to determine whether there were eligible children living in the household, and if they were willing to participate in the study. If the parents/guardian agreed to have their child(ren) participate, the study team member then made arrangements for an in-house interview and a clinic appointment for collection of blood samples. If the parents/guardian chose not to have their child(ren) participate, or through the discussions with the team member they were judged as ineligible to participate, their household was replaced by another randomly selected household.

Sample achieved and response rates

Table 2-1 contrasts the sample planned with the sample achieved. Overall, a total of 185 eligible children provided 119 blood samples (64% of planned sample). Compared to the original sampling plan, oversampling occurred in East Flin Flon, and Creighton, while under-sampling occurred in Channing and West Flin Flon. The primary reason for under-sampling in West Flin Flon was that there were far fewer children living in this neighbourhood than originally estimated. The estimates available for population of children were from the 2011 Census which groups all of Flin Flon together in one community. In the 2009 evaluation, the study team recruited an overall larger group of children under 15 years old (n=477) with 202 participants, under age 7, providing capillary blood samples (see Table 3-1 in Section 3.0). Children between the ages of 7 and 15 were recruited to supply urine samples for measurement of inorganic arsenic and inorganic mercury. Blood lead levels were measured in those under age 7, the target population for the present evaluation. In order to obtain 251 participating households, the study team was required to invite approximately 80% of the households in the study area to consider participation. Of those households successfully contacted after 5 attempts, approximately 25% had an eligible participant, and of those 61% agreed to participate in the study. Given that the current study focused on a smaller population (under 7 years old vs. under 15), it was anticipated that recruitment would involve greater levels of effort with respect to the number of households contacted in order to achieve a sample of...
approximately 250 participants. This assumption was correct. Although the household response rate was higher than in 2009 (61% vs. 68%) the individual response rate was substantially lower (94% vs. 64%). The lower individual response rate was a result of secondary attrition, whereby household agreed to participate initially, and then declined participation prior to having the child provide a blood sample.

Table 2-1  Response rate from 2009 and 2012

<table>
<thead>
<tr>
<th>Level</th>
<th>Criteria</th>
<th>2009</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Level</td>
<td>1: # households in FF and Creighton (census)</td>
<td>3045*</td>
<td>3032</td>
</tr>
<tr>
<td></td>
<td>2: # invitation letters delivered</td>
<td>2354</td>
<td>3032</td>
</tr>
<tr>
<td></td>
<td>3: # contacts made</td>
<td>1653</td>
<td>2190</td>
</tr>
<tr>
<td></td>
<td>4: # eligible households**</td>
<td>409</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>5: # households participated</td>
<td>251</td>
<td>89</td>
</tr>
<tr>
<td>Individual Level</td>
<td>6: # eligible children (from 5, above)</td>
<td>477</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>7: # children participated in survey</td>
<td>477</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>8: # children providing at least one bio sample</td>
<td>447</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>9: # of blood samples collected</td>
<td>202</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>10: # urine samples collected</td>
<td>379</td>
<td>n/a</td>
</tr>
</tbody>
</table>

| Response Level (Household) | 61% | 68% |
| Response Level (Individual) | 94% | 64% |


** In 2009 the age group was children under 15 years old and in 2009 the age group was children under 7 years old

Although Census data demonstrated that the population of the study area remained relatively unchanged, the study team anticipated that recruitment would be challenging. The main anticipated challenges included lack of individual level interest, despite community level concerns. To address this challenge significant communication activities were implemented to achieve the highest participation rate possible. General communications included ongoing newspaper advertisements, information sheets posted in public places, information sheets sent home through schools, and word-of-mouth through the community advisory committee. Recruiting efforts were also expanded, whereby study team members went door-to-door numerous times to attempt to meet with household members to directly communicate the study to sampled households. Without these expanded communication and recruiting efforts the sample size would likely have been smaller.

**Environmental Data Collection**

For all households recruited for participation in the study, participants were asked to consent to the environmental sampling component. For those households that were rental properties, consent was required from both the participants and the landlord/property owner.

A total of 93 households participated in the environmental sampling component. Of these households, participants withdrew from the blood sampling component for 11 households. Environmental sampling was not conducted for 6 households with child(ren) participating in the blood component. Of these 6 households, one declined participation in the environmental sampling component, and the remaining 5 households were rental properties for which the landlord could either not be reached or refused consent for environmental sampling, or an appointment could not be scheduled for sampling after landlord consent was given.
Table 2-2  Distribution of Households for which Environmental Sampling was Completed

<table>
<thead>
<tr>
<th>Region of Residence</th>
<th># Households with Environmental Sampling</th>
<th># Households with Environmental Sampling but no Blood Lead Results</th>
<th># Households with Blood Lead Results but no Environmental Sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channing</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Creighton</td>
<td>22</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>East Flin Flon</td>
<td>51</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>West Flin Flon</td>
<td>18</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>11</td>
<td>6</td>
</tr>
</tbody>
</table>

2.3 Household survey methods

Once a participant was recruited, a study team member visited the household to go through in detail the informed consent process with a parent or guardian. Informed consent was obtained to collect household information via a survey, collect a capillary blood sample, and collect environmental samples from the household (i.e., dust, soil, water, paint). For participants that resided in rental housing, consent for sampling of indoor dust, outdoor soil, tap water and other household materials was obtained from the property owner in addition to the tenant, prior to collection of environmental samples. In situations where property owners provided consent, the results of the environmental sampling only (not blood sampling) were shared with the property owners in addition to the parents/guardians of the participants occupying the property. Environmental sampling only occurred if both parties consented to the sampling.

Once informed consent was obtained and forms signed, the study team member conducted an interview with a parent/guardian using a structured survey instrument to collect information about the child’s environment and various personal factors including household characteristics, occupations of adults, outdoor and indoor play behaviours, diet, personal habits, etc. During the household visit a second study team member collected samples of house dust, tap water and yard soil, and conducted lead paint analysis. Before leaving, the study team member made an appointment for the child to visit a clinic location to provide a capillary blood sample. See Appendix C for participant consent forms; Appendix D for landlord consent forms; and Appendix E for the household survey instrument.

2.4 Blood sample collection and analytic methods

Having made an appointment at the time of the household visit, a parent/guardian brought the child to a scheduled appointment at a clinic, where a certified phlebotomist collected a capillary blood sample. The blood sample was obtained using the protocol outlined and approved for the study and employed for the 2009 evaluation (see Appendix F). In 2009 the blood sample collection period occurred in late summer and early fall, and a similar time period was implemented for the 2012 study.

Capillary blood samples were stored and shipped to the contracted laboratory according to the same protocols used in the 2009 evaluation (See Appendix G for protocols). Once received by the contracted laboratory, each sample was analysed according to the agreed upon protocols used in the 2009 evaluation (see Appendix H for the laboratory analysis protocols). The laboratory undertaking all the blood lead analyses was the Laboratoire de Toxicologie / INSPQ, the same laboratory used for the 2009 evaluation.
2.5 Environmental sample collection methods

To examine the potential influence of various environmental media on blood lead levels, a component of the follow-up study was the collection and analysis of outdoor soil, indoor dust, and tap water from homes of participating children. Although these media were sampled as part of the HHRA conducted for the Flin Flon Area, paired data was not available for these media from homes where children that participated in the original blood lead study reside. In addition, a portable X-ray fluorescence (XRF) analyzer was used to analyze painted surfaces in and around the home for the presence of lead paint.

This information allowed for an analysis of the correlation between concentrations of lead in each of these media with blood lead levels. Outdoor soil, indoor dust, and tap water samples were collected, and XRF analyses were conducted, by the study team during the in-home surveys that were completed for each household participating in the blood lead study.

2.5.1 Soil Sampling

Ingestion of soil may be a significant source of lead exposure to residents of the Flin Flon community. This is particularly true for young children who have more frequent hand-to-mouth activities and can spend a large amount of time in direct contact with soils. Elevated concentrations of lead were identified in residential soil throughout the Flin Flon Area within previous studies.

Composite soil samples were collected from all participating households for the purpose of identifying soil lead concentrations. Sampling methodologies were generally consistent with those used within previous investigations completed as part of the HHRA. A sampling location frequently used by the child(ren) participating in the blood lead survey was identified and sampled using a hand probe. Care was taken to avoid areas with potential sources of contamination such as play structures and fences which may contain paint or other components that include lead. A composite of a minimum of 10 individual cores collected in an “X” pattern was collected from a depth of approximately 2.5 cm and submitted for lead analysis. Lead concentrations in each sample were compared to the provisional trigger concentration (PTC) of 370 µg/g for residential soils derived within the HHRA for the Flin Flon Area. The PTC represented a concentration below which risks were considered to be negligible. The occurrence of concentrations in excess of the PTC indicated that additional investigation, such as the collection and analysis of blood samples for lead levels, may be beneficial to further assess exposure. A detailed sampling protocol is provided in Appendix I.

2.5.2 Indoor Dust Sampling

Indoor dust sampling involved the use of wipes (15cm x 15cm Ghost Wipe; meets ASTM E 1792) to collect dust from within a defined surface area from up to two hard floor surfaces within the home where children are anticipated to spend a significant amount of time. This included the kitchen floor for all homes (identified as ‘dust 1’) and an additional common or play area as identified by the parent or guardian (‘dust 2’). A 30 cm x 30 cm disposable template (purchased from Delta Scientific Laboratory Products Ltd.) was used to define each area sampled. Wipes were stored within a laboratory supplied glass jar and submitted for lead analysis.

This methodology allowed for the expression of lead concentrations in units of mass per area (i.e., µg lead/cm²) for comparison to the U.S. Department of Housing and Urban Development (HUD) guideline for uncarpeted floors (0.043 µg lead/cm²) (U.S. DHUD, 2012). An alternative
approach for characterizing lead in household dust is to collect dust using a vacuum sampler. Use of a vacuum sampler allows for the collection of a larger volume of dust which can be analyzed and reported on a mass per mass basis (i.e., µg/g) which is consistent with the units of measurement used for soils, however, this approach is significantly more time and labour intensive. Use of the wipes did not add a significant amount of time to the in-home survey and provided a quantitative measurement of lead in house dust to be used to identify potential associations with blood lead levels. A detailed sampling protocol is provided in Appendix J.

2.5.3 Tap Water Sampling

Residential water samples were collected to determine concentrations of lead in tap water. During the tap water collection period, participants were asked to refrain from using water in the home, including operating dishwashers and washing machines.

Three samples were collected from the kitchen faucet of each participating household: 1) a flushed sample (‘flushed’) (i.e., a sample collected following a sufficient amount of time to drain the water standing within the individual home’s plumbing), 2) a stagnant sample capturing water standing within the kitchen faucet and residential plumbing (‘stagnant 1’), and 3) a stagnant sample capturing water standing within residential plumbing and/or the service line leading into the residence (‘stagnant 2’). The flushed sample was collected after the kitchen faucet was run for a 5-minute duration. This sample was considered to be primarily representative of municipally supplied water. Stagnant samples were collected after tap water was left to stagnate for 30 minutes to characterize drinking water that may be influenced by residential plumbing and/or service lines. The first stagnant sample was the first litre of water following the 30-minute stagnation period. Two one-litre samples were then measured and discarded. The fourth one-litre sample following stagnation was retained as the second stagnant sample.

One litre samples were collected for each sample. A 250-mL sub-sample was transferred to a laboratory supplied plastic bottle for analysis. A nitric acid preservative was added to each sample immediately following collection. Lead concentrations in each sample were compared to the CCME Drinking Water Guideline (10 µg/L). A detailed sampling protocol is provided in Appendix K.

2.5.4 Lead Paint Analysis

A portable XRF analyzer (Niton XLp 700, Pine Environmental Services Inc., Mississauga, Ontario) was used to analyze up to ten (10) locations in and around each participating household for the presence of lead paint. For each household, painted surfaces within the kitchen, family room, and bedroom(s) of the participating child(ren) were analyzed. In addition, areas with frayed or chipping paint and areas where children spend significant amounts of time were also tested for the presence of lead paint. Calibration of the XRF analyzer was verified 3 times within each home prior to measurements using a Standard Reference Material (SRM 2573; 1.04±0.06 mg/cm²; Niton Lead Paint Standard: P/N 500-934). Two consecutive measurements were taken from separate areas of each analyzed surface.

Concentrations of lead in analyzed surfaces were reported as mg of lead per cm². Analyzed surfaces with concentrations in excess of the HUD guideline of 1.0 mg/cm² (U.S. DHUD, 2012) were considered to represent a positive result for the presence of lead-based paint.

A detailed sampling protocol is provided in Appendix L.
2.6 Environmental sample analytic methods

The analytic methods used to determine concentrations of lead in soil, indoor dust, and tap water are described in Sections 2.6.1 to 2.6.3, respectively.

2.6.1 Soil Analytic Method

Soil samples were stored at room temperature and submitted to ALS Environmental (ALS) in Winnipeg, Manitoba. The analysis was carried out using procedures adapted from U.S. EPA method 200.2. The sample preparation procedure was for the spectrochemical determination of total recoverable elements. Soil samples were dried at <60°C, homogenized, and a representative subsample was digested. Digested samples were analyzed by Inductively Coupled-Mass Spectrometry (ICP-MS). Concentrations of lead were reported on a mass per mass basis (µg/g). The detection limit was 0.2 µg/g.

2.6.2 Indoor Dust Analytic Method

Indoor dust wipe samples were stored at room temperature and submitted to ALS in Winnipeg, Manitoba. Analysis was performed by ALS in Waterloo, Ontario. The analysis was carried out using procedures adapted from U.S. EPA method 3050/EPA 200.7. Concentrations of lead were reported on a mass per wipe basis (µg/wipe) and converted to a mass per area basis (µg/cm²). The detection limit was 1.0 µg/wipe.

2.6.3 Tap Water Analytic Method

Tap water samples preserved with 3 mL nitric acid (1:3) were stored at room temperature and submitted to ALS in Winnipeg, Manitoba. Sample preparation procedures were adapted from Standard Methods for the examination of Water and Wastewater Method 3030E. Analytical procedures were adapted from U.S. EPA Method 200.8 for analysis of metals by ICP-MS. Concentrations of lead were reported on a mass per volume basis (mg/L). The detection limit was 0.00009 mg/L for most samples, and 0.001 mg/L for a small subset.

2.7 Follow-up and referrals

Once the laboratory analyses were completed for the capillary blood samples, the study team provided notification of individual results to the participants' parents/guardians. All individual results that did not require a follow-up were provided through written notification by mail, along with interpretation of results (see Appendix M for description of results notification process and notification letter templates). For the few results that required additional follow-up, an initial call was placed to the household by the team physician (or designate in one case) to go through the results and recommend follow-up procedures. The main steps recommended for follow-up included:

- Venous sample re-testing offered and arranged by the study team in cooperation with the Flin Flon General Hospital medical laboratory. The venous samples were analysed by the same laboratory used for the capillary samples;
- During the follow-up, the team physician obtained consent from parents/guardians to release capillary and venous blood test results to the local public health officials and the child’s family physician;
- The initial plan was, for persistent results over 5 µg/dL, the team physician would work with public health officials and the child’s family physician to select and implement
appropriate follow-up procedures with the family (ranging from no further follow-up required to, for example, further house inspection; additional sampling of other media such as dust, soil, paint; periodic monitoring of child’s blood lead levels). Once appropriate follow-up procedures were decided, public health officials in collaboration with the child’s physician would have continued to follow-up persistently elevated levels. However, no re-test results exceeded 5 µg/dL so this was not necessary;

- The team physician obtained consent from parents to use the data obtained from follow-up investigations if required for study-level reporting, ensuring confidentiality is respected and individuals and families cannot be identified through the reporting of any data.

For households in which there was an exceedance of the selected guideline for concentrations of lead in soil, dust, water, or paint, phone calls were made to the consenting adults prior to the mail-out of the individual results letters to make them aware of these exceedances. Three attempts were made to reach each household after which a message was left to notify them to contact the study investigators should they have any questions after reviewing their individual results letter. See Appendix N for an example of the environmental results notification letter template.
3.0 CHARACTERISTICS OF SAMPLE

The sample characteristics were quite similar to the sample characteristic in the 2009 study. As illustrated in Table 3-1, the proportion of males and females was fairly even in 2009 and in 2012. However, in 2012 there was a slightly higher proportion of females (52.5%) that participated compared to males (47.5%). In 2009, the study was comprised of more males (54.0%) than females (46.0%). The age distribution of participants was also quite similar across the two time periods. The most notable difference was with respect to sample sizes with samples collected from n=118 participants in 2012 compared with n=202 participants in 2009. In addition, there was a higher proportion of participants from East Flin Flon and a lower proportion of participants from West Flin Flon and Creighton. The explanation for this change was that recruiting efforts in West Flin Flon and Creighton exhausted the entire sample for these areas without reaching the desired target sample size. This was attributed to lower levels of interest in study participation when compared to the 2009 study. Therefore, in order to increase the overall sample size, additional effort was placed on recruiting participants from East Flin Flon (an area with many more households).

Table 3-1  Age, region and gender

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>2009</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>All</td>
<td>202</td>
<td>100%</td>
</tr>
<tr>
<td>Female</td>
<td>93</td>
<td>46.0%</td>
</tr>
<tr>
<td>Male</td>
<td>109</td>
<td>54.0%</td>
</tr>
<tr>
<td>Age at Interview</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 24 months (age 1)</td>
<td>48</td>
<td>23.8%</td>
</tr>
<tr>
<td>24 to 35.99 months (age 2)</td>
<td>33</td>
<td>16.3%</td>
</tr>
<tr>
<td>36 to 47.99 months (age 3)</td>
<td>23</td>
<td>11.4%</td>
</tr>
<tr>
<td>48 to 59.99 months (age 4)</td>
<td>43</td>
<td>21.3%</td>
</tr>
<tr>
<td>60 to 71.99 months (age 5)</td>
<td>28</td>
<td>13.9%</td>
</tr>
<tr>
<td>72 to 83.99 months (age 6)</td>
<td>27</td>
<td>13.4%</td>
</tr>
<tr>
<td>Region of Residence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Flin Flon</td>
<td>84</td>
<td>41.6%</td>
</tr>
<tr>
<td>West Flin Flon</td>
<td>43</td>
<td>21.3%</td>
</tr>
<tr>
<td>Channing</td>
<td>12</td>
<td>5.9%</td>
</tr>
<tr>
<td>Creighton</td>
<td>63</td>
<td>31.2%</td>
</tr>
</tbody>
</table>
4.0 COMPARISON OF INTERNAL EXPOSURE LEVELS

This section of the report has been designed to address the research questions of:

1) What is the current level of internal exposure to lead in the child population residing in the Flin Flon Area?
2) Compared to the lead exposure levels measured in 2009, have levels in Flin Flon Area children increased, decreased, or remained the same in 2012?

This section presents the overall results of the 2012 exposure study and then makes specific comparisons to results from 2009. The findings from the analyses conducted on possible relationships between internal exposure levels and specific environmental and personal characteristics are presented in Section 6.0.

4.1 Current Level of Exposure

Mean blood lead levels in 2012

As illustrated in Table 4-1, the overall geometric mean (GM) blood lead level (BLL) for study participants in 2012 was 1.41 μg/dL. Males were more likely to have higher BLL (GM=1.65 μg/dL) compared to females (GM=1.23 μg/dL). Blood lead levels varied slightly by age category with the lowest levels found among the children under age 2 (GM=1.11 μg/dL) and the highest level found among children between 2 and 3 years of age (GM=1.98 μg/dL).

Blood lead levels varied slightly across study regions. Geometric mean blood lead levels were lowest in East Flin Flon (GM=1.32 μg/dL) and Creighton (GM=1.30 μg/dL). Geometric mean blood lead levels in West Flin Flon (GM=2.11 μg/dL) were slightly higher than the community average of 1.41 μg/dL. It should be noted that only one study participant resided in Channing. As a result, this single result has been included in overall reporting but to protect confidentiality is not reported according to region.
4.2 COMPARISON OF EXPOSURE LEVELS

The overall GM BLL declined from 2.73 \(\mu g/dL\) in 2009 to 1.41 \(\mu g/dL\) in 2012. This marks a reduction of 1.32 \(\mu g/dL\) in geometric mean levels (Table 4-1).

Compared with the BLLs in 2009, the study found that 2012 blood lead levels were statistically significantly lower. Statistical significance was tested via analysis of variance using the log-transformed blood lead levels. See Figure 4-2. The p-value for the main effect of time was \(p<.001\). As illustrated in Table 4-1, the BLLs decreased in all sub-groups according to region, gender, and age. Results from factorial analyses of variance did not produce significant interaction effects which means that the main effect of time period was seen in all sub-groups. In addition, regression models found a significant amount of variance in BLLs explained by time period even once other potential explanatory factors such as gender, region, and age were held constant. This confirms the finding of significantly lower BLLs in 2012 compared with 2009 even though there was a larger proportion of samples taken from children living in the East Flin Flon area that generally has lower exposure levels compared to West Flin Flon.

Region

Blood lead levels declined across all study regions. It should be noted that only one study participant resided in Channing. Considering this, the results for Channing are not presented separately to protect the anonymity of the participant from Channing. For all other regions the average decrease in BLL was significant. The greatest decrease was observed in Creighton where the average BLL decreased 1.72 \(\mu g/dL\) (3.02 \(\mu g/dL\) to 1.30 \(\mu g/dL\)). This was followed closely by West Flin Flon where an average decrease of 1.53 \(\mu g/dL\) was observed (3.64 \(\mu g/dL\) to 2.11 \(\mu g/dL\)). Levels fell by 0.98 \(\mu g/dL\) in East Flin Flon (2.29 \(\mu g/dL\) to 1.32 \(\mu g/dL\)).

Gender

The BLLs for males decreased from a geometric mean level of 3.12 \(\mu g/dL\) in 2009 to 1.65 \(\mu g/dL\) in 2012 (a decrease of 1.47 \(\mu g/dL\)). The decrease in geometric mean BLLs was of a similar magnitude for females, declining from 2.34 \(\mu g/dL\) in 2009 to 1.23 \(\mu g/dL\) (a decline of 1.11 \(\mu g/dL\)).

Age

Blood lead levels declined significantly across all age categories. The largest decrease was observed in children 6 years old, where BLLs fell by an average of 2.61 \(\mu g/dL\) (4.04 \(\mu g/dL\) to 1.43 \(\mu g/dL\)). The smallest decrease was observed in children 2 years old, where BLLs fell by an average of 0.68 \(\mu g/dL\) (2.24 \(\mu g/dL\) to 1.57 \(\mu g/dL\)).

<table>
<thead>
<tr>
<th>Table 4-1: Distribution of follow-up blood lead levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>All</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Age at Interview</td>
</tr>
<tr>
<td>Less than 24 months (age 1)</td>
</tr>
</tbody>
</table>

Follow-up Evaluation of Lead Exposure Among Children (under 7) in Flin Flon and Creighton
### Table 4-1: Distribution of follow-up blood lead levels

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>2009 GeoMean (μg/dL)</th>
<th>2012 GeoMean (μg/dL)</th>
<th>Change in Mean (by μg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 to 35.99 months (age 2)</td>
<td>3.08</td>
<td>1.98</td>
<td>-1.10</td>
</tr>
<tr>
<td>36 to 47.99 months (age 3)</td>
<td>2.24</td>
<td>1.57</td>
<td>-0.68</td>
</tr>
<tr>
<td>48 to 59.99 months (age 4)</td>
<td>2.52</td>
<td>1.43</td>
<td>-1.08</td>
</tr>
<tr>
<td>60 to 71.99 months (age 5)</td>
<td>2.89</td>
<td>1.43</td>
<td>-1.46</td>
</tr>
<tr>
<td>72 to 83.99 months (age 6)</td>
<td>4.04</td>
<td>1.43</td>
<td>-2.61</td>
</tr>
<tr>
<td>Region of Residence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Flin Flon</td>
<td>2.29</td>
<td>1.32</td>
<td>-0.98</td>
</tr>
<tr>
<td>West Flin Flon</td>
<td>3.64</td>
<td>2.11</td>
<td>-1.53</td>
</tr>
<tr>
<td>Channing</td>
<td>1.99</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Creighton</td>
<td>3.02</td>
<td>1.30</td>
<td>-1.72</td>
</tr>
</tbody>
</table>

*Note: A few of the blood samples (1.7%; n=2) were found to be below the limit of detection for blood lead (0.10 μg/dL). Therefore, for analysis purposes, the results for these two samples were replaced with the detection limit.*

**Distribution of levels**

Figure 4-1 illustrates, the distribution of blood lead levels follows a lognormal distribution pattern with the majority of samples under 3 μg/dL.

![Distribution of blood lead levels](image)

**Figure 4-1** Distribution of blood lead levels
The box plots contained in Figures 4-2, 4-3, 4-4, and 4-5 illustrated the distribution of BLLs according to year, region of residence, sex and age, respectfully. The actual associations between age, sex, place of residence and BLLs are further explored in Section 5.0.

**Figure 4-2**  Comparison of 2009 and 2012 geometric mean blood lead levels

![Box plots comparing blood lead levels between 2009 and 2012.](image)

**Figure 4-3**  Blood lead levels by geographic region

![Box plots showing blood lead levels by region.](image)

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2 **Interpretation of boxplots** – Boxplots are interpreted as follows:

- The box itself contains the middle 50% of the data. The upper edge (hinge) of the box indicates the 75th percentile, and the lower hinge indicates the 25th percentile. The range of the middle two quartiles is known as the inter-quartile range.
- The line in the box indicates the median value of the data.
- If the median line within the box is not equidistant from the hinges, then the data is skewed.
- The ends of the vertical lines or “whiskers” indicate the minimum and maximum data values, unless outliers are present in which case the whiskers extend to a maximum of 1.5 times the inter quartile range.
- The points outside the ends of the whiskers are outliers or suspected outliers.
Figure 4-4  Blood lead levels by sex

Figure 4-5  Blood lead levels by age
4.3 Individual follow-up

Individuals referred for follow-up

An *a priori* decision was made at the study design phase to follow-up with any participant that had a capillary BLL above the 95th percentile for the sample, or a level that was at or above 5.00 µg/dL, whichever was lower. The 95th percentile value was 3.53 µg/dL, so it was selected as the follow-up level for the 2012 study. As would be expected with a 95th percentile-based follow-up level, 5% of the samples (n= 6) were at or above this level. As illustrated in Table 4-2, very few of the samples (2.5% n=3) were at or above 5.00 µg/dL, the follow-up level applied for the 2009 study. No samples were at or above the No samples were at or above the Canadian guidance of 10 µg/dL set in 1994 by the federal-provincial-territorial Committee on Environment and Occupational Health (CEOH 1994).

Compared to the 2009 results, this demonstrates a considerable drop in the proportion of children requiring follow-up. In 2009, approximately 13% of the samples (n= 27) were at or above 5.00 µg/dL and approximately 2% of the samples (n=5) were at or above the Committee on Environment and Occupational Health (CEOH) guidance level of 10 µg/dL.

<table>
<thead>
<tr>
<th>Table 4-2 Distribution of referrals for follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Samples</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Overall</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Region of Residence</td>
</tr>
<tr>
<td>East Flin Flon</td>
</tr>
<tr>
<td>West Flin Flon</td>
</tr>
<tr>
<td>Channing</td>
</tr>
<tr>
<td>Creighton</td>
</tr>
</tbody>
</table>

4.4 National surveys of blood lead levels and community surveys of blood lead levels

National level and community level comparisons of BLLs can be helpful in establishing a frame of reference to understand how BLLs in Flin Flon Area children compare to other communities and on a national level. This section provides a summary of BLLs recently reported in other studies. More detailed information and comparisons are found in Appendix O.

This section examines findings assembled from a few studies that can provide an indication of how the levels found in Flin Flon Area children compare with national level studies and levels found in other communities. None of these should be considered a “perfect” comparison - the Flin Flon Area population will likely have some characteristics that are unique, and not necessarily shared with these comparison areas of study (e.g., environment, diet, housing conditions). Instead, these comparisons should be considered as providing a context within which the present study’s BLL results can be interpreted. To provide this context for

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3 5 µg/dL was the follow-up level selected for the 2009 exposure study.
interpretation, comparisons were made with large national level studies in the United States and Canada, as well as with smaller studies of BLLs in atypically exposed communities in Canada. Where applicable, potential challenges with these comparisons are outlined for the reader’s consideration.

National level studies

As part of the second cycle of the Canadian Health Measures Study, Health Canada (2013a) collected biological specimens from Canadians aged 3 to 79 years between August 2009 and November 2011 from 18 sites across Canada. Samples were collected to allow for comparisons of baseline concentrations of chemicals in Canadians to concentrations within subpopulations. The study excluded people living on reserves or other Aboriginal settlements, remote areas, and areas with low population density (Health Canada, 2013a). A total of 495 children in the 3 to 5 year age group participated, with a geometric mean BLL of 0.93 µg/dL and a 95th percentile of 2.1 µg/dL. In the 6 to 11 year age group (n=961), the geometric mean BLL was 0.79 µg/dL with a 95th percentile of 1.8 µg/dL.

An age appropriate comparison can be made with the US CDC (2011) NHANES (2009-10) in which one age group studied is children between one and five years old. The challenge with this comparison is that cultural, regulatory, and environmental differences likely impact on comparability. With that caution in mind, the comparison demonstrates that the GM BLL for the comparable age group of one to five year olds from the NHANES was fairly similar. The GM BLL reported in NHANES was slightly lower (1.17 µg/dL) when compared with the GM BLL found among Flin Flon Area children (1.41 µg/dL). In addition, the 95th percentile GM BLL was similar. The 95th percentile GM BLL reported in NHANES (2009-10) was 3.37 µg/dL while the 95th percentile GM BLL for the 2012 Flin Flon Study was 3.53 µg/dL.

Studies of atypically exposed communities

While a national level survey of BLLs among younger children has not been undertaken in Canada, there have been a number of recent smaller studies that have been conducted with younger children in communities that would be considered atypically exposed (see Appendix O). When the Flin Flon Area children’s levels are compared with these studies, the GM obtained in the Flin Flon Area are considerably lower than GM ranges found in these other communities. For example, the GM BLLs found in the present study are considerably lower than those found among children in Trail, BC in 2012 (5.4 µg/dL), and also lower than levels found among children living in an area in proximity to a lead smelter in Belledune, NB in 2004 (3.54 µg/dL). In these cases, the studies were conducted in areas in proximity to smelters. Cautions in making these comparisons are that the soil levels and original BLLs found in Trail, BC are magnitudes higher than what has been measured in the Flin Flon Area. A caution with making the comparisons with the Belledune study that focused on children living beside a smelter is that it included only a small number of samples (n=10), and that Belledune is a coastal, rural area whose residents likely have significant differences in diet and activity, when compared with Flin Flon Area residents.

When compared with other atypically exposed communities where the exposure concern has not necessarily been soil, but rather water or food, the results obtained for children in the Flin Flon Area are again consistently lower than other study results. Results in Flin Flon Area children are lower than those found in similar aged children in North Hamilton in 2008 (2.3 µg/dL). Cautions in making this comparison are that the main exposure concern was water, and North Hamilton is a large, urban area with likely different environmental and population conditions.
characteristics when compared to the Flin Flon Area. Other studies which have focused primarily on exposure to local food have found higher GM BLLs of 5.3 µg/dL in five year old children in Nunavik, Quebec. The main challenges in making comparisons to this study is that it was undertaken in a northern, Aboriginal community which is likely to significantly differ in many ways from the Flin Flon Area.

In terms of comparison to an atypically exposed population, without a source point of exposure, recent results from a study of a sub-set of Montreal residents (Levallois et al, 2013) were similar to the results obtained in the current Flin Flon Study. This study was conducted in an older area of Montreal that was predicted to be atypically exposed due to risks associated with older homes, possibility of lead paint, lead service connections, lead in soil due to leaded gasoline. The Montreal study with children ages 12 to 71 months of age found a GM BLL of 1.35 µg/dL (95% CI: 1.27 - 1.43). Also, similar patterns were found when compared to the 2012 Flin Flon study results, such as a higher BLL measured in boys when compared to girls, and a higher BLL among children in the 2 year old age category when compared to other age categories.

The overall conclusion of this comparison is that Flin Flon Area children have comparable GM BLLs to those found among children in a national level US CDC (2011) study and a study of atypically exposed children in Montreal (Levallois et al, 2013). In addition the study found that the GM BLL among Flon Flon Area children is considerably lower when compared to children in communities with identified source points of exposure (i.e., Trail, Hamilton, Belledune, Nunavik).
5.0  LEVELS OF LEAD IN ENVIRONMENTAL MEDIA

Concentrations of lead in environmental media are described for each region of residence as well as for the Flin Flon Area as a whole. In addition to a description of the general statistics for these parameters, Section 5.5 provides an analysis of the relationships between environmental variables.

5.1  Outdoor Soil

Soil lead levels ranged from 3.4 to 791 µg/g (Table 5-1) and followed a lognormal distribution pattern with the majority of samples (~55%) under 100 µg/g. Of the 91 samples collected from participating households, four (4) samples contained lead at a concentration in excess of the PTC of 370 µg/g (3 in West Flin Flon (437, 470 and 791 µg/g); 1 in East Flin Flon (447 µg/g).

Table 5-1  Levels of Lead in Soil (µg/g) by Region of Residence

<table>
<thead>
<tr>
<th>Region</th>
<th>N</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>Geometric Mean</th>
<th>LCL</th>
<th>UCL</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channing</td>
<td>2</td>
<td>111.5</td>
<td>62.8</td>
<td>198</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Creighton</td>
<td>22</td>
<td>70.5</td>
<td>10.3</td>
<td>230</td>
<td>62.4</td>
<td>42.0</td>
<td>92.8</td>
<td>2.4</td>
</tr>
<tr>
<td>East Flin Flon</td>
<td>49</td>
<td>80.2</td>
<td>3.4</td>
<td>447</td>
<td>68.3</td>
<td>50.5</td>
<td>92.5</td>
<td>2.9</td>
</tr>
<tr>
<td>West Flin Flon</td>
<td>18</td>
<td>163.5</td>
<td>4.5</td>
<td>791</td>
<td>113.3</td>
<td>59.7</td>
<td>215.1</td>
<td>3.6</td>
</tr>
<tr>
<td>All</td>
<td>91</td>
<td>81.8</td>
<td>3.4</td>
<td>791</td>
<td>74.7</td>
<td>59.7</td>
<td>93.4</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Notes: N-number of soil samples (homes); Min-Minimum; Max-Maximum; LCL-95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD-Geometric Standard Deviation; dash (-) indicates that summary statistics were not calculated due to small sample size.

The overall geometric mean concentration was 74.7 µg/g, with the highest mean concentration found in West Flin Flon (113 µg/g) followed by East Flin Flon (68.3 µg/g) and Creighton (62.4 µg/g) (Figure 5-1). A mean concentration was not calculated for Channing since only two households participated from this region (62.8 and 198 µg/g).

Figure 5-1  Soil lead levels by geographic region

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Interpretation of boxplots – Boxplots are interpreted as follows:
- The box itself contains the middle 50% of the data. The upper edge (hinge) of the box indicates the 75th percentile, and the lower hinge indicates the 25th percentile. The range of the middle two quartiles is known as the inter-quartile range.
- The line in the box indicates the median value of the data.
- If the median line within the box is not equidistant from the hinges, then the data is skewed.
- The ends of the vertical lines or “whiskers” indicate the minimum and maximum data values, unless outliers are present in which case the whiskers extend to a maximum of 1.5 times the inter quartile range.
- The points outside the ends of the whiskers are outliers or suspected outliers.

5.2 Indoor Dust

Dust samples were collected from hard flooring surfaces in the kitchen for all homes (identified as ‘dust 1’) and an additional common or play area as identified by the parent or guardian (‘dust 2’). It was not possible to determine the distribution of ‘dust 1’ or ‘dust 2’ lead levels due to the high proportion of samples (~ 60%) with levels below the detection limit of 0.001 µg/cm². However, a lognormal distribution was assumed based on comparison to the distribution of lead in soil as described above.

Concentrations of lead in samples collected from kitchen floors (‘dust 1’) were similar to concentrations in samples collected from the second common location (‘dust 2’). Concentrations for both sample locations were similar for each region of residence (Table 5-2). All samples contained lead at a level below the HUD guideline of 0.043 µg/cm².

<table>
<thead>
<tr>
<th>Region</th>
<th>Dust 1</th>
<th>Dust 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion of data below detection limit</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>Median</td>
<td>0.0040</td>
<td>&lt;0.0011</td>
</tr>
<tr>
<td>Min</td>
<td>&lt;0.0011</td>
<td>&lt;0.0011</td>
</tr>
<tr>
<td>Max</td>
<td>0.0143</td>
<td>&lt;0.0011</td>
</tr>
<tr>
<td>Geometric* Mean</td>
<td>0.0014</td>
<td>0.0014</td>
</tr>
<tr>
<td>LCL</td>
<td>0.0011</td>
<td>0.0010</td>
</tr>
<tr>
<td>UCL</td>
<td>0.0017</td>
<td>0.0020</td>
</tr>
<tr>
<td>STD</td>
<td>1.51</td>
<td>1.89</td>
</tr>
</tbody>
</table>

Notes: N-number of dust samples; Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL- 95% Upper Confidence Limit; STD-Geometric Standard Deviation; dash (-) indicates that summary statistics were not calculated due to small sample size; *Geometric mean, LCL, UCL and STD were estimated by replacing non-detect values with the detection limit (0.001 µg/cm²) and therefore the mean, LCL, and UCL are likely somewhat higher than the true values while STD may underestimate data variability.

5.3 Tap Water

Flushed and stagnant tap water samples were collected from each participating household. All flushed samples contained lead at a level below the CCME Drinking water guideline (10 µg/L) (Table 5-3). For one (1) household, lead levels within both stagnant samples (47 µg/L and 11 µg/L) were above the CCME guideline.
Table 5-3  Levels of Lead in Tap Water (µg/L) by Region of Residence

<table>
<thead>
<tr>
<th>Region</th>
<th>N</th>
<th>Proportion of data below detection limit</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>Geometric* Mean</th>
<th>LCL</th>
<th>UCL</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flushed</td>
<td>2</td>
<td>0</td>
<td>1.52</td>
<td>1.00</td>
<td>2.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stagnant 1</td>
<td>2</td>
<td>0</td>
<td>2.30</td>
<td>1.60</td>
<td>3.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stagnant 2</td>
<td>2</td>
<td>0</td>
<td>1.61</td>
<td>1.30</td>
<td>2.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Creighton</td>
<td>22</td>
<td>0.27</td>
<td>0.77</td>
<td>0.12</td>
<td>8.10</td>
<td>0.69</td>
<td>0.47</td>
<td>1.02</td>
<td>2.41</td>
</tr>
<tr>
<td>Stagnant 1</td>
<td>22</td>
<td>0.18</td>
<td>1.45</td>
<td>0.75</td>
<td>47.00</td>
<td>1.89</td>
<td>1.26</td>
<td>2.85</td>
<td>2.51</td>
</tr>
<tr>
<td>Stagnant 2</td>
<td>22</td>
<td>0.23</td>
<td>1.00</td>
<td>0.34</td>
<td>11.00</td>
<td>1.05</td>
<td>0.77</td>
<td>1.44</td>
<td>2.03</td>
</tr>
<tr>
<td>East Flin Flon</td>
<td>51</td>
<td>0.02</td>
<td>0.87</td>
<td>0.45</td>
<td>3.50</td>
<td>1.01</td>
<td>0.86</td>
<td>1.18</td>
<td>1.77</td>
</tr>
<tr>
<td>Stagnant 1</td>
<td>50</td>
<td>0.02</td>
<td>2.55</td>
<td>0.33</td>
<td>9.50</td>
<td>2.21</td>
<td>1.79</td>
<td>2.72</td>
<td>2.10</td>
</tr>
<tr>
<td>Stagnant 2</td>
<td>50</td>
<td>0.02</td>
<td>1.10</td>
<td>0.16</td>
<td>4.50</td>
<td>1.21</td>
<td>0.99</td>
<td>1.47</td>
<td>2.02</td>
</tr>
<tr>
<td>West Flin Flon</td>
<td>18</td>
<td>0.17</td>
<td>0.91</td>
<td>0.09</td>
<td>2.10</td>
<td>0.80</td>
<td>0.56</td>
<td>1.13</td>
<td>2.03</td>
</tr>
<tr>
<td>Stagnant 1</td>
<td>18</td>
<td>0.11</td>
<td>2.35</td>
<td>0.09</td>
<td>5.50</td>
<td>1.89</td>
<td>1.15</td>
<td>3.11</td>
<td>2.73</td>
</tr>
<tr>
<td>Stagnant 2</td>
<td>18</td>
<td>0.11</td>
<td>1.35</td>
<td>0.09</td>
<td>9.20</td>
<td>1.21</td>
<td>0.75</td>
<td>1.96</td>
<td>2.61</td>
</tr>
<tr>
<td>All</td>
<td>92</td>
<td>0.11</td>
<td>0.90</td>
<td>0.09</td>
<td>8.09</td>
<td>0.89</td>
<td>1.02</td>
<td>0.77</td>
<td>2.00</td>
</tr>
<tr>
<td>Stagnant 1</td>
<td>92</td>
<td>0.08</td>
<td>2.20</td>
<td>0.09</td>
<td>47.00</td>
<td>2.07</td>
<td>1.74</td>
<td>2.45</td>
<td>2.29</td>
</tr>
<tr>
<td>Stagnant 2</td>
<td>92</td>
<td>0.09</td>
<td>1.10</td>
<td>0.09</td>
<td>11.00</td>
<td>1.18</td>
<td>1.01</td>
<td>1.37</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Notes: N-number of water samples (homes); Min-Minimum; Max-Maximum; LCL-95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD-Geometric Standard Deviation; dash (-) indicates that summary statistics were not calculated due to small sample size. *Geometric mean, LCL, UCL and STD were estimated by replacing non-detect values with the detection limit (which ranged from 0.09 to 1.0 µg/L) and therefore the mean, LCL, and UCL are likely somewhat higher than the true values while STD may underestimate data variability.

Concentrations of lead in all three water samples were highly correlated to each other in each household. As expected, lead concentrations were significantly lower in ‘flushed’ than in ‘stagnant 1’ and ‘stagnant 2’ and concentrations were significantly lower in ‘stagnant 2’ than in ‘stagnant 1’ (Figure 5-2). Overall, concentrations of lead in the municipal supply of water in each of the regions are significantly lower than concentrations in tap water that had been left to remain stagnant for a 30-minute period. Given that concentrations in the first stagnant water sample (‘stagnant 1’) were significantly higher than the flushed sample and the second stagnant sample (‘stagnant 2’), it appears that lead content in tap water samples were significantly influenced by kitchen faucets and/or residential plumbing. Given that ‘stagnant 2’ is intended to capture the influence of the service line leading into the household, it appears that service lines significantly increase lead content in tap water relative to the water provided by the municipality, but not to the same extent as faucets and/or residential plumbing.
Figure 5-2  Levels of lead in flushed and stagnant tap water

Interpretation of boxplots – Boxplots are interpreted as follows:
- The box itself contains the middle 50% of the data. The upper edge (hinge) of the box indicates the 75th percentile, and the lower hinge indicates the 25th percentile. The range of the middle two quartiles is known as the inter-quartile range.
- The line in the box indicates the median value of the data.
- If the median line within the box is not equidistant from the hinges, then the data is skewed.
- The ends of the vertical lines or “whiskers” indicate the minimum and maximum data values, unless outliers are present in which case the whiskers extend to a maximum of 1.5 times the inter-quartile range.
- The points outside the ends of the whiskers are outliers or suspected outliers.

5.4  Paint

The XRF analyzer was used to measure lead content in painted surfaces. Levels of lead in analyzed surfaces were reported as mg of lead per cm². Analyzed surfaces with levels in excess of the HUD guideline of 1.0 mg/cm² were considered to represent a positive result for the presence of lead-based paint. Eight (8) households had painted surfaces that tested positive for lead-based paint. Of these, four (4) were exterior housing surfaces.

<table>
<thead>
<tr>
<th>Region</th>
<th>N</th>
<th>Households Testing Positive for Interior Lead-Based Paint</th>
<th>Households Testing Positive for Exterior Lead-Based Paint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channing</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Creighton</td>
<td>22</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>East Flin Flon</td>
<td>51</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>West Flin Flon</td>
<td>18</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>All</td>
<td>93</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Notes: N - number of tested households. Positive tests for lead-based paint are concentrations greater than 1.0 mg/cm².

5.5  Relationships between Environmental Variables

Concentrations of lead in indoor dust has the potential to be influenced by lead content in outdoor soil which may enter homes through the deposition of windblown particulates or through track-in on pets or footwear. For households that had detected levels of lead in both soil and dust, a linear regression was applied to determine if soil lead concentrations were predictive of
indoor dust concentrations. This regression was not significant for either dust sample indicating that dust concentrations are not correlated to soil concentrations.

Since the majority of indoor dust samples were below the detection limit, a t-test was applied to investigate whether households with indoor dust lead concentrations that were below the detection limit had lower outdoor soil lead concentrations than household with detected indoor dust concentrations. No statistical difference was observed between soil concentrations in these households.

For households that had detected levels of lead in both paint and dust, a linear regression was applied to determine if paint lead concentrations were predictive of indoor dust concentrations. This regression was not significant indicating that dust lead concentrations are not correlated to lead in paint.

Overall, concentrations of lead in indoor dust appear to be independent of concentrations of lead in both outdoor soil and paint.
6.0 FACTORS ASSOCIATED WITH EXPOSURE LEVELS

This section of the report addresses the research question of:

*Are the personal factors associated with children’s lead exposure measured in 2009 (e.g., place of residence, age, gender) similar in 2012?*

6.1 Personal factors associated with blood lead levels

Using multivariate regression models to determine the extent that various factors were significant predictors of log BLLs, the 2009 study found that the main predictors of BLLs in 2009 were:

- Age – boys were more likely to have higher levels than girls;
- Area of residence – children living in West Flin Flon were more likely to have higher levels than children living in East Flin Flon;
- Adult currently smoking or using tobacco – children living in households with adults who smoke or used tobacco were more likely to have higher levels;
- Children who spend time away from home were more likely to have higher levels; and
- Year the house was constructed – children living in older households were more likely to have higher levels.

In the 2012 study, similar regression models were developed and analysed. The only factor that was a significant predictor of BLLs in 2012 was the year the house was constructed with children living in older households being more likely to have higher levels. This limited number of significant predictive factors is not surprising given the lower BLLs overall, and the smaller sample of children. The lower levels of BLL result in limited variance within the sample. Regression is most powerful when it can account for variance through various associations. As well, given that BLLs are relatively lower, the pathways of exposure or predictors are likely to be much more challenging to disentangle given that there are not just one or two pathways, but likely many contributing to a low background exposure level. Given the lower levels and the more limited variance, the sample sizes required to obtain statistical significance is greatly increased, as more cases are needed to detect smaller effect sizes.

As noted above, the only factor found to be significantly associated with blood lead exposure is age of housing. Similar to the 2009 study, individuals living in older housing stock were more likely to have higher (but not necessarily elevated) GM BLLs, compared to individuals living in newer housing stock. Specifically, housing stock constructed prior to 1946 was found to be significantly (p=.033) associated with higher GM BLLs. This result should be interpreted with caution because the GM BLL across the community was in a normal range, with little variance. The supporting descriptive statistics on each of the significant predictive factors are presented in Appendix P.

Within the questionnaire data, the study looked at factors associated with BLLs and public health messages. Hand-washing habits and awareness of public health messages were not found to be significantly associated with GM BLLs. However, significant activities have been undertaken since 2010, therefore Appendix Q characterizes the reach of these activities.
6.2 Environmental factors associated with blood lead levels

The environmental sampling component of the current study was included to examine the relationship between concentrations of lead in environmental media within a given household and the corresponding BLLs in participating children. Univariate regressions were performed using log10 transformed lead concentrations in blood and environmental media (Table 6-1). Regressions were performed for BLLs for each participating child with paired environmental concentrations for soil, dust, and tap water (flushed and stagnant samples) collected from the participating child’s household. In addition, regressions were also performed for blood lead and the maximum household lead paint concentration. The maximum paint concentration was selected to acknowledge the potential for a single elevated paint source to influence BLLs.

<table>
<thead>
<tr>
<th>Environmental Component</th>
<th>N*</th>
<th>r²</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil (µg/g)</td>
<td>108</td>
<td>0.07</td>
<td>0.005</td>
</tr>
<tr>
<td>Dust 1 (µg/cm²)</td>
<td>35</td>
<td>0.12</td>
<td>0.041</td>
</tr>
<tr>
<td>Dust 2 (µg/cm²)</td>
<td>29</td>
<td>0.02</td>
<td>0.475</td>
</tr>
<tr>
<td>Maximum in paint (mg/cm²)</td>
<td>95</td>
<td>0.06</td>
<td>0.018</td>
</tr>
<tr>
<td>Water (flushed) (µg/L)</td>
<td>95</td>
<td>0.01</td>
<td>0.365</td>
</tr>
<tr>
<td>Water (stagnant 1) (µg/L)</td>
<td>98</td>
<td>0.02</td>
<td>0.128</td>
</tr>
<tr>
<td>Water (stagnant 2) (µg/L)</td>
<td>97</td>
<td>0.001</td>
<td>0.778</td>
</tr>
</tbody>
</table>

* The number of samples (n-values) differed between environmental variables as each regression was performed using only samples that had a measured and detected lead concentration in both blood and the relevant environmental variable.

As shown in Table 6-1, three of the measured environmental factors (soil, ‘dust 1’, and paint) were found to be significantly correlated to blood lead based on a p-value of <0.05. Although a statistically significant association between concentrations of lead in these household media and the corresponding BLLs exists, the variability in BLLs is poorly explained by these factors alone as indicated by the low r² values for soil (0.07), ‘dust 1’ (0.12), and paint (0.06). This variability is also highlighted in Figure 6-1. Based on the regressions derived from the co-located environmental media concentrations and BLLs, there is a high degree of variability associated with BLLs at any given environmental lead concentration. For example, predicted BLLs at a soil concentration of 100 µg/g could be expected (with a 95% probability) to range from 0.54 to 4.15 µg/dL (Figure 6-1). At a much higher soil concentration of 800 µg/g, there is a large overlap in the predicted range in BLLs (0.73 to 5.4 µg/dL) as predicted at 100 µg/g (Figure 6-1).
Figure 6-1 Relationships Between a.) Soil Lead Levels, b.) ‘Dust 1’ Lead Levels, and c.) Maximum Paint Levels and Blood Lead Levels on a log-log scale (upper) and non-transformed (lower) scale. Grey Lines Indicate 95% Upper and Lower Prediction Limits (i.e., the range in which there is a 95% probability that future observations of blood lead will fall within based on the observed regressions). Each regression was performed using only samples that had a measured and detected lead concentration in both blood and the relevant environmental variable.

This analysis indicates that environmental factors measured as part of the current study may only slightly influence BLLs, and that they are poor predictors of BLLs and that additional factors likely represent a greater influence on BLLs in children in the Flin Flon Area.

One additional environmental factor that is anticipated to have contributed to the decline in BLLs observed between the 2009 and 2012 studies is the decrease in lead concentrations in air and the associated decrease in the deposition of lead particles to the environment following the closure of the smelter in June 2010 (Figure 6-2). In 2009, the average daily concentration of lead associated with total suspended particulates (TSP) was 0.062 and 0.025 µg/m³ as measured at samplers on Ruth Betts School in Flin Flon and Creighton School in Creighton, respectively. These averages dropped to 0.020 and 0.017 µg/m³ in 2010, and to 0.017 and 0.012 µg/m³ in 2011 at Ruth Betts and Creighton School, respectively.
Figure 6-2  Average daily concentrations of lead associated with TSP measured at Ruth Betts School in Flin Flon and Creighton School in Creighton
7.0 STUDY LIMITATIONS

Study quality can be judged in terms of both study design and execution. This study was designed to determine the extent to which BLLs among Flin Flon Area children had changed between 2009 and 2012. While the sample size was smaller than originally planned, given the magnitude of change, the power to detect this difference was sufficient. In addition to biological and environmental sample collection, detailed information was collected via questionnaires administered to the parents of study participants to assist in understanding the associations between personal characteristics and internal exposure levels. All biological and environmental samples were subject to well-defined collection, storage and analysis protocols, with multiple quality assurance and control checks.

Although the study was successful in addressing the main questions for which it was designed, there remain some limitations of which the reader should be aware in interpreting results. The main limitations are:

- **Study design:** The study followed a cross-sectional, once-only survey approach to capture a snap-shot representation of exposure to lead. The generalizability of the results arises from assumptions about the nature of exposure to lead found primarily in soil. All things being equal, considering the sample, we can assume that the average levels in the community during this period fairly reflect exposure fluctuations throughout a time of year where exposure is assumed to be elevated and that the averages found represent average exposures for individuals. If behaviours and exposure conditions change, absorption of lead from the environment will be affected.

- **Representativeness of sample:** As with any survey of a population, there are questions as to whether the sample achieved is representative of the overall population. Given the sample size is smaller than what was planned, the sample may be less representative than what would be desirable, particularly for the smaller subgroups separated out for analysis (e.g., age groups, gender, and region).

- **Biological sample collection methods:** As with the 2009 study, the study team opted to collect blood lead samples by capillary blood draw. This decision was made based on the comparability between venous and capillary samples, and previous experience that has demonstrated that parents are often hesitant to have their children provide venous blood which would ultimately have impacted negatively on the overall response rates achieved.

- **Environmental sample collection methods:** To characterize lead content in tap water that may be consumed by participants, three samples were collected. The flushed sample was considered to be representative of situations where faucets were run for a sufficient time to drain water that may have been standing within residential plumbing. The stagnant samples were intended to be representative of situations where water was not run prior to use/consumption. To allow for the environmental sampling to be completed within the same period as the in-home survey, a 30-minute stagnation duration was selected. Given that the results of the current study indicated that concentrations of lead in the stagnant samples were significantly higher than in flushed samples, it is anticipated that a longer stagnation period would have allowed for a greater influence of plumbing and service lines on lead content. The sampling protocol may not have allowed for the identification of elevated lead concentrations in tap water consumed by participants.

To characterize the influence of the service line on lead content in tap water, the 4th litre of water following the stagnation period was collected and analyzed. Given that the
volume of water required to drain residential plumbing is specific to each household, it is uncertain if this sample is consistently representative of water that was standing within the service line during the stagnation period.

A composite soil sample was collected in a 1-metre by 1-metre ‘X’ pattern from an area identified as being frequently used by the participating child(ren). Given that children are likely to move randomly throughout a larger area, this sample may represent an over or under-estimation of concentrations that they will be exposed to over an extended period of time. However, assuming that there are no significant point sources of lead contamination within the property, it can be reasonably anticipated that concentrations would be similar in soils throughout.

- **Seasonal timing of the study:** As with the 2009 study, data collection for the current study was conducted during September and October, 2012. Literature on surveys that depend on soil contaminant exposure opportunity supports the choice of late summer or early fall as a representative period during which to measure children’s exposure, as opposed to earlier summer collection that presents difficulties with resident summer absences. The choice of this period also corresponds to previous surveys in other communities. The limitation is that the levels measured in the current study are likely in the upper ranges of exposure, rather than an annual average.
8.0 SUMMARY AND CONCLUSIONS

There were three main research questions addressed by the current study. A summary of the findings used to address each question are presented below, according to question, along with main conclusions.

What is the current level of internal exposure to lead in the child population residing in the Flin Flon Area?

Flin Flon Area children’s internal exposure to lead was measured using capillary blood samples. Based on the 118 samples collected from children under 7 years old, the geometric mean was found to be 1.41 μg/dL. Blood lead levels ranged from below the detection limit for two samples (<0.10 μg/dL) to 8.35 μg/dL. The 95th percentile was assessed at 3.53 μg/dL. Children living in West Flin Flon were more likely to have higher levels on average (2.1 μg/dL) compared to children in East Flin Flon (1.3 μg/dL) or Creighton (1.3 μg/dL). Boys were more likely to have higher blood lead levels on average (1.7 μg/dL) compared to girls (1.2 μg/dL). Toddlers between 2 and 3 years of age were most likely to have the highest levels on average (1.98 μg/dL).

Compared to the lead exposure levels measured in 2009, have levels in Flin Flon Area children increased, decreased, or remained the same in 2012?

Children’s blood lead levels were statistically significantly lower in 2012 than in 2009. The geometric mean dropped from 2.73 μg/dL in 2009 to 1.41 μg/dL in 2012. This constitutes a drop in mean levels of 1.32 μg/dL. This finding is consistent across all sub-groups according to age, gender and region.

The proportion of children in the upper-levels of the distribution was also considerably smaller. In 2009, 13% of samples were at or above 5.00 μg/dL compared with 2% of samples in 2012.

Are the personal factors associated with children’s lead exposure measured in 2009 (e.g., place of residence, age, gender) similar in 2012?

There were very few factors associated with children’s lead exposure in 2012. The only factor that was found to be significant was age of housing. Children living in older housing were more likely to have higher blood lead levels. The limited number of significant associations is not surprising given the lower blood lead levels overall, and the smaller number of blood samples. When blood lead levels are lower, the pathways of exposure are more challenging to disentangle given that there are not just one or two dominant pathways, but likely many contributing to a low background exposure level. Given the lower blood lead levels, the sample sizes required to obtain statistical significance is greatly increased.

8.1 Overall Conclusions

In light of an increasing body of scientific research demonstrating a broad spectrum of health outcomes associated with lead exposure, most notably neurological effects among children at low blood lead levels (i.e., less than 10 μg/dL), various regulatory agencies have, or are in the midst of, updating their respective health-based policies and guidelines concerning lead. Health Canada (2013b) indicated that the relationship between IQ score (in children) and BLLs is the strongest line of evidence of adverse effects in humans below a BLL of 10 μg/dL and that
neurodevelopmental effects among infants and children is the primary health effect of concern, with IQ score being the most sensitive of all neurological related endpoints.

The Canadian Blood Lead Intervention Level of 10 µg/dL (CEOH 1994) is no longer considered to be health protective, as there is no evidence of a threshold for critical lead-induced health effect. Blood lead levels of Canadians have declined significantly over the past 30 years. That said, in response to the evidence that health effects are occurring at levels below 10 µg/dL, and in consideration that it is appropriate to apply a conservative approach when characterizing risk, it was concluded that additional measures to further reduce exposures of Canadians to lead, with a particular focus on vulnerable populations, are warranted. Accordingly, the proposed risk management objective for lead is to pursue additional management measures to reduce exposure to lead, and hence associated risks, to the greatest extent practicable.

The issue of what magnitude of lead exposure, as measured by a BLL, should trigger intervention remains outstanding. Often, this is a matter of weighing the effectiveness of intervention against the potential health effects of exposure. Historically blood lead intervention levels have been based on health risks. The absence of an identified threshold for the adverse effects of lead makes it difficult to set a blood lead intervention value that is without health risks. As a result, recent guidance recommends a “normative” approach to establishing blood lead action levels (ACCLPP, 2012; U.S. CDC, 2012). Under the normative approach, decision-making on the requirement for intervention is based on the following questions:

- Is the individual or community blood lead concentration atypical (i.e., higher than normal)?
- If so, what can be done to effectively reduce the atypical exposure?

In the absence of clear policy direction, the 2009 and 2012 Flin Flon blood lead studies utilized 5 ug/dL and 3.53 ug/dL (the 95th percentile of the Flin Flon dataset), respectively as the benchmarks for individual follow-up based on an analysis of the recent scientific literature and policy direction in other jurisdictions. Additional details on recent literature and lead policy are provided in Appendix R.

Review of the Flin Flon datasets from 2009 and 2012 indicated the following:

- All metrics of blood lead are lower in 2012 as compared to 2009:
  - Statistically significant decreases were noted across all subgroups including age, gender and region;
  - Geometric means, upper percentile and maximum BLLs were lower; and,
  - The number of children with BLLs greater than 5 µg/dL decreased.
- Mean and upper percentile BLLs for all subgroups in the 2012 dataset were less than the normative levels established by CDC (5 µg/dL).
- Mean and upper percentile BLLs for all subgroups in the 2012 dataset are similar to those observed in other Canadian cities.
- Other than age of home, personal factors were not associated with children’s lead exposure levels in 2012. This included knowledge of previously implemented intervention strategies (the hand washing campaign). It should be noted that the awareness of the hand washing campaign was quite high among families. It is challenging to statistically relate BLLs to campaign awareness levels given the lack of variability among awareness levels.
- Environmental factors are poor indicators of BLLs; additional factors likely represent a greater influence on BLLs in children in the Flin Flon Area.
Consideration of the Flin Flon dataset and the available regulatory and scientific information regarding lead intervention levels and strategies leads to the conclusion that operational changes to the HBMS facility has resulted in a significant decrease in the levels of lead exposure for children in the Flin Flon Area. Current levels are within the normative range and are consistent with or lower than levels found in other communities in Canada. Additional intervention strategies are not warranted and not likely to further influence BLLs in the Flin Flon Area. However, ongoing measures to reduce exposure to lead throughout the community should continue.

8.2 Recommendations for Ongoing Risk Management

The results of the current study provide a positive indication of a reduction in BLLs in the Flin Flon Area following the closure of the smelter and the implementation of various risk management measures. While these results indicate that BLLs are within the normative range, ongoing efforts to reduce exposure to lead are recommended to maintain or further reduce community levels and to be protective of individuals that may have unique opportunities for exposure. The following measures are outlined in the risk management plan provided by HBMS to the governing regulatory agencies on an annual basis:

- Mitigation measures to reduce dust produced from tailings impoundments and vehicular traffic within the Metallurgical Complex will continue to improve ambient air quality. This includes the paving of in-plant roads, material handling upgrades, and re-vegetation of the area in and around the complex which will reduce the distribution of lead particulates to the community.

- Public outreach and education programs targeted at raising awareness of potential sources of lead and practical methods for reducing exposure also have a strong benefit to the community. The distribution of resources to encourage proper hand washing, particularly among young children, still continues to be a positive practice in exposure reduction.

- Additional measures to raise awareness on limiting exposure to lead in paint through proper renovation techniques and reducing exposure to lead in drinking water are also encouraged.
9.0 REFERENCES


