EXPOSURE STUDY

Evaluation of Environmental Contaminant Exposure in Children (under 15) in Flin Flon, Manitoba and Creighton, Saskatchewan

intrinsik
SCIENCE INTEGRITY KNOWLEDGE

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Prepared for: Hudson Bay Mining and Smelting Co., Limited

Part of the FLIN FLON SOILS STUDY. An assessment of Exposure and Human Health Risks in the Flin Flon Area

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GENERAL PUBLIC SUMMARY

Why conduct an evaluation of exposure for Flin Flon Area children?

The preliminary review of the HHRA indicated that it would be beneficial to collect additional information on actual exposure levels for Flin Flon Area children to some chemicals (COCs). This information would help with the interpretation and validation of some of the key HHRA findings. The specific additional information required was children's' actual exposure levels to ***inorganic mercury***, ***lead*** and ***arsenic***.

What is an evaluation of exposure study?

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., urine, blood, hair).

Why focus on children and not other age groups?

The study focused on children for four main reasons. As outlined in the HHRA, children are generally more sensitive to exposure to COCs than adults. As well, children eat more food, drink more water, and breathe more air relative to their size than adults, and therefore may be exposed to relatively higher amounts of COCs in the environment. Additionally, children's normal activities and behaviors such as putting their hands in their mouth or playing on the ground create additional opportunities for exposures to COCs that most adults do not encounter. Finally, COCs may affect children more because their immune defenses are not fully developed, and their growing organs may be harmed more easily.

What questions did the evaluation of exposure answer?

The evaluation of exposure study was designed to answer the following four questions:

1. *What is the current level of internal exposure to lead, arsenic, and inorganic mercury in the child population residing in the Flin Flon Area?*
2. *Do Flin Flon Area child residents have higher lead, arsenic, and/or inorganic mercury levels than residents living in other parts of Canada?*
3. *Based upon the current scientific literature, what are the health risks from the levels of lead in blood, and arsenic and inorganic mercury in urine found in children in the Flin Flon Area?*
4. *What personal factors are associated with the level of measured internal exposure of children in Flin Flon Area (e.g., place of residence, place of work, level of COC in soil, age, gender, diet, personal habits, etc.)?*

How was the study implemented?

A random selection of children under the age of 15 years was invited to participate in the study from Flin Flon, Creighton and Channing. The younger children (0 to 2½ years old) were asked to provide a small blood sample from a finger prick at a local clinic. Children between 2½ and 7 years old were asked to provide both a blood sample and a urine sample collected at their own home. Children between the ages of 7 and 14 were asked to provide just a urine sample. Overall, 447 children participated in the study providing 202 blood samples and 379 urine samples. Blood samples were analysed for lead, while urine samples were analysed for inorganic mercury, inorganic arsenic and total arsenic. Parents received their children's lab results, and were referred to their family physician for follow-up if required. Households with participating children also provided information on a survey of characteristics of the house, children's play activities, diet and adults' occupations.

What is the current level of internal exposure to lead, arsenic, and inorganic mercury in the child population residing in the Flin Flon Area?

Lead

Children in the Flin Flon Area overall had average[1] blood lead levels of 2.75 µg/dL. Boys were more likely to have higher blood lead levels than girls. Children who were 6 years of age had the highest average levels when compared with the other age groups. When blood lead levels were examined by region, children in West Flin Flon had the highest average levels. The lowest average levels of blood lead were observed for children from the Channing area. Approximately 13% of the samples were at or above the level chosen for referral for follow-up with a physician (5 µg/dL). Approximately 2% of the samples were at or above the Health Canada blood lead intervention level guideline of 10 µg/dL.

Inorganic arsenic

The average inorganic arsenic levels in urine measured in Flin Flon Area children was 6.35 µg/L. Approximately 18% of urine samples were found to be below the limit of detection for urinary inorganic arsenic. Three percent of the samples were at or above the level selected for referral to a physician for follow-up (20 µg/L). The average levels (geometric means) were similar when broken down by sex, age, and region of residence.

Inorganic mercury

The average inorganic mercury levels in urine measured in Flin Flon Area children was 0.11 µg/g. Approximately 50% of urine samples were found to be below the limit of detection for urinary inorganic mercury. There were no samples measured at the level that was established for referral for follow-up (10 µg/L). The averages were similar when compared across sex, age groups and region of residence.

Do Flin Flon Area child residents have higher lead, arsenic, and/or inorganic mercury levels than residents living in other parts of Canada?

Lead

The blood lead levels measured in Flin Flon Area children (2.75 µg/dL), and in particular West Flin Flon children who had the higher blood lead levels (3.63 µg/L), were compared with numerous other studies. It should be noted that there were challenges in making each

[1] The "average" was calculated using a geometric mean. This was the most appropriate measurement of "average" given how the blood lead levels were distributed across the sample.

comparison as there is not a "perfect" comparison for Flin Flon Area children. When the results from this study are compared to a large national level study in the US, the Flin Flon Area results are slightly higher (2.75 µg/dL overall and 3.63 µg/dL in West Flin Flon compared with 1.77 µg/dL). It should be noted when making these comparisons that the US study (1.77 µg/dL) includes children from communities quite different from the Flin Flon Area.

When comparing the results for Flin Flon Area children with studies that have measured blood lead levels in other communities where there are potential concerns with lead exposure, the results for the Flin Flon Area children are comparable (2.75 µg/dL overall and 3.63 µg/dL in West Flin Flon compared with 2.3 µg/dL – 5.3 µg/dL). Again, caution should be used in making interpretations from these comparisons given that the communities studied in some cases had different sources for potential exposure, and are likely different from the Flin Flon Area communities in potentially important ways (e.g., diet, activities, housing stock, soil levels).

Inorganic Arsenic
When compared with results from other studies, the Flin Flon Area levels of inorganic arsenic were similar to other recent studies. The levels of urinary total and inorganic arsenic measured in Flin Flon Area children were at the same levels found in other Canadian communities including both communities with potential soil exposure (e.g., Falconbridge, Wawa, Deloro) and comparison communities with no soil contamination (e.g., Hanmer, Havelock).

Inorganic Mercury
When compared with results from other studies, the Flin Flon Area levels of inorganic arsenic were below levels found in other recent studies. It should be recalled that 50% of the samples obtained were below the detection limit. The levels of urinary inorganic mercury levels were lower than levels found in similarly aged populations in other studies.

Based upon the current scientific literature, what are the health risks from the levels of lead in blood, and arsenic and inorganic mercury in urine found in children in the Flin Flon Area?

Lead
The interpretation of blood lead levels in the Flin Flon Area is recommended in light of the most current information regarding the health effects of lead on children. The US Centers for Disease Control and Prevention state that there is no known minimum threshold of harm for lead exposure and Health Canada's policy is to reduce exposure to lead wherever practical. Health Canada's 1994 guidance statement for a blood lead intervention level of 10 µg/dL is currently under review because of concern that adverse health effects may occur below 10 µg/dL. Certain other agencies (e.g. City of New York) advise action at 5 µg/dL for children or during pregnancy, and the literature indicates that adverse health effects may occur below 5 µg/dL.

Inorganic Arsenic
Urinary inorganic arsenic levels found in children in the Flin Flon Area were not high enough to be associated with health risks. Finding a measurable amount of arsenic in urine does not mean that the level of arsenic causes an adverse health effect. The results found in Flin Flon Area children were very similar to levels observed in children in other Canadian communities with limited exposure to arsenic in soil.

Inorganic Mercury
The large majority of samples collected from the Flin Flon Area children had no detectable levels of inorganic mercury. Overall, the geometric mean of urinary inorganic mercury levels in the Flin Flon Area was at a level with no associated health risks.

What personal factors are associated with the level of measured internal exposure of children in Flin Flon Area?

An attempt was made to find associations between the exposure levels measured and various personal factors or characteristics that theoretically could be related to exposure levels. It is quite important for the reader to note that these are measured *associations* and should not be thought of as one thing *causing* another. In some cases, there may be additional factors or characteristics that were not measured directly that may be contributing to the various associations.

Lead
The personal factors associated with the measured blood lead levels in Flin Flon Area children were a child's gender, their area of residence, whether or not adults in the house smoke or use tobacco, the time a child spends away from home, and the year their house was constructed. These factors are those that showed stronger associations with blood lead levels. These relationships tend to support logical relationships with lead exposure.

Inorganic Arsenic
The main factors associated with levels of inorganic arsenic included a child's age, whether or not they eat soil, it they had eaten outside within the 7 days of being tested, and their source of water for drinking and cooking. Given previously established relationships between activities and arsenic exposure, the associations found in the current study are similar in nature (e.g., active outdoors, water source).

Inorganic Mercury
The levels of inorganic mercury measured in Flin Flon Area children were lower compared to other communities, and were not associated with health risks. The factors associated with levels of inorganic mercury included the number of silver-colored fillings the child has in their teeth, whether or not they eat local game, and their area of residence.

OVERVIEW

The purpose of this document is to present the results of an evaluation of environmental contaminant exposure in children (under age 15) in Flin Flon, Manitoba and Creighton, Saskatchewan conducted in Fall 2009. This evaluation study is one component of a larger Human Health Risk Assessment (HHRA) being conducted for the area. As part of the HHRA, the evaluation of exposure study was commissioned by Hudson Bay Mining and Smelting Co. Ltd. (HBMS), and was overseen by the HHRA Technical Advisory Committee (TAC) and HHRA Community Advisory Committee (CAC). The TAC was engaged to provide technical guidance on this component of the HHRA. 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. For the evaluation of exposure, 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 evaluation of exposure study team was composed of four research firms working as a consortium (Intrinsik Environmental Sciences Inc., Goss Gilroy Inc., Habitat Health Impact Consulting Corp., and Environmental and Occupational Health Plus Inc.)

This document provides a technical description of the methods and the analyses undertaken for the study, as well as the detailed results. It is intended for a scientific audience. A plain language summary document suitable for a general audience will be prepared as one component of the summary report for the overall Human Health Risk Assessment (HHRA) conducted for Flin Flon and Creighton.

The main sections of this report are:

- Section 1.0 – Study rationale and objectives
- Section 2.0 – Overall study approach and methods
- Section 3.0 – Characteristics of sample
- Section 4.0 – Current levels of internal exposure
- Section 5.0 – Comparison of exposure levels
- Section 6.0 – Potential health risks associated with exposure levels
- Section 7.0 – Factors associated with exposure levels
- Section 8.0 – Study limitations
- Section 9.0 – Summary and conclusions

The appendices attached to this report are:

- Appendix A – Background on environmental contamination in the Flin Flon area
- Appendix B – Population sampling protocols
- Appendix C – Survey Instrument
- Appendix D – Blood collection protocol
- Appendix E – Biological sample shipping and storage protocol
- Appendix F – Urine collection protocol
- Appendix G – Laboratory analysis protocol
- Appendix H – Process for notification of results
- Appendix I – Arsenic Fact Sheet
- Appendix J – Lead Fact Sheet

1.0 STUDY RATIONALE AND OBJECTIVES

1.1 What is an evaluation of exposure?

An evaluation of exposure is a study that examines the levels of internal exposure to selected chemicals that a person or group of people encounters. These types of studies are sometimes described as biomonitoring studies, referring to the focus on quantifying and determining exposures and effects in humans through the use of biomarkers (Boogaard and Money, 2008). Biomarkers for measuring exposure are generally measurements of chemicals or chemical components that are found in people's fluids or tissues. For example, biomarkers of exposure could include the level of lead in a sample of a child's blood, or the level of arsenic and its metabolites in a sample of a person's urine.

These types of evaluations of exposure through biomonitoring have advantages to environmental monitoring (such as measuring chemicals in soil, air and water) as they provide information on the actual exposures experienced by people and account for exposures from all potential sources, pathways and routes that a person encounters (Health Risk Assessment Guidance for Metals, 2007). This is advantageous when the total exposures to a given substance or chemical are of interest, but can be a disadvantage if the intent is to attribute measured exposure to a particular source, pathway or route.

While evaluations of exposure can be used to identify if exposure has occurred (or is occurring), these types of studies on their own cannot indicate whether measured exposure levels in people suggest human health risk (United States Environmental Protection Agency, 2008). It should also be noted that for chronic exposure to some substances, biomonitoring cannot provide an accurate prediction of cumulative health risk (e.g., chronic inhalation exposure associated with carcinogenic risk). By combining the findings from evaluations of exposure with environmental data and HHRA findings, the multiple lines of evidence will assist in determining both exposures and potential health risks.

1.2 Rationale: Why conduct this evaluation of exposure?

Recently, an extensive HHRA was completed for the communities of Flin Flon, Manitoba and Creighton, Saskatchewan, which underwent an external independent review. An HHRA is a scientific study that evaluates the potential for the occurrence of adverse health effects from exposures of people (receptors) to chemicals of concern (COCs) present in surrounding environmental media (e.g., air, soil, sediment, surface water, groundwater, food and biota, etc.), under existing or predicted exposure conditions. In this case, the HHRA was conducted to address the potential human health risks associated with exposure to smelter-related metals in soils and other environmental media in the Flin Flon and Creighton area[2]. Based on the preliminary findings from the HHRA, the HHRA study team recommended that an evaluation of environmental contaminant exposures be undertaken for child residents of these communities to further assist in validating some of the specific findings from the HHRA.

[2] For additional information and background on the HHRA and the two communities of Flin Flon and Creighton, please refer to Appendix A.

The rationale for evaluating environmental contaminant exposure among Flin Flon area child residents was that an assessment of biomarkers of exposure would help refine and validate the HHRA's exposure estimates of COCs associated with elevated levels of risk. More specifically:

- ***Inorganic Mercury***: A more accurate assessment of inorganic mercury exposure for children in West Flin Flon given the potential elevated risk for health impacts among young children would be beneficial;
- ***Lead***: Assessment of actual blood lead levels present in young children would assist in reducing the uncertainty with the lead exposure assessment, given soil lead level concentrations,; and,
- ***Arsenic***: An accurate assessment of urinary arsenic levels would validate the conservative nature of the HHRA results, and further contribute to the weight-of-evidence evaluation of potential risks for children.

Additional information and background on the environmental contamination issues for the Flin Flon Area[3] can be found in Appendix A.

1.3 Objectives: What questions did the study answer?

The study team developed four overall research questions (presented below) that formed the main focus of the present study, based on the rationale for the study and the advantages and limitations of an evaluation of exposure. The study focused on children for several reasons. As outlined in the HHRA, children are generally more sensitive to exposure of environmental contaminants than adults. Children eat more food, drink more water, and breathe more air relative to their size than adults, and therefore may be exposed to relatively higher amounts of contaminants in these media. Children's normal activities and behaviors, such as putting their hands in their mouth or playing on the ground, create additional opportunities for exposure to environmental contaminants that most adults do not encounter. Finally, environmental contaminants may affect children disproportionately because their immune defenses are not fully developed and their growing organs may be harmed more easily.

In addition to the special vulnerabilities of children to environmental contaminants, another rationale for focusing on children was that this age grouping aligned with the age groupings used in the HHRA, which facilitates refining and validating the HHRA findings for children. Consistent age groupings facilitated the comparison of HHRA predicted environmental exposures for this population to lead, arsenic, and mercury, to internal exposure measured by biomonitoring and excluding occupational exposures. In addition, these age groupings were similar to those used in other biomonitoring studies, ensuring that some comparisons could be made between these and other communities.

The following four questions were used to guide the development of the overall approach, and the specific methods implemented.

1. *What is the current level of internal exposure to lead, arsenic, and inorganic mercury in the child population residing in the Flin Flon Area?*
2. *Do Flin Flon Area child residents have higher lead, arsenic, and/or inorganic mercury levels than residents living in other parts of Canada?*

[3] Throughout this report we use the term "Flin Flon Area" to refer to Flin Flon, Manitoba, Flin Flon, Saskatchewan Channing, Manitoba, and Creighton, Saskatchewan.

3. *Based upon the current scientific literature, what are the health risks from the levels of lead in blood, and arsenic and inorganic mercury in urine found in children in the Flin Flon Area?*
4. *What personal factors are associated with the level of measured internal exposure of children in Flin Flon Area (e.g., place of residence, place of work, level of COC in soil, age, gender, diet, personal habits, etc.)?*

2.0 OVERALL STUDY APPROACH AND METHODS

2.1 Overall approach

This cross-sectional study consisted of two components: the analysis of biological samples (blood and urine) from children and youth under 15 years of age, and information about participants' daily habits from household surveys. The overall study was conducted in four phases, as illustrated in Figure 2.1. Throughout each phase, emphasis was placed on community consultations and communications.

Figure 2-1: Overall approach for study

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
Peer Review

Timeline: April to July 2009

PHASE TWO:
Sample Collection and Survey Implementation

Develop Sampling Frame and Sample Participants
Recruit Participants
Household Interview
Provide Urine Sampling Kits and Collect Sample
Collect Blood Sample
Community Updates

Timeline: August to October 2009

PHASE THREE:
Laboratory and Survey Analyses

Urine analyses for inorganic mercury, total arsenic, speciated aresenic and creatinine
Blood analyses for lead
Analyses of survey data
Comparative analyses with other studies

Timeline: November to February 2010

PHASE FOUR:
Summary Reporting and Reporting Individual Results

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

Timeline: December 2009 to June 2010

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 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 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.

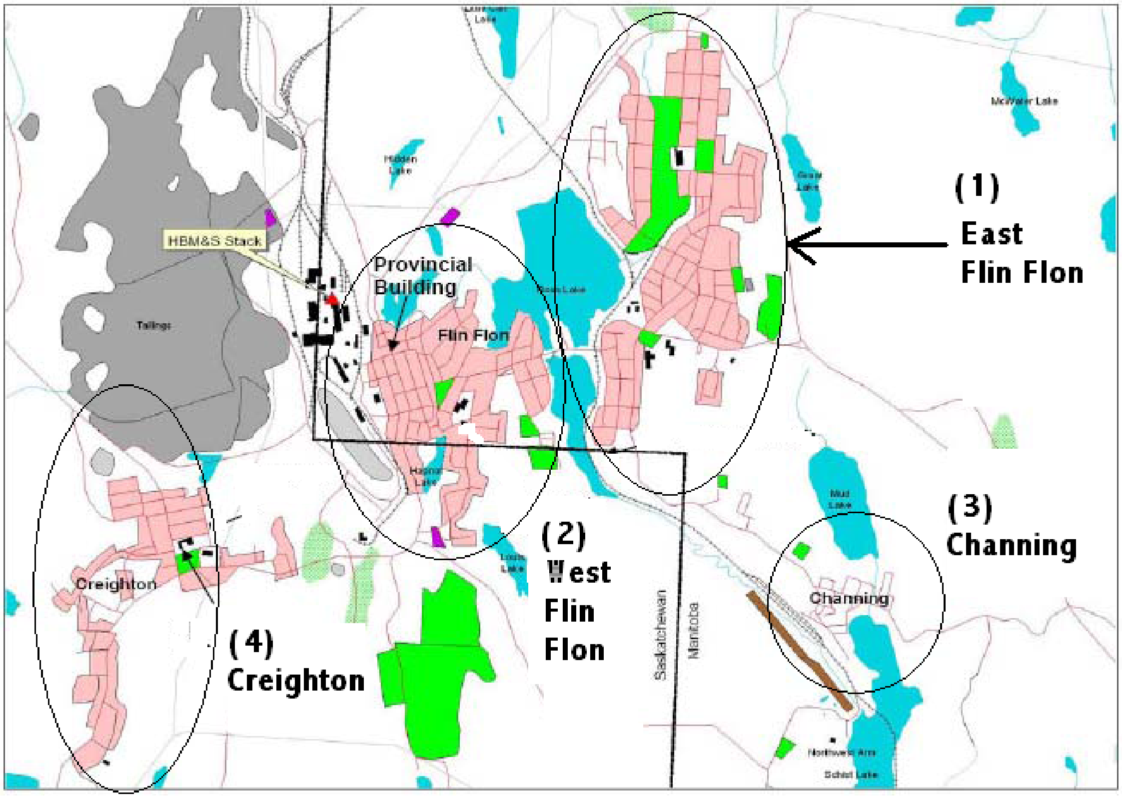


Table 2-1 summarises the average soil concentration of COCs found in the soil for these four sub-communities in the HHRA. The results indicate that the highest levels of lead and mercury were observed in West Flin Flon, while higher levels of arsenic were found in West Flin Flon and Creighton. East Flin Flon and Channing have relatively lower soil concentration of the COCs.

Table 2-1: Soil concentrations of Chemicals of Concern in East and West Flin Flon, Creighton and Channing

Chemical of Concern	East Flin Flon	West Flin Flon	Creighton	Channing
Arsenic	16.0	67.0	64.0	17.0
Lead	141	332.0	164.0	112.0
Mercury	6.0	106.0	6.0	2.8

The selection of **age groups** was influenced by the need to focus on those age groups for which the HHRA needed additional data for validation purposes.

In general, the HHRA considered five age groups for evaluation, as defined by Health Canada:

1. Infant (0 to 6 months);
2. Preschool child or toddler (7 months to 4 years);
3. Child (5 years to 11 years);
4. Adolescent or teen (12 to 19 years); and,
5. Adult (20 years and over).

In addition to the consideration of individual age groups, for chemicals considered to be carcinogenic, it is common to assess exposure over a lifetime. For the evaluation of lead, children between the ages of 0 and 7 years were considered on a year by year basis.

The following age groups were established for the analysis of biological samples:

- 0-83 months (0-7 years) for lead, and
- 2.5 years to under 15 years old (30 to 179 months) for arsenic and mercury.

As such, the age groups within the exposure study correspond well with the children's age groups considered in the HHRA. Consistent age groupings facilitated comparison of HHRA predicted environmental exposures for the population to lead, arsenic, and mercury with internal exposures measured by biomonitoring. By focusing on children under 15, the biomonitoring results would also exclude any potential occupational exposures which might occur with an older cohort. As well, these age groups were similar to other recent studies, and hence facilitated external comparisons.

As illustrated in Table 2-2, data from the most recent Census (2006) indicates that approximately 1,040 children under the age of 15 reside in Flin Flon and another 315 children in Creighton.

Table 2-2: Age and sex distribution of residents of Flin Flon and Creighton aged 14 and under (Census 2006)

Age Groups (Years)	Flin Flon (Part) - City (Census subdivision)			Creighton - Town (Census subdivision)		
	Total	Male	Female	Total	Male	Female
0 to 4	305	165	140	90	55	35
5 to 9	325	165	160	110	55	55
10 to 14	410	205	210	115	55	60
Total	**1,040**	**535**	**510**	**315**	**165**	**150**

Planned sample sizes

The study design took into account the sample sizes required to estimate the geometric mean levels of COCs (lead in blood, inorganic mercury in urine, total and inorganic arsenic in urine) to a precision level of approximately 2% or less (with 95% confidence) for the overall population[4]. The actual precision estimates and sample sizes for each COC are provided in Appendix B. The planned sample sizes for each stratum of geographic area and age are summarized in Table 2-3. The sampling plan called for a total of 400 children to participate in the study, with 100 children under 30 months providing only a blood sample, 150 children between 30 months and 83 months of age providing both blood and urine samples, and 150 children between 84 and 179 months of age providing only urine samples. The sampling plan also indicated that the sample be stratified according to geographical area with 200 children living in West Flin Flon

[4] The precision estimates would be larger for subgroups when the population is divided by gender, age or region.

(the area with the highest concentrations of soil contamination), 100 children from East Flin Flon, and 100 children from the communities of Channing and Creighton[5].

Table 2-3: Planned sample of children by age group and area

	Under 30 months	30 to 83 months	84 to 179 months	
Area	**Blood Only**	**Blood and Urine**	**Urine Only**	**Total**
West Flin Flon	50	100	50	**200**
East Flin Flon	25	25	50	**100**
Creighton and Channing	25	25	50	**100**
Total	**100**	**150**	**150**	**400**

Sampling frame 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 3,237 households in Flin Flon and Creighton. The tax rolls provided complete information with 3,439 residential addresses identified in total. The primary sampling unit used was the household. 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.

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 collection of blood and urine 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 2-4 contrasts the sample planned with the sample achieved by geographic area. Overall, a total of 447 children provided 202 blood samples (81% of planned samples) and 379[6] urine samples (126% of planned samples). Compared to the original sampling plan, oversampling occurred in East Flin Flon, Creighton and Channing for both blood and urine samples, while under-sampling occurred in 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[7].

[5] It should be noted that for determining sample sizes, Creighton and Channing were combined given the small size of Channing. Given their distinct nature, however, analyses were conducted separately for the four geographic areas.

[6] Four samples were collected from participants outside of the targeted age range of 30 to 179 months. These were not included in the overall study analyses.

[7] The estimates available for population of children were from the 2006 Census which groups all of Flin Flon together in one community.

Table 2-4: Planned and achieved sample of children by age group and area

Area	Blood Planned	Blood Achieved	Urine Planned	Urine Achieved
West Flin Flon	150	43	150	86
East Flin Flon	50	84	75	156
Creighton and Channing	50	75	75	137
Total	**250**	**202**	**300**	**379**

As illustrated in Table 2-5, the overall household response level was 61%. Of those households who agreed to participate, the participation rate for eligible children was 94%.

Table 2-5: Response rate

Level	Criteria	Count
Household Level	1: # households in FF and Creighton (census)	2945
	2: # invitation letters delivered	2354
	3: # contacts made	1653
	4: # eligible households (children <15 years)	409
	5: # households participated	251
Individual Level	6: # eligible children (from 5, above)	477
	7: # children participated in survey	477
	8: # children providing at least one bio sample	447
	9: # of blood samples collected	202
	10: # urine samples collected	379
	Response Level (Household)	61%
	Response Level (Individual)	94%

2.3 Household survey methods

An in-home interview lasting approximately 60 minutes was completed with all participating households. The interview covered potential exposure pathways such as diet, occupation, and outdoor activities (see Appendix C for the survey instrument). Interviews were conducted with the adult member(s) (i.e., parent or guardian) of the household who were most familiar with the child(ren)'s daily activity patterns. The interview was conducted by trained interviewers in the participant's home, unless an alternative location was preferred. The interview followed a structured format outlined in the questionnaire appended.

Obtaining informed consent

Prior to the start of each interview, the interviewer undertook an informed consent process with the interviewee to ensure that the parent/guardian understood the voluntary nature of all components of the study, that they were aware of the participation requirements, any potential risks involved, and that they had an opportunity to ask questions and be provided with additional information, as requested. As well, the parent/guardian were provided with documentation outlining the goals and purpose of the study, and contact information if they had additional questions or required further information. All participants received a full copy of the consent form they signed for their records. Child participants who were able to read and understand the basic concepts of the study were asked to meet with the interviewer in the presence of their parent/guardian and listen to a brief description of the study, and sign an age-appropriate assent form.

Nominal anonymity of participants was maintained to the extent that the research team did not divulge to any individual or organization whether a specific resident had or had not participated in the study. Complete anonymity could not be guaranteed, as the study team was working in a small community where the required house visits could have been noticed by other residents. Individuals have not been identified in any publication or report resulting from this study.

2.4 Biological sample collection methods

Blood samples

The study team adhered to established protocols in the collection of whole capillary blood samples, for the purpose of assessing the level of lead of child participants in the Flin Flon Area. Blood samples were collected within a clinic setting. Capillary blood was collected via the finger or heel of the participant, depending on age. For infants of less than one year, the lateral or medial plantar surface of the heel was punctured; whereas, for children over one year the palmar surface of the distal segment of the middle or ring finger was punctured. The skin was punctured using a lancet, and the 0.5ml blood sample was collected in a plastic microtainer. Upon collection of the blood sample, the tube was inverted 8 to 10 times in order to properly dissolve the spray-dried anticoagulant to prevent hemolysis. (For complete collection protocol, see Appendix D; for storage and shipping protocols, including integrated quality assurance procedures, see Appendix E).

Urine samples

The study team adhered to established protocols in the collection of urine samples, for the purpose of assessing the levels of total and inorganic arsenic and inorganic mercury among child residents in the Flin Flon and Creighton Area. Urine samples were collected within the participant's home environment, under the supervision of their parent/guardian. The parent/guardian was provided with a sampling kit and provided instructions by the study team member. A minimum of 10ml of urine was collected from participants. Urine was collected via two methods, depending on the age and sex of the participant. For older male children, urine was collected in the morning directly via a 125 ml Nalgene bottle. For younger children and females, a toilet insert was used to collect the urine sample in the morning. Samples collected using a toilet insert were immediately transferred into the Nalgene bottle. Once the urine sample had been collected, the bottles were placed within a cooler bag with an ice pack for pick up by the study team. (For complete protocol, see Appendix F; for storage and shipping protocols, including integrated quality assurance procedures, see Appendix E).

2.5 Biological sample analytic methods

The *Laboratoire de Toxicologie / Institut national de santé publique du Québec (INSPQ)* undertook all biomarker analyses. Each urine sample was analysed for total arsenic, inorganic[8] arsenic, inorganic mercury, and creatinine. Each blood sample was analysed for lead. The analytic methods employed for each of the analyses are reported in Table 2-6 below. More detailed information on biomarker analysis protocols, including quality assurance measures, can be found in Appendix G.

[8] In this document the term 'inorganic arsenic' refers to the species found in urine as a result of inorganic arsenic exposure, calculated as the sum of As+3, As+5, MAA and DMAA in urine.

Table 2-6: Overview of biomarker analyses

Biomarker	Analytic method	Detection limit	Reproducibility
Urinary Total and Inorganic Arsenic	ICP-MS	0.05 µmol/L	~ 5% (0.5 nmol/L)
Urinary Inorganic Mercury	Cold Vapour Atomic Absorption Spectrophotometry	0.5 nmol/L	5% (12 nmol/L)
Blood lead	ICP-MS	0.001 µmol/L	~ 3% (0.3 µmol/L)

2.6 Statistical analyses

A variety of statistical analytic procedures were used to address the research questions. The predominant analyses included:

- Descriptive analyses (geometric means, geometric standard deviations, medians, and frequency distributions were used to summarize data; box plots were used to compare the levels of COC's to the responses to survey questions; histograms and normal probability plots to determine goodness of fit to a normal distribution; and, scatter grams were used to examine the association between two continuous variables);
- Log transformations to improve the fit of the data to a normal distribution were implemented. Data for blood lead levels and total arsenic were transformed using $\log_{10}$, while data for inorganic arsenic and inorganic mercury were transformed using $\log_n$. For ease of interpretation, inverse log transformations were performed for all estimates presented in the multivariate regression models.;
- Univariate analyses (the relating of one variable to one outcome);
- Interval regression analysis to include levels of COC's that are below the limit of detection; and,
- Multivariate analyses (e.g., multiple linear robust regression[9]) to relate multiple variables to one outcome.

The assumptions and decisions that were used throughout the analytic process, included:

- *Choice of statistical significance level:* To test a hypothesis, the statistical significance level of 0.95 (95%) probability was used. For some preliminary selection of variables for inclusion in regression models, a more liberal statistical significance level of 0.85 (85%) probability was used to ensure all potential predictor variables were included in the models.
- *Treatment of outliers:* Outliers are data points that are further from the mean value than would be expected by chance variation. An outlier may reflect a data value that is not valid or an individual whose exposure level is out of the normal range for the population. Generally, outliers are further than 2 standard deviations from the mean as 2 standard deviations corresponds to the 5% probability level that is commonly used to separate the usual amount of random variation from non-random variations. The multivariate analytic methods selected for regression (i.e., *ROBUSTREG* procedures) limit the influence of outliers in the analyses presented in this report for lead and total arsenic, where all observed levels were above the limit of detection. For the regression analyses involving the measures of inorganic arsenic and inorganic mercury for which there were a substantial number of samples below the detection limit, a sensitivity analysis was performed to determine the impact of inclusion/exclusion of those cases with residuals equal to or greater than 2.

[9] Chen, C. Robust Regression and Outlier Detection with ROBUSTREG Procedure, Statistical and Data Analysis. SUGI 27-Paper 265-27

- *Data transformation:* Environmental and biological data often fit better to a normal distribution when their values are transformed to the logarithmic scale. As demonstrated in the results, this pattern was evident in the data for all three COCs for this study. As a result, the log transformed values were used in the analyses, where appropriate.
- *Treatment of missing and censored data:* For models involving levels below the limit of detection, standardized residuals for levels above the limit of detection were examined. The standardized residuals are the difference between the observed and predicted values divided by the standard deviation of the difference. For example, to address the 50% of the inorganic mercury levels that were below the limit of detection, an interval regression model was used to analyze the association between mercury levels and other factors such as age and place of residence. The analytic procedure employed (STATA v.11 *INTREG*) uses maximum likelihood methods that account for levels that are below the limit of detection. With respect to missing data, when survey respondents were unable to answer survey questions, their response to a survey question was coded as "*unknown/don't know*" and grouped with other respondents who could not answer the same question.
- *Approach to modeling:* Modelling for predictors of internal exposure began by selecting survey responses that, based upon current knowledge, could potentially be associated with the level of exposure to a given COC (e.g., blood lead level). The association between the selected survey response and the level of the COC was examined graphically through box plots or scatter grams and tested for statistical significance. Survey questions that were found to have p-values below 0.15 in the univariate analyses were considered for inclusions in a multivariate regression model. A regression of variables in the multivariate model that were found to be statistically significantly (i.e. p-values p=<0.05) related to the COC were deemed to be predictors of internal exposure to a given COC.
- *Statistical software packages used:* STATA v.11 and SAS v 9.1 were used to analyze the data.

2.7 Follow-up and referrals

Once the laboratory analyses had been completed, the study team provided notification of individual results to the parents/guardians of the participants. All results that did not require a follow-up were provided through written notification by mail, along with general information on exposure and interpretation of results. For those results that required additional follow-up, a call was placed to the household by the team physician to go through the results and recommended follow-up procedures with an identified local physician. These discussions included general exposure reduction steps. This was followed by a notification letter in the mail outlining the results and recommendations for follow-up as discussed in the phone call. The letter also included public health fact sheets regarding exposure reduction (Appendix I and J). The notification letters were also provided to the identified local physician (assuming consent was provided by the parent/guardian) (see Appendix H for description of results notification process and notification letter templates).

2.8 Creatinine adjustments

Measuring the amount of arsenic and mercury in urine samples is a generally accepted method for the evaluation of exposure to environmental contaminants, and is commonly used in assessment of populations (Pearson MA, 2009). Given that urinary concentrations can vary depending on timing of collection, collecting spot urine samples to assess contaminant levels requires consideration of potential fluctuations in concentration. By adjusting for creatinine concentration in urine, this adjustment allows for more a more accurate reflection of urine levels, and a closer alignment with blood levels.

The kidney filters mercury and arsenic from blood at a relatively constant rate, while the volume of urinary output varies during the day according to the intake of water. Hence, the ratios of mercury and arsenic in urine to the volume of urine need to be adjusted so that they reflect the concentration of the contaminants in the system, and are more reflective of the levels found in blood. Creatinine is a byproduct of muscle metabolism and is also filtered from the kidney at a constant rate during the day. Hence, mercury and arsenic concentrations in urine samples are commonly expressed in relation to the creatinine level in the urine sample. The ratio of mercury or arsenic per gram creatinine in urine and blood are assumed to be the same and not affected by other factors.

One recent study (Barr, 2005) evaluated the effect of age, gender, time of day and season on creatinine concentrations in urine and the specific gravity of urine samples collected in the morning's first void. While age, gender, time of day and season were associated with creatinine levels, only time of day was associated with specific gravity. For the present exposure study, inorganic mercury, total arsenic, and inorganic arsenic levels were divided by the creatinine level and used as the dependent variable.[10]

Population studies commonly report arsenic and inorganic mercury levels in urine either unadjusted (i.e., grams of contaminant per litre of urine) or creatinine adjusted (i.e., grams of contaminant per gram creatinine). In order to be able to compare the results of this study with others, the study team has opted to report arsenic and inorganic mercury levels in both adjusted and unadjusted.

[10] It is noted that some authors have recommended (Gamble MV, Liu X 2005, Barr DB et al, 2005) that specific gravity or creatinine levels in urine be included in the regression modeling of environmental contaminants in urine to better understand the uptake of contaminants from the environment. In this approach the creatinine level would be used as an independent variable in the regression model and the regression calculation would determine the correction factor.

3.0 CHARACTERISTICS OF SAMPLE

As illustrated in Table 3-1, overall there was a slightly larger proportion of males (n=237; 53%) in the obtained sample as compared with females (n=210; 47%). For the overall sample, the median age was the same (7.00 years) for both males and females, and the mean ages were very close (M=6.74 for females; M=6.79 for males). Mean and median ages were relatively similar when examined by gender within geographic region.

Table 3-1: Mean and median age by region and gender

Region	Gender	N	Mean Age (Years)	Std Dev	Median
All Regions	**Female**	**210**	**6.74**	**3.87**	**7.00**
	Male	**237**	**6.79**	**3.90**	**7.00**
East Flin Flon	Female	85	6.66	3.99	7.00
	Male	97	6.67	3.88	6.00
West Flin Flon	Female	46	6.80	3.94	7.00
	Male	60	6.68	3.76	6.50
Channing	Female	12	6.25	3.52	5.50
	Male	15	7.07	4.18	8.00
Creighton	Female	67	6.88	3.82	6.00
	Male	65	7.02	4.06	7.00

The actual distribution of ages by region and gender were also relatively similar, as illustrated in Table 3-2. Approximately one quarter of the sample (24%) was three years of age or younger.

Table 3-2: Age distribution by region and gender

Age at Interview (Years)	East Flin Flon			West Flin Flon			Channing			Creighton			Total
	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	
1 to 4	31	34	65	15	18	33	6	5	11	23	22	45	**154**
5 to 12	41	47	88	24	36	60	5	7	12	35	33	68	**228**
12 to 14	13	16	29	7	6	13	1	3	4	9	10	19	**65**
Total	**85**	**97**	**182**	**46**	**60**	**106**	**12**	**15**	**27**	**67**	**65**	**132**	**447**

4.0 CURRENT LEVELS OF INTERNAL EXPOSURE

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

> *What is the current level of internal exposure to lead, arsenic, and inorganic mercury in the child population residing in the Flin Flon Area?*

The results for each of the COCs along with additional analyses stratified by geographic region, age and gender are presented in the subsections below. The findings from the analyses conducted on possible relationships between internal exposure levels and specific environmental and personal characteristics are presented in Section 7.0.

4.1 Lead exposure

Samples below the detectable limit
None of the blood samples was found to be below the limit of detection for blood lead (0.02 µg/dL).

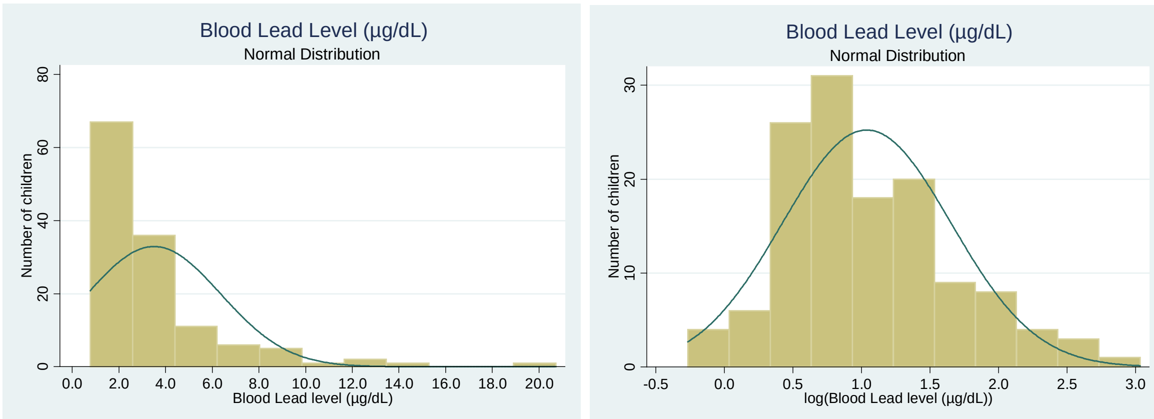
Samples referred for follow-up
Approximately 13% of the samples (n= 27) were at or above the level chosen a priori for referral for follow-up (5 µg/dL). Approximately 2% of the samples (n=5) were at or above the Health Canada blood lead intervention level guideline of 10 µg/dL.

Table 4-1: Distribution of follow-up blood lead levels

	All Samples	10 µg/dL or greater		5 µg/dL or greater	
	N	**N**	**%**	**N**	**%**
Overall	**202**	**5**	**2.5%**	**27**	**13.4%**
Gender					
Male	109	5	4.6%	23	21.1%
Female	93	0	0.0%	4	4.3%
Region of Residence					
East Flin Flon	84	3	3.6%	5	6.0%
West Flin Flon	43	0	0.0%	12	27.9%
Channing	12	0	0.0%	0	0.0%
Creighton	63	2	3.2%	10	15.9%

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

Figure 4-1: Distribution of blood lead levels



As illustrated in Table 4-2, the geometric mean blood lead level measured in Flin Flon Area children was 2.75 µg/dL (95% CI: 2.51 – 2.95). The median was measured as 2.49 µg/dL. When stratified by gender, boys were more likely to have higher blood lead levels (3.09 µg/dL) than girls (2.34 µg/dL). Children who were 6 years of age (4.07 µg/dL) had the highest geometric means compared with the other age groups. When blood lead levels were examined by region, children in West Flin Flon (3.63 µg/dL) had the highest geometric mean levels. The lowest geometric mean levels of blood lead were observed for children from the Channing area (2.00 µg/dL).

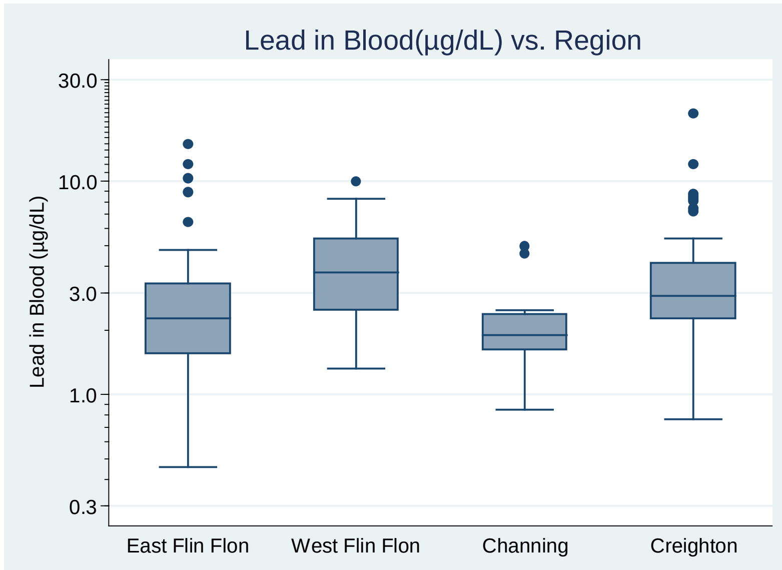
Table 4-2: Blood lead levels (µg/dL) by age, sex, and region of residence

Characteristics	N	Median	Min	Max	Geometric			
					Mean	LCL	UCL	STD
All	202	2.49	0.46	20.72	2.75	2.51	2.95	1.86
Sex								
Females	93	2.28	*	*	2.34	2.14	2.57	1.62
Males	109	3.11	*	*	3.09	2.75	3.55	1.95
Age (at interview)								
1 year	48	2.38	*	*	2.34	1.91	2.82	1.95
2	33	3.52	*	*	3.09	2.63	3.55	1.51
3	23	2.28	*	*	2.24	1.82	2.82	1.66
4	43	2.28	*	*	2.51	2.09	3.02	1.86
5	28	2.49	*	*	2.88	2.34	3.55	1.74
6 years	27	3.73	*	*	4.07	3.09	5.25	2.00
Region of residence								
East Flin Flon	84	2.28	0.46	14.92	2.29	2.00	2.63	1.82
West Flin Flon	43	3.73	1.33	9.95	3.63	3.09	4.27	1.66
Channing	12	1.90	0.85	4.97	2.00	1.45	2.75	1.66
Creighton	63	2.90	0.77	20.72	3.02	2.57	3.55	1.86

Notes: N-number of blood samples (individuals); Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD-Geometric Standard Deviation; * value censored to protect anonymity of participants

The boxplots contained in Figures 4-2, 4-3, 4-4, and 4-5 illustrate the distribution of blood lead levels according to region of residence, sex and age, respectively. The actual associations between age, sex, place of residence, and blood lead levels are further explored in detail in Section 7.0.

Figure 4-2: Blood lead levels by geographic region[11]



[11] **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 4-3: Blood lead levels by sex

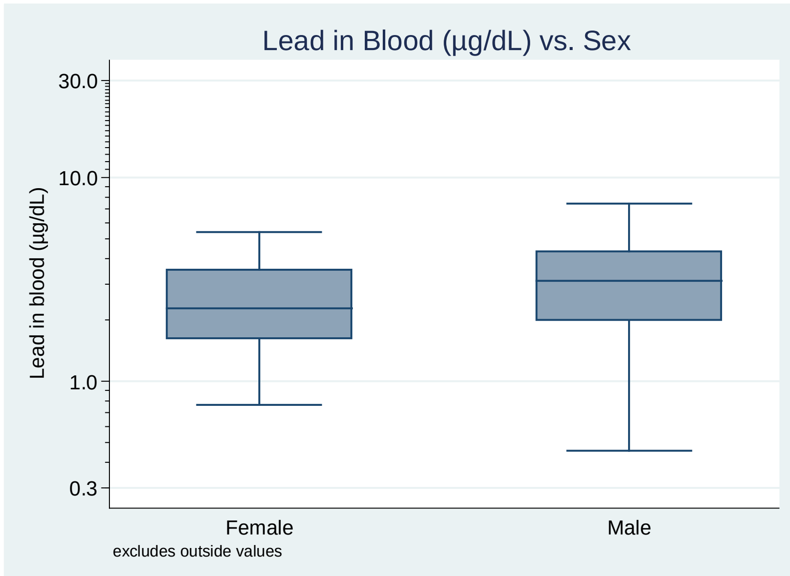


Figure 4-4: Blood lead levels by age

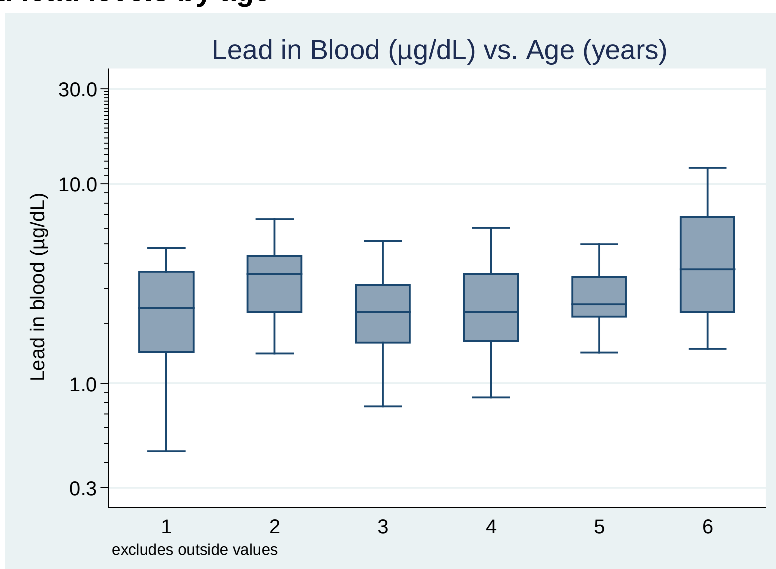
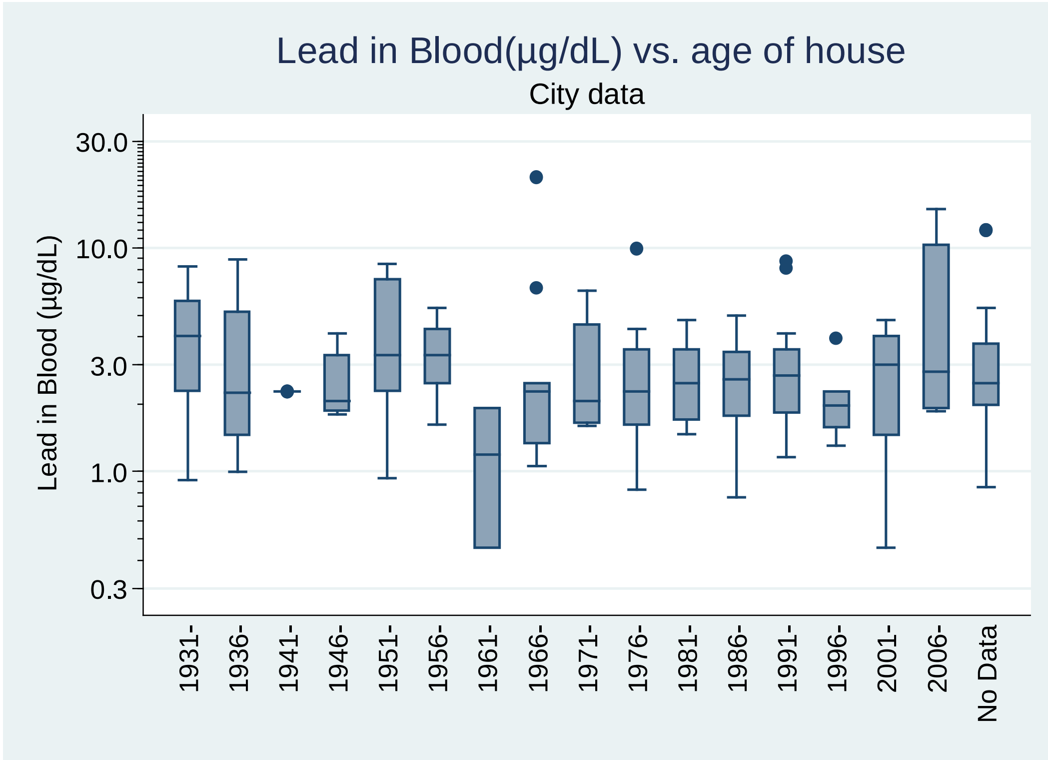


Figure 4-5: Blood lead levels by age of housing stock



4.2 Arsenic exposure

Internal exposure to arsenic was measured in first morning void spot urine samples from children between the ages of 2.5 years to under 15 years old (30 to 179 months). There are two main types of arsenic found in the body- organic and inorganic forms arsenic. Organic arsenic is predominantly obtained by people through the diet (e.g., seafood, shellfish) and not specific to local environmental exposures. Inorganic arsenic is more often obtained from exposure in the environment (e.g., soil, air, water). Health impacts have been primarily associated with exposure to inorganic arsenic. As a result, urinary arsenic studies focus primarily on measuring inorganic arsenic in residents' urine. Measures of total arsenic and inorganic can help to determine the portion of urinary arsenic that is organic and not related to local environmental factors.

Total and inorganic arsenic were quantified, along with creatinine levels. In total, four sets of urinary arsenic levels were analysed:

- total arsenic unadjusted (µg/L);
- total arsenic creatinine adjusted (µg/g);
- inorganic arsenic unadjusted (µg/L); and
- inorganic arsenic creatinine adjusted (µg/g).

4.2.1 Total Arsenic Exposure

Samples below the detectable limit
None of the urine samples were found to be below the limit of detection for urinary total arsenic (3.745 µg/L).

Samples referred for follow-up
None of the samples were at or above the level chosen a priori for referral for follow-up (100 µg/L).

Distribution of levels
As illustrated in Figure 4-6, the distribution of unadjusted urinary total arsenic levels follows a lognormal distribution. Similarly, as illustrated in Figure 4-7 when adjusted for creatinine, the urinary total arsenic levels are distributed in a lognormal fashion.

Figure 4-6: Distribution of unadjusted urinary total arsenic levels

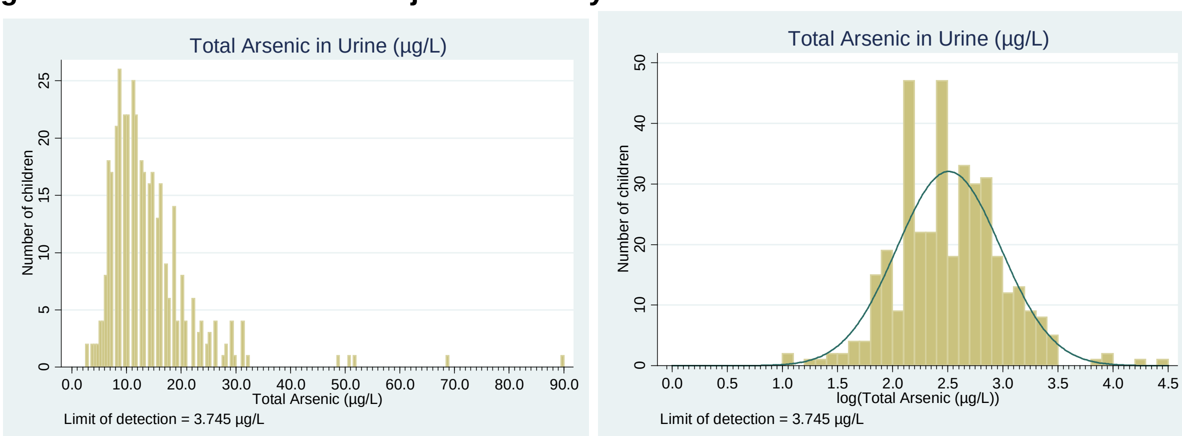
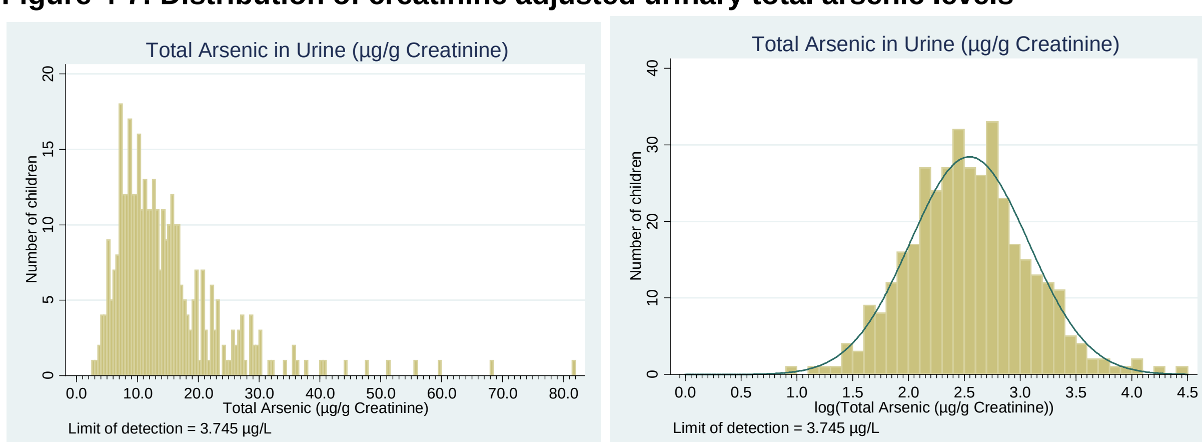


Figure 4-7: Distribution of creatinine adjusted urinary total arsenic levels



As illustrated in Table 4-3, the geometric mean for unadjusted urinary total arsenic level measured in Flin Flon Area children was 12.30 µg/L (95% CI: 11.75 – 12.88 µg/L). The median was measured as 11.98 µg/L. When broken down by gender, the geometric mean was comparable for boys (12.59 µg/L) and girls (12.02 µg/L). Similarly, geometric means according to age groups were quite similar, ranging from 11.48 µg/L for children under 5 years of age to 13.80 µg/L for children 5 to 8 years old. Similar results were also obtained for each geographic area with geometric means ranging from 11.22 µg/L in East Flin Flon to 14.45 µg/L in West Flin Flon. As illustrated in Table 4-4, the creatinine adjusted values demonstrated similar patterns.

Table 4-3: Unadjusted urinary total arsenic levels (µg/L) by age, sex, and region of residence

Characteristics	N	Median	Min	Max	Geometric			
					Mean	LCL	UCL	STD
All	375	11.98	3.00	89.88	12.30	11.75	12.88	1.58
Sex								
Females	179	11.98	*	*	12.02	11.22	13.18	1.62
Males	196	12.73	*	*	12.59	11.75	13.49	1.58
Age Groups*								
< 5 years	82	11.98	*	*	11.48	10.23	12.59	1.58
5-8 years	129	12.73	*	*	13.80	12.59	14.79	1.58
9+ years	164	11.24	*	*	11.75	10.96	12.88	1.58
Region of residence								
East Flin Flon	155	11.24	3.00	29.21	11.22	10.47	12.02	1.51
West Flin Flon	85	13.48	6.07	89.88	14.45	12.59	16.22	1.74
Channing	22	13.86	6.14	26.22	13.18	10.96	15.49	1.48
Creighton	113	12.73	3.82	68.91	12.30	11.48	13.49	1.58

Notes: N-number of urine samples (individuals); Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD- Geometric Standard Deviation * value censored to protect anonymity of participants

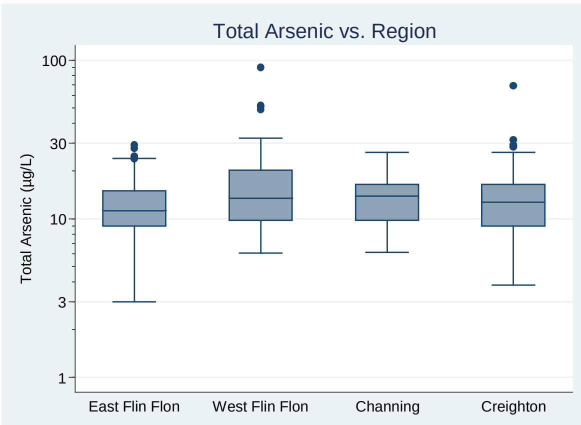
Table 4-4: Creatinine adjusted urinary total arsenic (µg/g) by age, sex, and region of residence

Characteristics	N	Median	Min	Max	Geometric			
					Mean	LCL	UCL	STD
All	375	12.63	2.62	81.85	12.59	12.02	13.49	1.70
Sex								
Females	179	12.63	*	*	12.59	11.48	13.49	1.66
Males	196	12.60	*	*	12.88	12.02	13.80	1.74
Age Groups*								
< 5 years	82	16.65	*	*	16.60	15.14	18.62	1.62
5-8 years	129	14.52	*	*	14.79	13.80	16.22	1.62
9+ years	164	9.65	*	*	9.77	9.12	10.47	1.62
Region of residence								
East Flin Flon	155	11.67	3.31	59.55	11.75	11.75	11.75	11.75
West Flin Flon	85	14.50	4.28	81.85	14.79	12.88	16.98	1.86
Channing	22	12.09	6.07	28.67	12.59	10.47	14.79	1.48
Creighton	113	12.87	2.62	37.81	12.59	11.48	13.80	1.62

Notes: N-number of urine samples (individuals); Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD- Geometric Standard Deviation * value censored to protect anonymity of participants

The boxplots contained in Figures 4-8, 4-9 and 4-10 illustrate the distribution of adjusted and unadjusted urinary total arsenic levels according to region of residence, sex and age, respectively. The actual associations between age, sex, place of residence, and urinary total arsenic levels are further explored in detail in Section 7.0.

Figure 4-8: Unadjusted and adjusted urinary total arsenic levels by geographic region



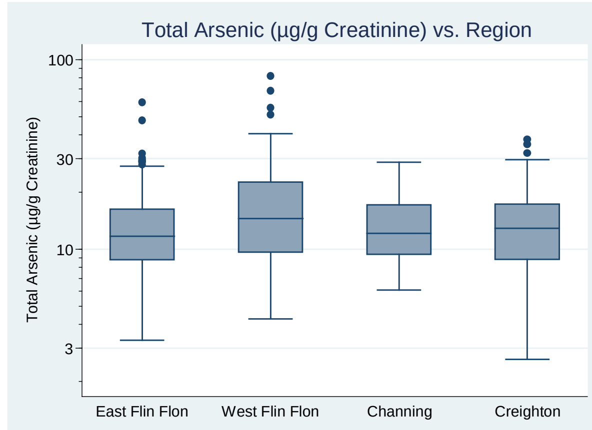
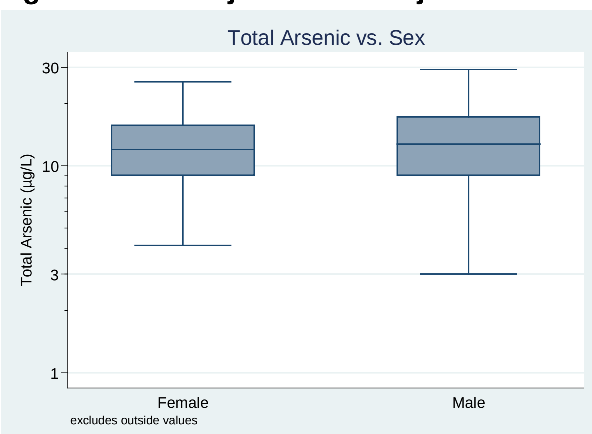


Figure 4-9: Unadjusted and adjusted urinary total arsenic levels by sex



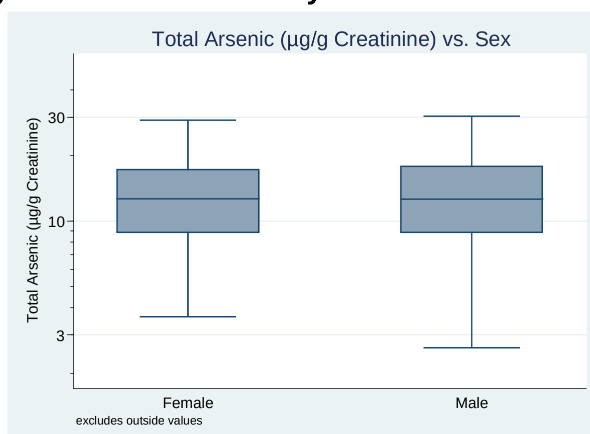
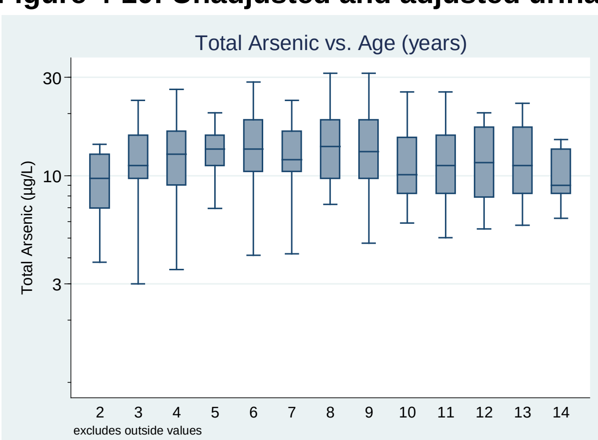
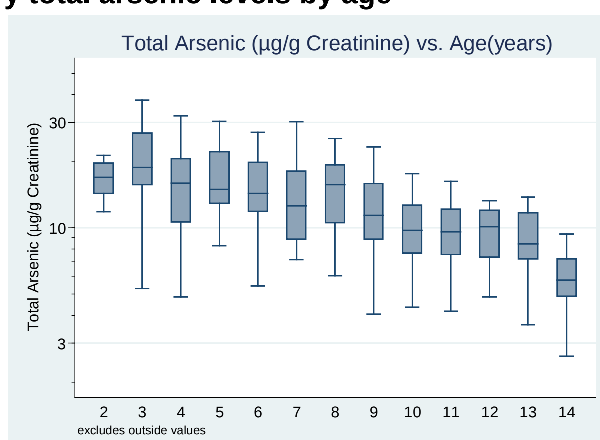


Figure 4-10: Unadjusted and adjusted urinary total arsenic levels by age





4.2.2 Inorganic Arsenic Exposure

Samples below the detectable limit
Approximately 18% of urine samples (n=67) were found to be below the limit of detection for urinary inorganic arsenic (3.745 µg/L).

Samples referred for follow-up
Eleven (n=11) of the samples (3%) were at the level chosen a priori for referral for follow-up (20 µg/L).

Distribution of levels
Figures 4-11 and 4-12 demonstrate that log transformations of both the creatinine adjusted and unadjusted measures of urinary inorganic arsenic improved the fit of the frequency distributions to a normal curve.

Figure 4-11: Distribution of unadjusted urinary inorganic arsenic levels

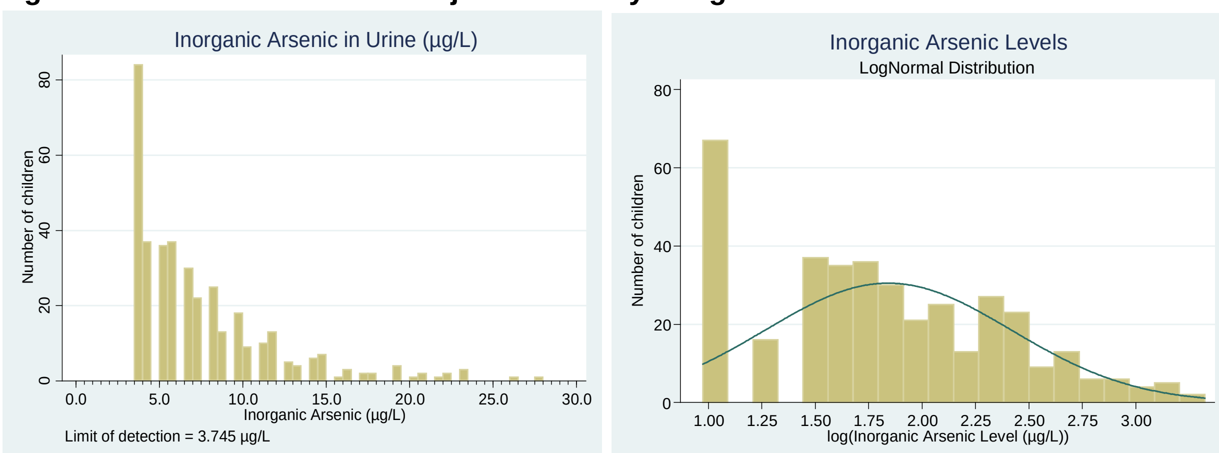
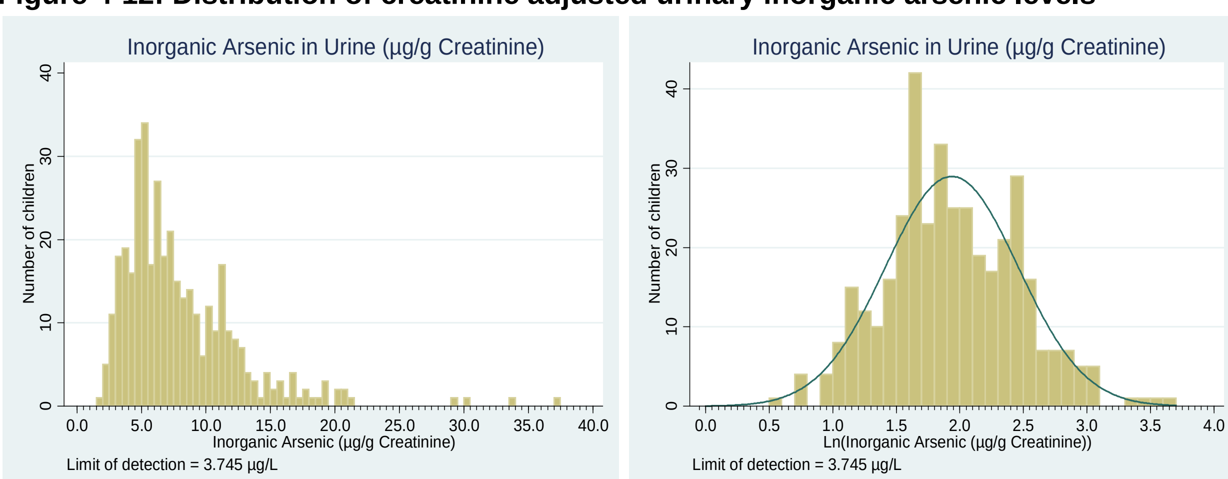


Figure 4-12: Distribution of creatinine adjusted urinary inorganic arsenic levels



As illustrated in Table 4-5, the geometric mean for unadjusted urinary inorganic arsenic levels measured in Flin Flon Area children was 6.35 µg/L (95% CI: 5.98– 6.74 µg/L). The median was measured as 5.99 µg/L. When broken down by gender, the geometric mean was similar for boys (6.41 µg/L) and girls (6.28 µg/L). Similar geometric means were also found across age groups ranging from 5.72 µg/L among 9 to 14 years old children to 7.25 µg/L among children aged 5 to 8 years. Comparable geometric means were also measured according to geographic region ranging from 5.87 µg/L among East Flin Flon children to 6.98 among children living in Channing. As illustrated in Table 4-6, the pattern of results for creatinine adjusted values is similar to that found for the unadjusted values.

Table 4-5: Unadjusted urinary inorganic arsenic levels (µg/L) by age, sex, and region of residence

						Geometric			
Characteristics	**N**	**Median**	**BDL**	**Min**	**Max**	**Mean**	**LCL**	**UCL**	**STD**
All	375	5.99	67	3.75	27.71	6.35	5.98	6.74	1.78
Sex									
Females	179	5.99	32	*	*	6.28	5.76	6.84	1.77
Males	196	5.99	35	*	*	6.41	5.90	6.97	1.79
Age (at interview)									
30 months to 4 years	82	6.74	16	*	*	6.26	5.47	7.17	1.83
5 to 8 years	129	7.49	14	*	*	7.25	6.63	7.93	1.67
9 to 14 years	164	5.24	37	*	*	5.72	5.20	6.29	1.82
Region of residence									
East Flin Flon	155	5.99	27	3.745	19.47	5.87	5.43	6.35	1.63
West Flin Flon	85	7.34	15	3.745	26.22	6.94	6.03	7.98	1.90
Channing	22	7.12	3	3.745	19.47	6.98	5.52	8.84	1.74
Creighton	113	6.74	22	3.745	27.71	6.50	5.78	7.31	1.86

Notes: N-number of urine samples (individuals); Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD-Geometric Standard Deviation; BDL Below Limit of Detection * value censored to protect anonymity of participants

Table 4-6: Creatinine adjusted urinary inorganic arsenic levels (µg/g) by age, sex, and region of residence

						Geometric			
Characteristics	**N**	**Median**	**BDL**	**Min**	**Max**	**Mean**	**LCL**	**UCL**	**STD**
All	375	6.62	67	1.66	37.20	6.34	5.97	6.73	1.76
Sex									
Females	179	6.62	32	*	*	6.32	5.82	6.87	1.72
Males	196	6.58	35	*	*	6.36	5.84	6.92	1.79
Age (at interview)									
30 months to 4yrs	82	10.05	16	*	*	8.82	7.86	9.90	1.66
5 to 8 years	129	7.72	14	*	*	7.79	7.24	8.37	1.51
9 yrs to 14 yrs	164	4.99	37	*	*	4.68	4.29	5.10	1.71
Region of residence									
East Flin Flon	155	6.11	27	1.66	20.81	6.01	5.52	6.54	1.68
West Flin Flon	85	7.04	15	2.55	37.20	6.91	5.99	7.97	1.91
Channing	22	6.90	3	2.76	11.92	6.36	5.69	7.11	1.78
Creighton	113	7.06	22	2.02	21.36	6.56	5.56	7.74	1.47

Notes: N-number of urine samples (individuals); Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD-Geometric Standard Deviation; BDL Below Limit of Detection * value censored to protect anonymity of participants

The boxplots contained in Figures 4-13, 4-14 and 4-15 illustrate the distribution of adjusted and unadjusted urinary inorganic arsenic levels according to region of residence, sex and age, respectively. A multivariate analysis that considers age, gender, region, and other factors that might be associated with inorganic arsenic levels in urine is presented in Section 7.0.

Figure 4-13: Unadjusted and adjusted urinary inorganic arsenic levels by geographic region

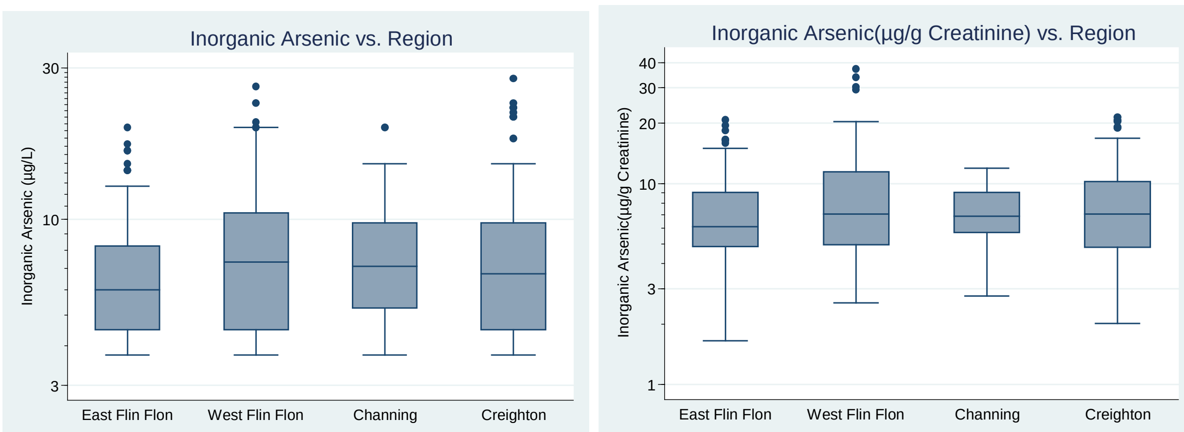


Figure 4-14: Unadjusted and adjusted urinary inorganic arsenic levels by sex

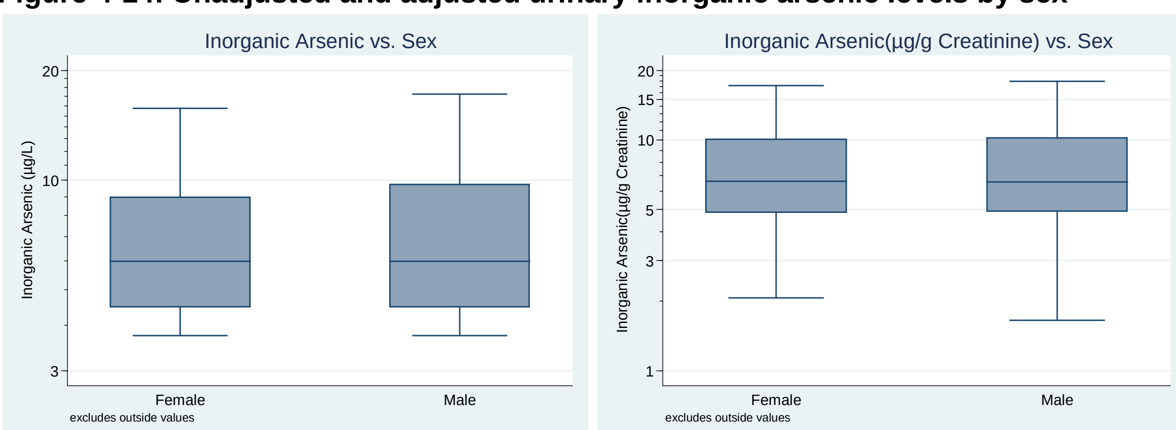
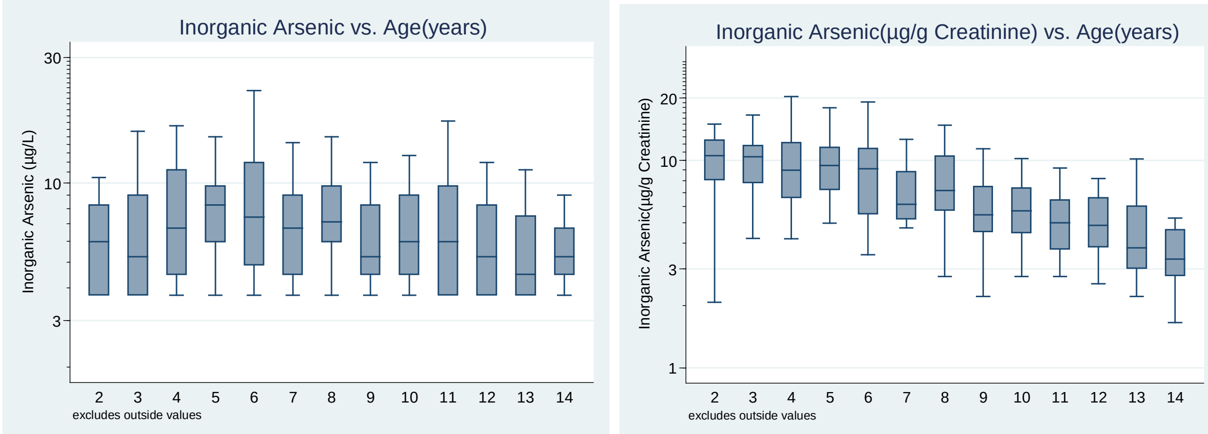


Figure 4-15: Unadjusted and adjusted urinary inorganic arsenic levels by age



4.3 Inorganic mercury exposure

Samples below the detectable limit

Approximately 50% of urine samples (n=188) were found to be below the limit of detection for urinary inorganic mercury (0.1 µg/L).

Samples referred for follow-up

None of the samples were at the level chosen a priori for referral for follow-up (10 µg/L).

Distribution of levels

As illustrated in Figure 4-16, the distribution of unadjusted inorganic mercury levels is challenging to assess given the large number of samples (50%) that were below detection limit. The distribution of samples followed neither a normal nor lognormal distribution.

Figure 4-16: Distribution of unadjusted urinary inorganic mercury levels

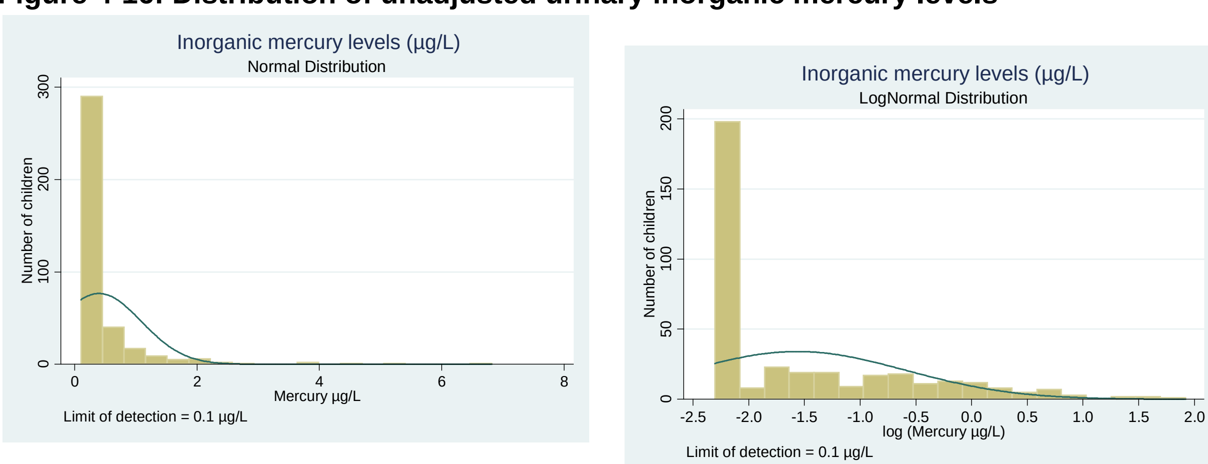
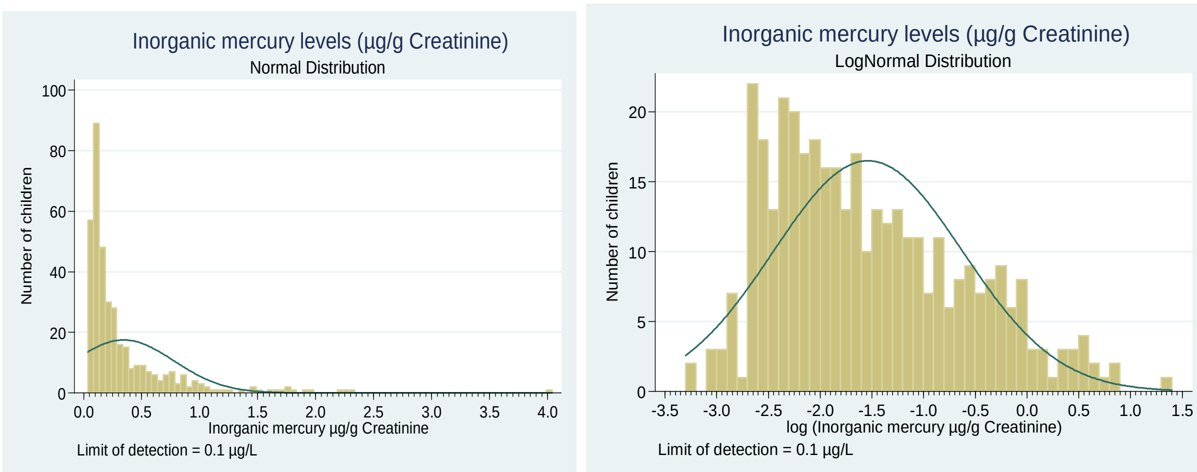


Figure 4-17: Distribution of creatinine adjusted urinary inorganic mercury levels



As illustrated in Table 4-7, the geometric mean for adjusted urinary inorganic mercury levels measured in Flin Flon Area children was 0.11 µg/g (95% CI: 0.09– 0.14 µg/g). The geometric mean was calculated using maximum likelihood estimates given that 50% of the children had urinary inorganic mercury levels below the limit of detection. Given this, the geometric mean provides a better estimate than the median. When broken down by gender, the geometric mean was similar for boys (0.11 µg/g) and girls (0.12 µg/g). Similar geometric means were also found across age groups ranging from 0.09 µg/g among 5 to 8 years old children to 0.15 µg/g among children aged 9 to 14 years. Comparable geometric means were also measured according to geographic region ranging from 0.05 µg/g among Channing children to a slightly higher geometric mean among children living in Creighton (0.22).

Table 4-7: Creatinine adjusted urinary inorganic mercury levels (µg/g) by age, sex, and region of residence

Characteristics	N	BDL	Median	Min	Max	Geometric Mean	LCL	UCL	STD
All	375	188	0.18	0.04	4.02	0.11	0.09	0.14	4.66
Sex									
Females	179	92	0.17	0.05	2.31	0.11	0.08	0.14	4.54
Males	196	96	0.19	0.04	4.02	0.12	0.09	0.16	4.74
Age (at interview)									
30 months to 4 years	82	51	0.19	0.07	0.87	0.10	0.07	0.14	2.88
5 to 8 years	129	73	0.16	0.05	2.25	0.09	0.06	0.14	5.90
9 to 14 years	164	64	0.18	0.04	2.31	0.15	0.11	0.19	4.57
Region of residence									
East Flin Flon	155	86	0.16	0.04	2.31	0.09	0.07	0.13	5.00
West Flin Flon	85	49	0.16	0.05	1.79	0.08	0.05	0.13	6.10
Channing	22	15	0.11	0.05	0.91	0.05	0.02	0.13	4.19
Creighton	113	38	0.27	0.04	4.02	0.22	0.17	0.28	3.37

Notes: N-number of urine samples (individuals); Min-Minimum; Max-Maximum; LCL- 95% Lower Confidence Limit; UCL-95% Upper Confidence Limit; STD-Standard Deviation; BDL – Below Detection Limit

The boxplots contained in Figures 4-18, 4-19 and 4-20 illustrate the distribution of adjusted and unadjusted urinary inorganic mercury levels according to region of residence, sex and age, respectively. A multivariate analysis that considers age, gender, region, and other factors that might be associated with inorganic mercury levels in urine is presented in Chapter 7.

Figure 4-18: Creatinine adjusted urinary inorganic mercury levels by geographic region

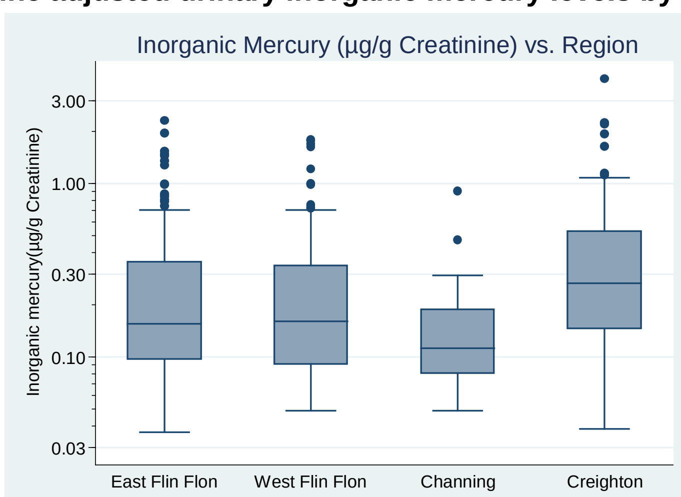


Figure 4-19: Creatinine adjusted urinary inorganic mercury levels by sex

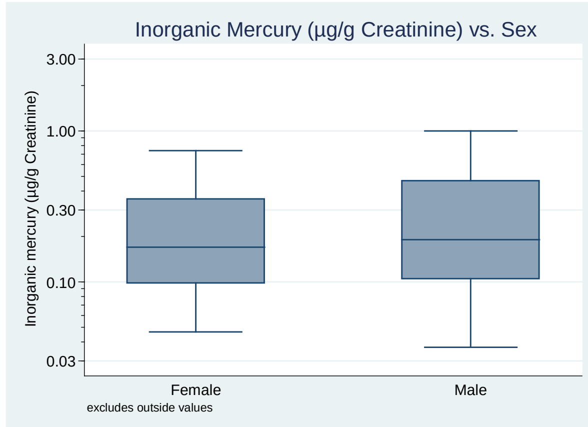
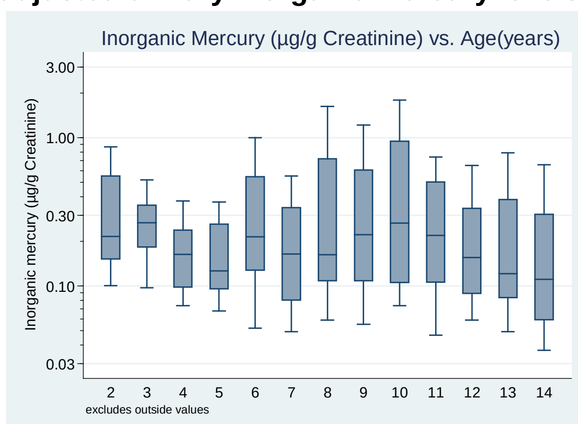


Figure 4-20: Creatinine adjusted urinary inorganic mercury levels by age



5.0 COMPARISON OF EXPOSURE LEVELS

This section of the report addresses the research question of:

> *Do Flin Flon Area child residents have higher lead, arsenic, and/or inorganic mercury levels than residents living in other parts of Canada?*

5.1 Comparison of blood lead levels

Unfortunately, no national baseline study has been undertaken that assesses blood lead levels in younger children under six years of age in Canada. As a result, in order to compare blood lead levels, the study team has assembled findings from a number of studies that can provide an indication of how the levels found in Flin Flon Area children compare with 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 blood lead level results can be interpreted.

To provide this context for interpretation, comparisons were made with a large national level study in the United States, as well as with smaller studies of blood lead levels in atypically exposed communities in Canada.[12] Where applicable, potential challenges with these comparisons are outlined for the reader's consideration.

5.1.1 National surveys of blood lead levels

An age appropriate comparison can be made with the United States' NHANES (2007-08) 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, as illustrated in Table 5-1, the geometric mean blood level for the comparable age group of one to five year olds from the NHANES was lower (1.77 µg/dL) when compared with the geometric mean found among Flin Flon Area children (2.75 µg/dL overall; 3.39 µg/dL West Flin Flon).

[12] The Canadian Health Measures Survey (CHMS) is currently underway. Preliminary data for blood lead levels did not include the age group used for the Flin Flon Area study, so results are not comparable at this point.

Table 5-1: Blood lead concentrations as reported by a U.S. National Population Biomonitoring Studies

Age	Data Source	Geometric Mean (µg/dL)	Reference
0-6 years	**Flin Flon Area Overall**	**2.75 (2.51-2.95)**	**Current Study**
0-5 years	**Flin Flon Area Overall**	**2.57 (95% CI: 2.34-2.82)**	**Current Study**
0-6 years	**West Flin Flon**	**3.63 (3.09-4.27)**	**Current Study**
0-5 years	**West Flin Flon**	**3.39 (95% CI:2.88-4.07)**	**Current Study**
1-5 years	U.S. NHANES (2003-04)	1.77 (1.60-1.95)	U.S. CDC 2009

Note: No Canadian national data are available for children less than 6 years of age.

5.1.2 Community surveys of blood lead levels

While a national level survey of blood lead levels 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 Table 5-2). When the Flin Flon Area children's levels are compared with these studies, the geometric means obtained in the Flin Flon Area are in the mid-range of geometric ranges found in other communities.

Among recent community studies where exposure to soil has been a primary concern, the geometric means found in the present study are lower than those found among children in Trail, BC (5.3 µg/dL), and similar to levels found among children living in an area in proximity to a lead smelter in Belledune, NB (3.54 µg/dL). In these cases, similar to the Flin Flon Area, the studies were conducted in areas in proximity to smelters. Cautions in making these comparisons are that the soil levels and original blood lead levels 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 somewhat in mid-range with the other study results. Results in Flin Flon Area children are slightly higher than those found in similar aged children in North Hamilton (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 characteristics when compared to the Flin Flon Area. Other studies which have focused primarily on exposure to local food have found higher levels 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.

Table 5-2: Blood Lead Concentrations for Atypically Exposed Communities

Age	Community	Date of Measurement	Exposure Concerns	N	Geometric Mean (µg/dL)	Reference
Children 0-6 years old	**Flin Flon Area Overall**	**2009**	**Soil**	**202**	**2.75 (95% CI: 2.51-2.95)**	**Current Study**
Children 0-5 years old	**Flin Flon Area Overall**	**2009**	**Soil**	**175**	**2.57 (95% CI: 2.34-2.82)**	**Current Study**
Children 0-6 years old	**West Flin Flon**	**2009**	**Soil**	**43**	**3.63 (95% CI: 3.09-4.27)**	**Current Study**
Children 0-5 years old	**West Flin Flon**	**2009**	**Soil**	**36**	**3.39 (95% CI:2.88-4.07)**	**Current Study**
Children 0.5-5 years old	Trail, BC	2007	Soil	132	5.1	Trail Health and Environment Committee 2007
Children 0-6 years old	North Hamilton, ON	2008	Water	616	2.3 (95% CI: 2.1-2.4)	EOHP Inc. 2009
Children 3-6 years old	Belledune, NB (proximity to smelter)	2004	Soil	10	3.54	Gov. NB 2005 (a)
Children 5 years old	Nunavik, QC	2000-2003	Local Food	110	5.3	Fraser *et al.*, 2006

5.2 Comparison of total and inorganic urinary arsenic levels

When compared with results from other studies, the Flin Flon Area levels of inorganic arsenic were similar to other recent studies. In addition to some of the cautions outlined in the previous section on lead, the reader should be aware that not all of the studies cited below have necessarily used the same analytic procedures, or collection procedures, and, as a result, some of the differences in the results are likely due to the differences in approaches. It is not possible to determine to what extent the small differences that are observed are as a result of true differences in arsenic levels, differences in collection and analyses, or characteristics of participants (e.g., sex, age, etc.).

As illustrated in Tables 5-3 and 5-4, the levels of urinary total and inorganic arsenic measured in Flin Flon Area children were similar to levels found in other Canadian communities, including communities with potential soil exposure (e.g., Falconbridge, Wawa, Deloro) and comparison communities with no soil contamination (e.g., Hanmer, Havelock).

Table 5-3: Urinary Total Arsenic Levels as Reported in other Canadian Studies

Age	Community	Date of Measurement	Exposure Concern	N	Geometric Mean* (µg/L)	Reference
Children 2½ -14 years old	**Flin Flon Area**	**2009**	**Soil**	**375**	**12.30 µg/L (95% CI: 11.75-12.88) (GSD: 1.58)**	**Current Study**
Children <5 years old	**Flin Flon Area**	**2009**	**Soil**	**82**	**11.48 µg/L (95% CI: 10.23-12.59) (GSD: 1.58)**	**Current Study**
Children 5-8 years old	**Flin Flon Area**	**2009**	**Soil**	**129**	**13.80 µg/L (95% CI: 12.59-14.79) (GSD: 1.58)**	**Current Study**
Children 9-14 years old	**Flin Flon Area**	**2009**	**Soil**	**164**	**11.75 µg/L (95% CI: 10.96-12.88) (GSD: 1.58)**	**Current Study**
Children 0-5 years old	Falconbridge, ON	2004	Soil	18	13.22 µg/L (SD:73.25)	GGI *et al.*, 2005
Children 6-12 years old	Falconbridge, ON	2004	Soil	53	13.49 µg/L (SD:126.07)	GGI *et al.*, 2005
Children 13-17 years old	Falconbridge, ON	2004	Soil	29	10.09 µg/L (SD:16.76)	GGI *et al.*, 2005
Children 0-5 years old	Hanmer, ON	2004	Comparison	17	11.68 µg/L (SD:30.88)	GGI *et al.*, 2005
Children 6-12 years old	Hanmer, ON	2004	Comparison	61	12.33 µg/L (SD:12.35)	GGI *et al.*, 2005
Children 13-17 years old	Hanmer, ON	2004	Comparison	17	12.01 µg/L (SD:6.78)	GGI *et al.*, 2005

* Means provided for Hanmer and Falconbridge are arithmetic means.

Table 5-4: Urinary Inorganic Arsenic Levels as Reported in other Canadian Studies

Age	Community	Date of Measurement	Exposure Concern	N	Mean* (µg/L)	Reference
Children 2½ -14 years old	**Flin Flon Area**	**2009**	**Soil**	**375**	**6.35 µg/L (95% CI: 5.98 - 6.74) (GSD : 1.78)**	**Current Study**
30 mos. to 4 years	**Flin Flon Area**	**2009**	**Soil**	**82**	**6.26 µg/L (95% CI: 5.47-7.17) (GSD : 1.83)**	**Current Study**
5 to 8 years	**Flin Flon Area**	**2009**	**Soil**	**129**	**7.25 µg/L (95% CI: 6.63-7.93) (GSD : 1.67)**	**Current Study**
9 to 14 years	**Flin Flon Area**	**2009**	**Soil**	**164**	**5.72 µg/L (95% CI: 5.20-6.29) (GSD : 1.82)**	**Current Study**
Children 0-5 years old	Falconbridge, ON	2004	Soil	18	8.66 µg/L (SD: 4.65)	GGI *et al.*, 2005
Children 6-12 years old	Falconbridge, ON	2004	Soil	53	9.51 µg/L (SD: 6.45)	GGI *et al.*, 2005
Children 13-17 years old	Falconbridge, ON	2004	Soil	29	7.77 µg/L (SD: 4.32)	GGI *et al.*, 2005
Children 0-5 years old	Hanmer, ON	2004	Comparison	17	7.53 µg/L (SD:3.63)	GGI *et al.*, 2005
Children 6-12 years old	Hanmer, ON	2004	Comparison	61	9.30 µg/L (SD: 6.24)	GGI *et al.*, 2005
Children 13-17 years old	Hanmer, ON	2004	Comparison	17	7.89 µg/L (SD:4.18)	GGI *et al.*, 2005
Children < 13 years old	Wawa, ON	2001	Soil	44	7.0 µg/L (SD: 5.1)	GGI, 2001
Children < 13 years old	Wawa, ON	2002	Soil	53	5.6 µg/L (SD: 3.4)	GGI, 2002
Children < 13 years old	Deloro, ON	1999	Soil	n/a	5.34 µg/L (SD: 5.6)	MOE, 1999
Children < 13 years old	Havelock, ON	1999	Comparison	n/a	7.01 µg/L (SD: 4.4)	MOE, 1999

* Means provided for Hanmer and Falconbridge are arithmetic means.

5.3 Comparison of Inorganic Urinary Mercury Levels

When compared with results from other studies, the Flin Flon Area levels of inorganic arsenic were below levels found in other recent studies. It should be recalled that 50% of the samples obtained were below the detection limit. As with the previous comparisons for lead and arsenic, the same cautions and challenges with making comparisons are applicable to the comparisons made for urinary inorganic arsenic. As illustrated in Table 5-5, the levels of urinary inorganic mercury levels are lower than levels found in similar aged populations in other studies.

Table 5-5: Urinary Inorganic Mercury Levels as Reported in other Studies

Age	Community	Date of Measurement	N	Geometric Mean (µg/L; µg/g)	Reference
Children 2½ -14 years old	**Flin Flon Area Overall**	**2009**	**375**	**0.11 µg/g (95% CI: 0.09-0.14)**	**Current Study**
30 months to 4 years	**Flin Flon Area**	**2009**	**82**	**0.10 µg/g (95% CI: 0.07-0.14)**	**Current Study**
5 to 8 years	**Flin Flon Area**	**2009**	**129**	**0.09 µg/g (95% CI: 0.06-0.14)**	**Current Study**
9 to 14 years	**Flin Flon Area**	**2009**	**164**	**0.15 µg/g (95% CI: 0.11-0.19)**	**Current Study**
< 10 years old	New York City	2007	460	0.31 µg/L	Rogers et al. 2007
2 to 10 years	Chicago (clinics, home visits and anonymous)	2007	406	0.32 µg/g (95% CI 0.28-0.36)	Rogers et al. 2007
All (children and adults)	US population	2003-2004	2,537	0.443 µg/g (95% CI: .404-.486)	US CDC, 2009
6 to 11 years	US population	2003-2004	286	0.297 µg/g (95% CI: .246-.358)	US CDC, 2009

6.0 POTENTIAL HEALTH RISKS ASSOCIATED WITH EXPOSURE LEVELS

This section of the report addresses the research question of:

> *Based upon the current scientific literature, what are the health risks from the levels of lead in blood, and arsenic and inorganic mercury in urine found in children in the Flin Flon Area?*

6.1 Potential health risks associated with blood lead levels

Lead can be found in soil, dust, air, drinking water, food and consumer products, exposure can occur through inhalation, ingestion, and to a lesser extent, dermal contact. Pathways, exposure routes, and metabolism may be complex in any setting. Once lead enters the body, it circulates in the bloodstream and is deposited in bone and other tissues where it stays for many years. Some is excreted. The half life of lead in blood varies, and on average is about 30 days. 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) (IARC, 2006). 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 (Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre, 1995). Even at low levels of lead exposure, studies have shown that children may experience impaired physical and mental development.

A detailed toxicological profile was prepared for the overall Human Health Risk Assessment. For a detailed summary of the potential health risks associated with blood lead levels, the reader is referred to the Human Health Risk Assessment document (Intrinsik, 2010). The most commonly reported and well-studied effects of environmental lead exposure are: 1) adverse effects on neurological function and neurobehavioural development in children; and, 2) reduced growth rate. However, it remains unclear if lead causes such effects in adults (U.S. EPA IRIS, 2004). The effects in children often manifest as decreased IQ and memory, decreased gestation period, and retarded growth rate. While the debate continues as to whether or not a threshold exists for the cognitive effects of lead in children, there is consistent information from the available lead health effects literature indicating that childhood blood lead levels greater than 10 µg/dL are linked to decreased intelligence and impaired neurobehavioral development (ATSDR, 2007; CDC, 2009; Jusko et al., 2008, Lanphear et al., 2005; U.S. EPA IRIS, 2004; WHO, 1995). The interpretation of blood lead levels is recommended in light of the most current information regarding the health effects of lead on children. Health Canada’s 1994 guidance statement for a blood lead intervention level of 10 µg/dL is currently under review because of concern that adverse health effects may occur below 10 µg/dL. Certain other agencies (e.g. City of New York) advise action at 5 µg/dL for children or during pregnancy, and the literature indicates that adverse health effects may occur below 5 µg/dL. The US Centres for Disease Control and Prevention state that there is no known minimum threshold of harm for lead exposure, and Health Canada’s policy is to reduce exposure to lead wherever practical.

As described in Section 4.0, the geometric mean of blood lead levels in Greater Flin Flon Area was 2.75µg/dL (95% CI: 2.51 – 2.95). The geometric mean of blood lead levels in the sub-community of West Flin Flon was higher at 3.63 µg/dL. As discussed in Section 5.0, these are slightly higher than those found among similar ages in the general U.S. population, and comparable with levels found in children in other atypically exposed Canadian communities. However, the overall blood lead level for the Flin Flon area does not represent an immediate health concern.

6.2 Potential health risks associated with urinary arsenic levels

Arsenic is a naturally occurring element in the earth's crust, and is found throughout the environment. It is usually found combined with other elements such as oxygen, chlorine, and sulphur. When combined with these elements, it is referred to as inorganic arsenic. However, when arsenic is combined with carbon-containing compounds, it is referred to as organic arsenic. While arsenic-containing substances, both organic and inorganic, are naturally occurring, some are manmade. Arsenic can be released naturally from ore bodies; however, human activity accounts for a significant amount of localized arsenic contamination in the environment.

Arsenic is among the most pervasive toxicants in the world. Many large populations (Taiwan, Argentina, Chile, Bengal, India, Bangladesh, and the USA) are exposed to moderately elevated levels of arsenic from drinking water. Naturally high concentration of arsenic in soil does occur in several regions of the world as well, from natural background and human activity, such as mining. In addition, people who eat a lot of fish and seafood, or who live in areas with localized arsenic in soil, may experience increased repeated exposures to arsenic.

Food and drinking water are the main sources of arsenic exposure in Canada. In general, arsenic from soil and air provide less than 0.01 and 0.2% of total exposure commitment to arsenic in adults. Canadian data indicate that dust and soil provide about 0.4 to 3% of the total daily exposure to arsenic in all age groups, with children's exposure being about 4-9% from soil and dust. In the US, about 92% of arsenic exposure is from food, and about 7% from drinking water. The absolute amount of arsenic exposure from soil will vary for each person depending on arsenic concentration in soil, and the individual's access to the soil (personal habits) and eating of produce grown in the affected soil. Smoking also causes exposure to arsenic. There are few studies of Canadian populations impacted by arsenic in soil [Deloro (MOE, 1999); Wawa 2001, 2002 (Goss Gilroy, 2002); Nova Scotia - Sydney Tar Ponds 2001 (Nova Scotia Department of Health, 2001), Falconbridge (Goss Gilroy et al., 2005)] and only two involving arsenic in drinking water (Nova Scotia,2001; Newfoundland, 2002). Most of these involve urinary measures reflecting exposure, rather than epidemiologic studies relating exposure to adverse health events.

Similar to lead, a detailed toxicological profile for arsenic was prepared for the HHRA. For a detailed summary of the potential health risks associated with arsenic exposure, the reader is referred to the Human Health Risk Assessment document (Intrinsik, 2010). The half-life of arsenic in urine is relatively short; thus chronic, persistent exposures, as opposed to periodic episodes, are required to sustain elevated body fluid levels. Total arsenic values in excess of 100 µg/L are considered abnormal (ATSDR, 2007). However, total arsenic measurement in human urine assesses the combined exposure from all routes of exposure and all species of arsenic. Where total urinary arsenic level is high and seafood is considered a possible contributor, inorganic arsenic (i.e., analysis of organo-arsenicals or different inorganic species, rather than total) should be considered. Some non-cancer effects of arsenic (e.g., dermal keratosis, vasospasm, and peripheral neuropathy) have been associated with total urinary arsenic levels as low as 50–100 µg/L in chronically exposed populations (ACGIH, 2001; Blom et al., 1985; Tseng et al., 2005; Valenzuela et al., 2005; WHO, 2001). These associations are stronger at higher urinary levels, and other factors such as nutrition, methylation capacity, and duration of exposure are also considered important. Finding a measurable amount of arsenic in urine does not mean that the level of arsenic causes an adverse health effect. Biomonitoring studies of urinary arsenic can provide physicians and public health officials with reference values so that they can determine whether people have been exposed to higher levels of arsenic than are found in the general population. Biomonitoring data can also help scientists plan and conduct research on exposure and health effects.

As described in Section 4.0, the geometric mean of urinary total arsenic levels in the Flin Flon Area was 12.30µg/L (or 12.59 µg/g). Finding a measurable amount of arsenic in urine does not mean that the level of arsenic causes an adverse health effect. These results are similar to levels observed in children in other Canadian communities with limited exposure to arsenic in soil.

Urinary inorganic arsenic levels found in children in the Flin Flon Area were not high enough to be associated with health risks. The geometric mean of urinary inorganic arsenic levels in the Flin Flon Area was 6.35 µg/L (or 6.34 µg/g). Finding a measurable amount of arsenic in urine does not mean that the level of arsenic causes an adverse health effect. These results are similar to levels observed in children in other Canadian communities with limited exposure to arsenic in soil.

6.3 Potential health risks associated with urinary inorganic mercury levels

Mercury occurs in nature in a variety of chemical forms. Organic (methylmercury) occurs in fish when inorganic mercury is deposited in water, and organisms in the sediments convert it to organic forms, which are then taken up by fish in increasing fashion as the food chain is amplified (that is, big fish eat smaller fish and organisms). Inorganic mercury occurs in the vapor form in air and in the form of mercury salts and other compounds found in soil and some pharmaceuticals. In Canada, exposure to mercury in general occurs from all of these sources: fish, air, soils, pharmaceuticals, and as has been shown in many studies, from dental amalgams (dental cavities filled with mercury- silver compounds).

Mercury is toxic, and all mercury compounds affect the central nervous system (the brain). However, there are many manifestations of mercury's toxic effects. Frank toxicity of mercury vapor is manifest by fine tremor, psychological changes, gum irritation (gingivitis), insomnia, loss of appetite, depression, irritability, headache, short-term memory loss, and muscle wasting.

Mercury vapor also causes damage to lungs when inhaled, skin, eyes, and gums. If the exposure is high enough, symptoms will progress to pneumonia (interstitial pneumonitis), kidney damage, increased blood pressure and heart rate, and pulmonary edema (swelling of lung tissue and fluid retention in the lungs).

Many studies have shown that dental amalgam fillings have an impact on the amount of mercury excreted in a child's urine as measured by spot urine tests. Maserejian et al. (2008) showed in their large prospective study that for every dental amalgam, the urine mercury can be expected to be increase by 10% (± 1%).

Similar to lead and arsenic, a detailed toxicological profile was prepared for mercury for the HHRA. For a detailed summary of the potential health risks associated with inorganic exposure, the reader is referred to the Human Health Risk Assessment document (Intrinsik, 2010). The limit of inorganic mercury exposure for adults has been set by the World Health Organization (WHO) at 20 µg/L as a spot urine measurement. Limits for children have not been set. Two studies have examined levels in urban children (Rogers et al, 2007a; Rogers et al, 2007b). The summary results for these two studies as well as an additional study of children with and without amalgam dental fillings (Maserejian et al, 2008) demonstrated geometric means of less than 0.5 µg/L, and 95th percentiles ranging from 1.2 µg/L to 4.6 µg/L.

As described in Section 4.0, the majority of samples collected from the Flin Flon Area had no detectable levels of inorganic mercury. Overall, the geometric mean of urinary inorganic mercury levels in the Flin Flon Area was 0.11 µg/g (95% CI: 0.09-0.13 µg/g), and therefore, there are no health risks associated with these levels.

7.0 FACTORS ASSOCIATED WITH EXPOSURE LEVELS

This section of the report addresses the research question of:

> *What personal factors are associated with the level of measured internal exposure of children in Flin Flon Area (e.g., place of residence, place of work, level of COC in soil, age, gender, diet, personal habits, etc.)?*

To assess the factors associated with exposure levels, simple univariate regression models were developed to determine which personal factors were potentially related to the exposure level of the COC. The findings from these initial univariate models were then used to develop multivariate regression models that were used to determine the unique variance in COC levels accounted for by each of the measured personal factors. The results are presented according to each COC below.

It should be noted by the reader in reviewing the results in this section that the data herein describe ***associations*** and should not be inferred as cause and effect.

7.1 Personal factors associated with blood lead levels

Initially, 14 factors measured on the household survey that were hypothesized as being potentially associated with blood lead levels were formulated into simple regression models to determine their individual levels of association with blood lead levels (µg/dL) in Flin Flon Area children.[13] Given the distribution of blood lead levels as illustrated in Section 4.0, the blood lead levels were log transformed prior to analysis. As illustrated in Table 7-1, based on a p-value of 0.15, eight factors were identified as being potentially associated with blood lead levels, including:

- Child's gender
- Child's age
- Region of residence
- Adult use of tobacco
- Child's exposure to second-hand smoke
- Child's tendency to chew on toys or other objects
- Average number of hours child spends away from home
- Year house was constructed (according to municipal tax rolls).

[13] The type of water pipes in the house is also a potential associated factor; however examination of the responses on this survey item indicated that the data were of questionable quality. Approximately one third (31%) of respondents did not know what types of water pipes they had in their homes. As well, there were indications that for another sizeable proportion were making a "best guess" without knowing definitively. As a result, these data were not used in the models.

Table 7-1: Univariate regressions to select personal factors for inclusion in multivariate model of log blood lead levels (µg/dL)

Variable	P-value Log Blood Lead
Gender	***0.0009***
Age at interview	***0.0041***
Region of residence	***0.0356***
Ever employed in a mine or smelter	0.8392
Highest level of education	0.0174
Current smoke or tobacco use	***0.0040***
Second hand smoke	***0.0365***
Eaten outside	0.6814
Washing hands and face before going to sleep	0.2000
Eating dirt	0.3273
Chew on toys and other objects	***0.0726***
Peeling and picking at chips of paint	0.9807
Average hours spend away from home	***0.0138***
Year house was constructed	***0.0132***
Source of water supply	0.2091

The eight personal factors identified in the univariate regression models were then entered into a multivariate regression model to determine the extent to which each factor was a significant predictor of log blood lead levels. As illustrated in Table 7-2, the multivariate regression indicates that the significant predictors of log blood lead levels (µg/dL) in Flon Flon children were:

- Child's gender
  - 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 East Flin Flon and Channing children
- Adult currently smoking or using tobacco
  - Children living in households with adults who smoke or used tobacco were more likely to have higher levels
- Average hours child spends away from home
  - Children who spent more hours away from home were more likely to have higher levels
- Year the house was constructed
  - Children living in older houses were more likely to have higher levels.

Table 7-2: Multivariate analysis to identify predictors of the log of blood lead (µg/dL) concentration among children under seven years of age[14]

Variable	Estimate	Standard Error	95% Confidence Interval		P-value
Constant	2.95	1.36	1.62	5.39	*<0.01*
Gender	0.77	1.08	0.67	0.89	***<0.01***
Age at interview	1.03	1.02	0.98	1.07	0.25
Area of residence					
West Flin Flon	1.00				
Channing	0.57	1.24	0.38	0.88	***0.01***
Creighton	0.93	1.14	0.71	1.22	0.60
East Flin Flon	0.65	1.13	0.52	0.83	***0.00***
Current smoke or tobacco use	1.15	1.04	1.06	1.26	***0.00***
Second hand smoke	1.11	1.13	0.87	1.41	0.42
Chew on toys and other objects	1.01	1.01	1.00	1.02	0.08
Average hours spend away from home	1.04	1.01	1.02	1.06	***<0.01***
Period in which the house was built	0.98	1.01	0.96	0.99	**0.01**

To illustrate the direction of the associations and provide further interpretation of the significant predictive factors associated with lead levels, additional descriptive statistics on each of the significant predictive factors are presented in the table below (Table 7-3). These have been derived from responses on the household survey and municipal data (i.e., year house was constructed).

[14] The following is a brief description of the key components included in this table. The *constant* is the geometric mean blood lead level at the zero level of a continuous variable (e.g., age). For a categorical variable, the *constant* is the geometric mean blood lead level at the base line category for a categorical variable (e.g., region). For continuous variables, the *estimate* represents the increase in blood lead level per unit change in the continuous predictor variable. For continuous variables, the associated blood lead level for a particular predictor variable value greater than 0 is calculated by the following equation: $(estimate^{\text{value of continuous variable}})(constant)$. For categorical variables, the estimate represents the proportional increase relative to the baseline category level. With categorical predictor variables, the associated blood lead level with a specific category is calculated using the following equation: *constant* * *estimate*. As a note of caution, when examining one particular predictor variable in this manner, the assumption is that all other predictor variables in the model are at zero or baseline.

Table 7-3: Descriptive statistics for significant predictor factors for blood lead levels

Variables	N	Median	Geometric Mean	LCL	UCL	STD
All	202	2.49	2.75	2.51	2.95	1.86
Child's gender						
Females	93	2.28	2.34	2.14	2.57	1.62
Males	109	3.11	3.09	2.75	3.55	1.95
Region of residence						
East Flin Flon	84	2.28	2.29	2.00	2.63	1.82
West Flin Flon	43	3.73	3.63	3.09	4.27	1.66
Channing	12	1.90	2.00	1.45	2.75	1.66
Creighton	63	2.90	3.02	2.57	3.55	1.86
Number of members of household *currently* smoke or use tobacco						
0 (none)	109	2.28	2.45	2.19	2.75	1.82
1	44	3.21	3.02	2.57	3.47	1.66
2	45	2.69	2.95	2.40	3.55	1.95
3	3	8.91	7.59	2.82	19.95	1.48
4	1	5.18	5.13	NA	NA	NA
Average number of hours per day spent away from home						
<5 hours	103	2.00	2.40	2.19	2.69	1.78
5-9 hours	76	3.11	3.16	2.69	3.63	1.91
10+ hours	23	3.11	2.95	2.29	3.89	1.82
Year in which house/apartment originally built						
1931 to 1936	28	3.63	3.31	2.63	4.17	1.82
1936 to 1940	16	2.38	2.82	1.91	4.17	2.09
1941 to 1946	4	2.80	2.82	1.91	4.27	1.29
1946 to 1950	26	3.32	2.95	2.40	3.63	1.70
1951 to 1955	15	3.32	3.39	2.34	4.90	1.95
1956 to 1960	7	3.11	3.02	2.09	4.47	1.51
1961 to 1965	3	1.93	2.24	0.85	6.03	1.48
1966 to 1970	7	2.49	2.88	1.10	7.76	2.88
1971 to 1975	2	1.42	1.41	0.29	6.92	1.20
1976 to 1980	20	2.49	2.63	2.00	3.39	1.74
1981 to 1985	10	1.99	1.95	1.55	2.51	1.38
1986 to 1990	20	2.13	2.14	1.78	2.63	1.55
1991 to 1995	15	2.90	3.24	2.24	4.57	1.91
1996 to 2000	2	1.62	1.62	1.17	2.24	1.05
2001 to 2005	2	0.94	0.81	0.00	1148.15	2.24
2006 to 2010	2	1.90	1.91	1.55	2.34	1.02

7.2 Personal factors associated with urinary inorganic arsenic levels

Important Note: The assessment of personal factors associated with exposure levels is usually undertaken to improve understanding of elevated community exposure levels. As described in previous sections, the levels of urinary inorganic arsenic measured in Flin Flon Area children were similar to levels found in studies of children who are not exposed to elevated arsenic soil levels. Similarly, the geometric mean levels in Flin Flon Area children were well below the levels that would be associated with health effects. As a result, the assessment of associations between personal factors and urinary inorganic arsenic levels in Flin Flon Area children presented in this section should be used for background information, rather than to guide future actions in the community.

Initially, 17 factors measured on the household survey that were hypothesized as being potentially associated with urinary inorganic arsenic levels were formulated into simple regression models to determine their individual levels of association with urinary inorganic arsenic levels (µg/L and µg/g creatinine) in Flin Flon Area children. Given the distribution of urinary inorganic arsenic levels as illustrated in Section 4.0, the urinary inorganic arsenic levels were log transformed prior to analysis.

Those variables where the p-value in the univariate analysis was less than 0.15 were included in the multivariate models. As illustrated in Table 7-4, for the log unadjusted urinary inorganic arsenic levels, the eight variables that were identified as being potentially associated with unadjusted levels were:

- Time since start of survey
- Age group
- Region of residence
- Eating fish in the past 7 days
- Child eats dirt
- Hours spent outside 3 days ago
- Parent worked at mine or smelter
- Eaten outside in past 7 days
- Source of water for drinking and cooking.

For the log creatinine adjusted urinary inorganic arsenic levels, the six variables that were identified as being potentially associated were:

- Time since start of survey
- Age group
- Region
- Eating fish in the past 7 days
- Child eats dirt
- Hours spent outside 3 days ago
- Source of water for drinking and cooking.

Table 7-4: Univariate regressions to select personal factors for inclusion in multivariate models of log urinary inorganic arsenic levels unadjusted (µg/L) and creatinine adjusted (µg/g)

Variable	P-value Log Unadjusted Inorganic Arsenic	P-value Log Creatinine Adjusted Inorganic Arsenic
Time since start of survey	***0.120***	***0.600***
Age group	***0.003***	***<0.0001***
Region	***0.090***	0.400
Gender	0.700	0.600
Eating fish in the past 7 days	***0.006***	***0.001***
Child eats dirt	***0.060***	***<0.0001***
Used slag around house	0.700	0.400
Hours spent outside 3 days ago	***0.005***	***0.070***
Self-reported arsenic exposure at work	0.500	0.400
Parent worked at mine or smelter	***0.050***	0.310
Highest level of education	0.950	0.770
Parent smoker or tobacco use	0.210	0.680
Second hand smoke	0.920	0.620
Eaten outside in past 7 days	***0.007***	0.300
Washing hands and face before going to sleep	0.400	0.600
Chew on toys and other objects	0.400	0.600
Source of water for drinking and cooking	***<0.0001***	***<0.0001***

As illustrated in Table 7-5, the overall regression model for log unadjusted urinary inorganic arsenic values was statistically significant ($p<0.0001$). The log unadjusted arsenic levels were found to be significantly associated with:

- Child's age
    - Older children (9-14) were likely to have lower levels than younger children (2.5-4)
- Eating fish in the past 7 days
    - Children who consumed fish in the past 7 days were more likely to have higher levels.
- Child eats dirt
    - Children who ingest soil or dirt were more likely to have higher levels.
- Hours spent outside 3 days ago
    - Children who spent more time outdoors 3 days prior were more likely to have higher levels
- Eating outside 7 days ago
- Source of water for drinking and cooking
    - Children who used only bottled water for drinking and cooking were more likely to have lower levels than those children who use only tap water

Table 7-5: Multivariate analysis of log unadjusted inorganic arsenic levels in urine

Variable	Estimate	Standard Error	95% Confidence Interval		P-value
Constant	4.81	1.08	4.06	5.64	*<0.01*
Age at interview					
30 months to 4 years old	1.00				
5 to 8 years old	1.09	1.07	0.95	1.25	0.22
9 yrs to 14 yrs old	0.84	1.08	0.72	0.96	***0.02***
Fish consumption in past 7 days					
Did not eat fish in past 7 days	1.00				
Ate fish in past 7 days	1.25	1.06	1.11	1.40	***<0.01***
Unknown fish consumption in past 7 days	0.98	1.14	0.75	1.27	0.87
Missing fish diary	1.13	1.15	0.86	1.48	0.39
Eating dirt					
Child does not eat dirt	1.00				
Child eats dirt	1.28	1.11	1.06	1.57	***0.01***
Not known if child eats dirt	0.74	1.17	0.54	1.02	0.07
Hours spent playing outside 3 days ago	1.04	1.02	1.01	1.07	***0.02***
Time since start of survey	1.00	1.00	1.00	1.01	0.23
Area of residence					
East Flin Flon	1.00				
West Flin Flon	1.04	1.12	0.84	1.30	0.69
Channing	1.01	1.15	0.76	1.34	0.94
Creighton	1.14	1.07	1.00	1.31	0.06
Any adult in family ever worked in smelter or mine	1.05	1.07	0.92	1.20	0.48
Eating outside					
Did not eat outside in past 7 days	1.00				
Ate outside in past 7 days	1.08	1.07	0.93	1.25	0.29
Not known if child ate outside in past 7 days	0.53	1.34	0.30	0.01	*0.03*
Source of drinking and cooking water					
Use only tap water	1.00				
Use tap and bottled water	0.93	1.07	0.82	1.06	0.27
Use only bottled water	0.59	1.13	0.47	0.74	***<0.01***
Source of drinking and cooking water unknown	1.43	1.15	1.07	1.90	*0.02*

As illustrated in Table 7-6, the overall regression model for log creatinine adjusted urinary inorganic arsenic values was statistically significant ($p<0.0001$). The log creatinine adjusted arsenic levels were found to be significantly associated with:

- Child's age
  - Older children were more likely to have lower levels than younger children
- Eating fish in the past 7 days
  - Children who consumed fish in the past 7 days were more likely to have higher levels.
- Child eats dirt
  - Children who ingested soil or dirt were more likely to have higher levels
- Eating outside 7 days ago
  - Children who ate outside were more likely to have higher levels
- Source of water for drinking and cooking

- o Children who used only bottled water for drinking and cooking were more likely to have lower levels than those children who use only tap water

Table 7-6: Multivariate analysis of log creatinine adjusted inorganic arsenic levels in urine

Variable	Estimate	Standard Error	95% Confidence Interval		P-value
Constant	7.17	1.07	6.30	8.17	*<0.01*
Age at interview					
30 months to 4 years old	1.00				
5 to 8 years old	0.86	1.06	0.76	0.98	***0.02***
9 yrs to 14 yrs old	0.50	1.07	0.43	0.58	***<0.01***
Fish consumption in past 7 days					
Did not eat fish in past 7 days	1.00				
Ate fish in past 7 days	1.19	1.06	1.05	1.32	***<0.01***
Unknown fish consumption in past 7 days	0.95	1.12	0.77	1.17	0.64
Missing fish diary	1.03	1.12	0.84	1.27	0.80
Eating dirt					
Child does not eat dirt	1.00				
Child eats dirt	1.27	1.08	1.09	1.49	***<0.01***
Not known if child eats dirt	0.73	1.13	0.58	0.91	*0.01*
Hours spent playing outside 3 days ago	1.01	1.01	0.99	1.04	0.41
Time since start of survey	1.00	1.00	1.00	1.01	0.14
Area of residence					
East Flin Flon	1.00				
West Flin Flon	1.04	1.07	0.90	1.20	0.59
Channing	0.93	1.12	0.74	1.16	0.51
Creighton	1.07	1.06	0.95	1.21	0.24
Any adult in family ever worked in smelter or mine	0.98	1.05	0.89	1.08	0.68
Eating outside					
Did not eat outside in past 7 days	1.00				
Ate outside in past 7 days	1.15	1.06	1.03	1.28	***0.01***
Not known if child ate outside in past 7 days	1.06	1.23	0.70	1.60	0.77
Source of drinking and cooking water					
Use only tap water	1.00				
Use tap and bottled water	0.98	1.06	0.88	1.09	0.72
Use only bottled water	0.72	1.13	0.57	0.91	***0.01***
Source of drinking and cooking water unknown	1.70	1.12	1.39	2.10	*<0.01*

7.3 Personal factors associated with urinary total arsenic levels

Important Note: The assessment of personal factors associated with exposure levels is usually undertaken to improve understanding of elevated community exposure levels. As described in previous sections, the levels of urinary total arsenic measured in Flin Flon Area children were similar to levels found in studies of children who are <u>not</u> exposed to elevated arsenic soil levels. Similarly, the geometric mean levels in Flin Flon Area children were well below the levels that would be associated with health effects. As a result, the assessment of associations between personal factors and urinary total arsenic levels in Flin Flon Area children presented in this section should be used for background information, rather than to guide future actions in the community.

Initially, 16 factors measured on the household survey that were hypothesized as being potentially associated with urinary total arsenic levels were formulated into simple regression models to determine their individual levels of association with urinary total arsenic levels (µg/L and µg/g creatinine) in Flin Flon Area children. Given the distribution of urinary total arsenic levels as illustrated in Section 4.0, the urinary total arsenic levels were log transformed prior to analysis.

As illustrated in Table 7-7, the five variables that were found at this initial stage to predict log unadjusted urinary total arsenic values were:

- Child's age
- Area of residence
- Eating outside within the past 7 days
- Eating dirt
- Eating fish within the past 7 days.

The variables that were found at this initial stage to predict log creatinine adjusted urinary total arsenic values were:

- Child's age
- Area of residence
- Eating outside within the past 7 days
- Adult in house currently smokes or uses tobacco
- Eating dirt
- Child chews on toys or objects
- Eating fish within the past 7 days
- Average number of hours spent away from home.

Table 7-7: Univariate regressions to select personal factors for inclusion in multivariate models of log urinary total arsenic levels unadjusted (µg/L) and creatinine adjusted (µg/g)

Variable	P-value Log Unadjusted Total Arsenic	P-value Log Creatinine Adjusted Total Arsenic
Gender	0.1880	0.7291
Age at interview (years)	***0.1101***	***<.0001***
Area of Residence		
West Flin Flon	-	-
Channing	0.7977	0.2570
Creighton	***0.1264***	***0.1054***
East Flin Flon	***0.0029***	***0.0048***
Ever employed in a mine or smelter	0.3586	0.1710
Highest level of education	0.5714	0.3136
Adult in house currently smokes or uses tobacco	0.6621	***0.1208***
Child exposed to second hand smoke	0.8086	0.6318
Eaten outside in last 7 days	***0.0026***	***0.1277***
Washing hands and face before going to sleep	0.5333	0.9777
Eating dirt	***0.1163***	***0.0016***
Chews on toys and other objects	0.1877	***0.0083***
Average number of hours away from home	0.2402	***0.0991***
Type of water supply in the house	0.4417	0.9179
Ate fish within the past 7 days	***0.0004***	***0.1048***
Slag usage around the house	0.3612	0.7587
Pressure treated wood burned	0.6673	0.6305

Note: *Model excludes those with missing data and responses that included 'Don't Know'; **Variables significant at the level of p= 0.15 are bolded and italicized

As illustrated in Table 7-8, the overall regression model for log unadjusted urinary total arsenic values was statistically significant (p<0.0001). The log unadjusted total arsenic levels were found to be significantly associated with:

- Area of residence
  - Children in East Flin Flon were more likely to have lower levels.

Table 7-8: Multivariate analysis of log unadjusted total arsenic levels in urine

Variable	Estimate	Standard Error	95% Confidence Limits		P-value
Constant	15.35	1.09	12.87	18.29	<.01
Age at interview	0.99	1.01	0.98	1.00	0.11
Area of Residence					
West Flin Flon	1.00				
Channing	0.96	1.11	0.78	1.19	0.73
Creighton	0.90	1.07	0.79	1.02	0.11
East Flin Flon	0.83	1.06	0.73	0.94	**0.00**
Eaten outside	1.00	1.00	0.99	1.00	0.08
Eating dirt	1.00	1.00	0.99	1.00	0.42
Ate Fish within the past 7 days	0.99	1.02	0.96	1.03	0.78

As illustrated in Table 7-9, the overall regression model for log creatinine adjusted urinary total arsenic values was statistically significant (p<0.0001). The log creatinine adjusted total arsenic levels were found to be significantly associated with:

- Child's age
  - o Younger children were more likely to have higher levels than older children.
- Area of residence
  - o Children in East Flin Flon were more likely to have lower levels.

Table 7-9: Multivariate analysis of log creatinine adjusted total arsenic levels in urine

Variable	Estimate	Standard Error	95% Confidence Limits		P-value
Constant	23.55	1.11	19.29	28.73	<.01
Age at interview	0.92	1.01	0.91	0.93	**<.01**
Area of Residence					
West Flin Flon	1.00				
Channing	0.94	1.11	0.76	1.16	0.55
Creighton	0.92	1.07	0.81	1.05	0.21
East Flin Flon	0.83	1.06	0.73	0.93	**0.00**
Eaten outside	1.00	1.00	1.00	1.01	0.39
Eating dirt	1.00	1.00	0.99	1.00	0.49
Ate Fish within the past 7 days	1.00	1.02	0.97	1.04	0.79
Adult in house currently smokes	1.03	1.03	0.97	1.09	0.30
Chew on toys and other objects	1.00	1.00	1.00	1.01	0.43
Average number of hours away from home	1.01	1.01	1.00	1.03	0.14

7.4 Personal factors associated with inorganic mercury levels

Important Note: The assessment of personal factors associated with exposure levels is usually undertaken to improve understanding of elevated community exposure levels. As described in previous sections, the levels of urinary inorganic mercury measured in Flin Flon Area children were lower than levels found in general population studies of children. One half of the samples (50%) were below detection limits. Similarly, the geometric mean levels in Flin Flon Area children were well below the levels that would be associated with health effects. As a result, the assessment of associations between personal factors and urinary inorganic mercury levels in Flin Flon Area children presented in this section should be used for background information, rather than to guide future actions in the community.

Initially, seven factors measured on the household survey that were hypothesized as being potentially associated with urinary inorganic mercury levels were formulated into simple regression models to determine their individual levels of association with urinary inorganic mercury levels (µg/g creatinine) in Flin Flon Area children. Given the distribution of urinary inorganic mercury levels as illustrated in Section 4.0, the urinary inorganic mercury levels were log transformed and adjusted for creatinine levels in urine prior to analysis. The histograms in Section 4.0 demonstrate that the analysis of creatinine adjusted inorganic mercury is more defensible than unadjusted inorganic mercury levels given the frequency distributions fit better to a normal distribution than the unadjusted inorganic mercury levels.

As illustrated in Table 7-10, the six factors that were found at this initial stage to predict urinary inorganic mercury levels were:

- Child's age
- Region of residence
- Eating local game
- Number of dental amalgams
- Eating dirt
- Eating fish in the past 7 days.

Table 7-10: Univariate regressions to select personal factors for inclusion in multivariate models of log creatinine adjusted (µg/g)urinary inorganic mercury levels

Variable	P-value Log Creatinine Adjusted Inorganic Mercury
Gender	0.9800
Age at interview (years)	***<0.0001***
Area of Residence	***<0.0001***
Eating local game	***0.0002***
Number of dental amalgams (continuous) *excludes children with unknown number of amalgams*	***0.0001***
Adult self-reported occupational mercury exposure	0.8000
Eating dirt	***<0.0001***
Ate fish in past 7 days	***0.049***

As illustrated in Table 7-11, the overall regression model for log creatinine adjusted urinary inorganic mercury values was statistically significant ($p<0.0001$). The log creatinine adjusted urinary inorganic mercury levels were found to be significantly associated with:

- Number of dental amalgams
  - Children with more dental amalgams were more likely to have higher urinary inorganic mercury levels
- Eating local game
  - Children who ate local game were more likely to have higher urinary inorganic mercury levels
- Area of residence
  - Children who lived in Channing were more likely to have lower levels of urinary inorganic mercury
  - Children who lived in Creighton were more likely to have higher levels of urinary inorganic mercury

Table 7-11: Multivariate analysis of log creatinine adjusted inorganic mercury

Variable	Estimate	Geometric Standard Error	95% Confidence Interval		P-value
Constant	0.064	1.292	0.039	0.106	*<0.01*
Age					
Under 5 years old	1.00				
5 to 8 years old	0.98	1.26	0.62	1.55	0.93
9 yrs to 14 yrs old	1.35	1.27	0.84	2.17	0.21
Area of residence					
East Flin Flon	1.00				
West Flin Flon	0.97	1.41	0.50	1.91	0.94
Channing	0.40	1.48	0.19	0.88	***0.02***
Creighton	1.68	1.20	1.17	2.41	***<0.01***
Number of dental amalgams	1.29	1.07	1.13	1.47	***<0.01***
Eats local game	1.88	1.22	1.28	2.76	***<0.01***
Eating dirt					
Yes	0.99	1.32	0.57	1.71	0.969
No	1.00				
Don't know	0.000	1.543	0.000	0.001	*<0.01*
Ate fish in past 7 days					
Yes	1.17	1.25	0.75	1.84	0.479
No	1.00				
No data sheet	0.97	1.42	0.49	1.93	0.937
Don't know	2.35	1.37	1.26	4.41	*<0.01*

8.0 STUDY LIMITATIONS

Study quality can be judged in terms of both study design and execution. This study is characterized by a relatively large sample size that represents children from all parts of the Flin Flon Area. The study focused on critical age groups of children living in specific geographical areas in the overall Flin Flon Area where exposures from soil were expected to be highest. In addition to biological 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 samples were subject to well-defined collection, storage and analysis protocols, with multiple quality assurance and control checks.

Given the strengths outlined above, the study team deemed the study as an overall success; however, as with any study, there are some limitations that should be considered by the reader when reviewing the study 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 the COCs. The generalizability of the results arises from assumptions about the nature of exposure to contaminants found primarily in soil. All things being equal, considering the large 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. However, there may be differences in the relationship from individual to individual due to physical differences, as well as short term variations related to the intake of COCs. If behaviours and exposure conditions change, absorption of these contaminants 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 large sample and relatively high response rate for this study, we assume that the sample is representative of the overall population of children in the Flin Flon Area. The sample may be less representative of the smaller subgroups separated out for analysis (e.g., age groups, gender, and region) given the sample sizes are smaller and estimates, as a result, are less precise.

- **Biological sample collection methods:** Spot sample (first morning void) urine sample collection could be considered a limitation, when compared to 24-hour urine sample collection. However, for a large-scale community study such as this, 24-hour urine collection was not feasible and would likely have detrimentally affected the response rates obtained, in turn making the sample less representative of the population. Similarly, 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.

- **Seasonal timing of the study:** Data collection for the current study was conducted during September and October, 2010. 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.

- **Outliers and values below the limits of detection:** A large proportion of the samples of inorganic arsenic and inorganic mercury were below the detection limit (18% of inorganic arsenic levels and 50% of inorganic mercury). To account for levels that were below the limit of detection, an interval regression model using maximum likelihood methods was used to analyze the association between urine levels and other factors, such as age and place of residence. Outliers were identified through the examination of residuals. Residuals could only be calculated for levels above the limit of detection, and hence only outliers above the limit of detection could be removed from the analysis. The limitation for the study is that outliers that may have existed below the detection limit could not be identified, and were therefore not removed from the analyses.

9.0 SUMMARY AND CONCLUSIONS

There were four 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.

9.1 What is the current level of internal exposure to lead, arsenic, and inorganic mercury in the child population residing in the Flin Flon Area?

Lead

Overall, 202 blood samples were collected from Flin Flon Area children who were under seven years old (0 to 83 months). Blood lead levels ranged considerably from 0.46 µg/dL to 20.72 µg/dL. None of the blood samples was found to be below the limit of detection for blood lead (0.2 ug/dL). Approximately 13% of the samples (n= 27) were at or above the level chosen a priori for referral for follow-up (5 µg/dL). Approximately 2% of the samples (n=5) were at or above the Health Canada blood lead intervention level guideline of 10 µg/dL.

The geometric mean blood lead level measured in Flin Flon Area children was 2.75 µg/dL (95% CI: 2.51 – 2.95). The median was measured as 2.49 µg/dL. When stratified by gender, boys were more likely to have higher blood lead levels (3.09 µg/dL) than girls (2.34 µg/dL). Children who were 6 years of age (4.07 µg/dL) had the highest geometric means compared with the younger age groups. When blood lead levels were examined by region, children in West Flin Flon (3.63 µg/dL) had the highest geometric mean levels although no children in this region had levels at or above the current Health Canada intervention level of 10 µg/dL. The lowest geometric mean levels of blood lead were observed for children from the Channing area (2.00 µg/dL). Twenty-eight per cent (28%) of the children who provided samples in West Flin Flon were at or above 5 µg/dL compared to 16% in Creighton, 6% in East Flin Flon, and 0% in Channing.

Total Arsenic

Overall, 375 urine samples were obtained from Flin Flon Area children between the ages of 30 months and 179 months (2 ½ to 14 years). None of the urine samples were below the limit of detection for urinary total arsenic (3.745 µg/L). None of the samples were at or above the level chosen a priori for referral for follow-up (100 µg/L).

The geometric mean for unadjusted urinary total arsenic level measured in Flin Flon Area children was 12.30 µg/L (95% CI: 11.75 – 12.88 µg/L). The median was measured as 11.98 µg/L. When broken down by gender, the geometric mean was comparable for boys (12.59 µg/L) and girls (12.02 µg/L). Similarly, geometric means according to age groups were quite similar ranging from 11.48 µg/L for children under 5 years of age to 13.80 µg/L for children 5 to 8 years old. Similar results were also obtained for each geographic area with geometric means ranging from 11.22 µg/L in East Flin Flon to 14.45 µg/L in West Flin Flon. Creatinine adjusted values demonstrated similar patterns.

Inorganic Arsenic

The 375 urine samples analyzed for total arsenic were also analyzed for inorganic arsenic. Approximately 18% of urine samples (n=67) were found to be below the limit of detection for urinary inorganic arsenic (3.745 µg/L). Eleven of the samples (3%) were at the level chosen a priori for referral for follow-up (20 µg/L).

The geometric mean for unadjusted urinary inorganic arsenic levels measured in Flin Flon Area children was 6.35 µg/L (95% CI: 5.98– 6.74 µg/L). The median was measured as 5.99 µg/L. When broken down by gender, the geometric mean was similar for boys (6.41 µg/L) and girls (6.28 µg/L). Similar geometric means were also found across age groups ranging from 5.72 µg/L among 9 to 14 years old children to 7.25 µg/L among children aged 5 to 8 years. Comparable geometric means were also measured according to geographic region ranging from 5.87 µg/L among East Flin Flon children to 6.98 among children living in Channing. The pattern of results for creatinine adjusted values is similar to that found for the unadjusted values.

Inorganic Mercury

The 375 urine samples analysed for were also analysed for inorganic mercury. Approximately 50% of urine samples (n=188) were found to be below the limit of detection for urinary inorganic arsenic (0.1 µg/L). None of the samples were at the level chosen a priori for referral for follow-up (10 µg/L).

The geometric mean for adjusted urinary inorganic mercury levels measured in Flin Flon Area children was 0.11 µg/g (95% CI: 0.09– 0.14 µg/g). The geometric mean was calculated using maximum likelihood estimates given that 50% of the children had urinary inorganic mercury levels below the limit of detection. Given this, the geometric mean provides a better estimate than the median. When broken down by gender, the geometric mean was similar for boys (0.11 µg/g) and girls (0.12 µg/g). Similar geometric means were also found across age groups ranging from 0.09 µg/g among 5 to 8 years old children to 0.15 µg/g among children aged 9 to 14 years. Comparable geometric means were also measured according to geographic region ranging from 0.05 µg/g among Channing children to a slightly higher geometric mean among children living in Creighton (0.22).

9.2 Do Flin Flon Area child residents have higher lead, arsenic, and/or inorganic mercury levels than residents living in other parts of Canada?

Lead

The blood lead levels measured in Flin Flon Area children, and in particular West Flin Flon children who had the higher blood lead levels, were compared with numerous other studies. It should be noted that there were challenges in making each comparison as there is not a "perfect" comparison for Flin Flon Area children. For example, the communities being compared were likely quite different from the Flin Flon Area. With these cautions in mind, comparisons that have been made should be considered as providing a *context* within which the study results can be interpreted.

When the results from this study are compared to national level studies in the US, the Flin Flon Area results are slightly higher (2.75 µg/dL overall and 3.63 µg/dL in West Flin Flon compared with 1.77 µg/dL). It should be noted when making these comparisons that the US study (1.77 µg/dL) includes children from communities quite different from the Flin Flon Area.

When comparing the results for Flin Flon Area children with studies that have measured blood lead levels in other communities where there are potential concerns with lead exposure, the results for the Flin Flon Area children are comparable or even slightly lower (2.75 µg/dL overall and 3.63 µg/dL in West Flin Flon compared with 2.3 µg/dL – 5.3 µg/dL). Again, caution should be used in making interpretations from these comparisons given that the communities studied in some cases had different sources potential exposure, and are likely different from the Flin Flon Area communities in potentially important ways (e.g., diet, activities, housing stock, soil levels).

Total and Inorganic Arsenic

When compared with results from other studies, ***the Flin Flon Area levels of both total and inorganic arsenic were similar to other recent studies***. The levels of urinary total and inorganic arsenic measured in ***Flin Flon Area children were at the same levels found in other Canadian communities*** including communities with potential soil exposure (e.g., Falconbridge, Wawa, Deloro) and comparison communities with no soil contamination (e.g., Hanmer, Havelock).

Inorganic Mercury

When compared with results from other studies, ***the Flin Flon Area levels of inorganic arsenic were below levels found in other recent studies.*** It should be recalled that 50% of the samples obtained were below the detection limit. The levels of urinary inorganic mercury levels were lower than levels found in similarly aged populations in other studies.

9.3 Based upon the current scientific literature, what are the health risks from the levels of lead in blood, and arsenic and inorganic mercury in urine found in children in the Flin Flon Area?

Lead

The overall blood lead level for the Flin Flon area does not represent an immediate health concern. The most commonly reported and well-studied effects of environmental lead exposure are: 1) adverse effects on neurological function and neurobehavioural development in children; and, 2) reduced growth rate. However, it remains unclear if lead causes such effects in adults (U.S. EPA IRIS, 2004). The effects in children often manifest as decreased IQ and memory, decreased gestation period, and retarded growth rate. While the debate as to whether or not a threshold exists for the cognitive effects of lead in children continues, there is consistent information from the available lead health effects literature indicating that childhood blood lead levels >10 µg/dL are linked to decreased intelligence and impaired neurobehavioral development (ATSDR, 2007; CDC, 2009; Jusko et al., 2008, Lanphear et al., 2005; U.S. EPA IRIS, 2004; WHO, 1995).

The interpretation of blood lead levels in the Flin Flon Area is recommended in light of the most current information regarding the health effects of lead on children. ***The US Centers for Disease Control and Prevention state that there is no known minimum threshold of harm for lead exposure and Health Canada's policy is to reduce exposure to lead wherever practical***. Health Canada's 1994 guidance statement for a blood lead intervention level of 10 µg/dL is currently under review because of concern that adverse health effects may occur below 10 µg/dL. Certain other agencies (e.g. City of New York) advise action at 5 µg/dL for children or during pregnancy, and the literature indicates that adverse health effects may occur below 5 µg/dL.

Total and Inorganic Arsenic

Urinary arsenic levels found in children in the Flin Flon Area were not high enough to be associated with health risks. Finding a measurable amount of arsenic in urine does not mean that the level of arsenic causes an adverse health effect. The results found in Flin Flon Area children were very similar to levels observed in children in other Canadian communities with limited exposure to arsenic in soil.

Inorganic Mercury

The large majority of samples collected from the Flin Flon Area children had no detectable levels of inorganic mercury. ***Overall, the geometric mean of urinary inorganic mercury levels in the Flin Flon Area was at a level with no associated health risks***.

9.4 What personal factors are associated with the level of measured internal exposure of children in Flin Flon Area?

An attempt was made to find associations between the exposure levels measured and various personal factors or characteristics that theoretically could be related to exposure levels. It is quite important for the reader to note that these are measured ***associations*** and should not be inferred as cause and effect. In some cases, there may be additional factors or characteristics that were not measured directly that may be contributing to the various associations.

Lead

The personal factors associated with the measured blood lead levels in Flin Flon Area children were:

- Child's gender
  - 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 East Flin Flon children
- Adult currently smoking or using tobacco
  - Children living in households with adults who smoke or used tobacco were more likely to have higher levels
- Average hours child spends away from home
  - Children who spend more hours away from home were more likely to have higher levels
- Year the house was constructed
  - Children living in older houses were more likely to have higher levels.

These factors are those that showed stronger associations with blood lead levels. Most of them support logical relationships with lead exposure. One association that is less evident is the relationship between the average hours a child spends away from home and blood lead levels. This is likely a relationship that is masking other relationships which were not measured such as exposure in secondary residences (e.g., diet, household characteristics). Similarly, an association was found between adults who smoke in the household and blood lead levels, however there was not an association between child's exposure to second-hand smoke and blood lead levels. This may be attributable to an underestimation on the part of the parent as to the extent to which children are exposed to second-hand smoke or residue.

Total and Inorganic Arsenic
As previously described, the levels of both total and inorganic arsenic measured in Flin Flon Area children were similar to other Canadian communities, and were not associated with health risks. The only personal factors associated with total arsenic exposure levels was area of residence and age. Children in East Flin Flon being more likely to have lower levels of total arsenic exposure and younger children were more likely to have higher levels than older children. The main factors associated with levels of inorganic arsenic included:

- Child's age
  - Older children were more likely to have higher levels than younger children
- Child eats dirt
  - Children who ingested soil or dirt were more likely to have higher levels.
- Eating outside 7 days ago
  - Children who ate outside were more likely to have higher levels
- Eating fish in the past 7 days
  - Children who consumed fish in the past 7 days were more likely to have higher levels
- Source of water for drinking and cooking
  - Children who used only bottled water for drinking and cooking were more likely to have lower levels than those children who used only tap water

Given previously established relationships between activities and arsenic exposure, the associations found in the current study are similar in nature (e.g., active outdoors, water source).

Inorganic Mercury
The levels of inorganic mercury measured in Flin Flon Area children were lower compared to other communities, and were not associated with health risks. The factors associated with levels of inorganic mercury included:

- Number of dental amalgams
  - Children with more dental amalgams were more likely to have higher urinary inorganic mercury levels
- Eating local game
  - Children who ate local game were more likely to have higher urinary inorganic mercury levels
- Area of residence
  - Children who lived in Channing were more likely to have lower levels of urinary inorganic mercury
  - Children who lived in Creighton were more likely to have higher levels of urinary inorganic mercury

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