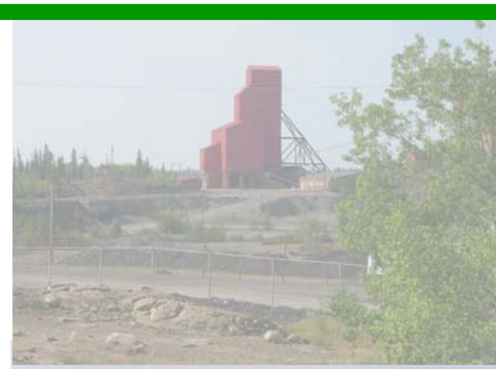
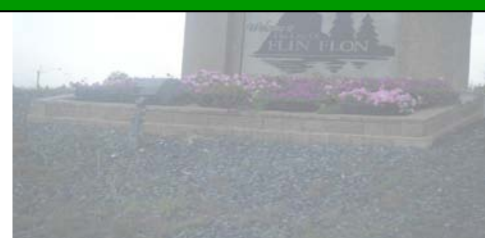
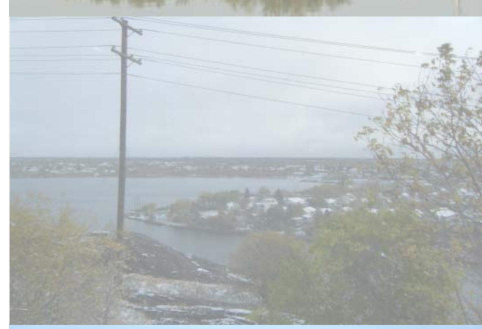
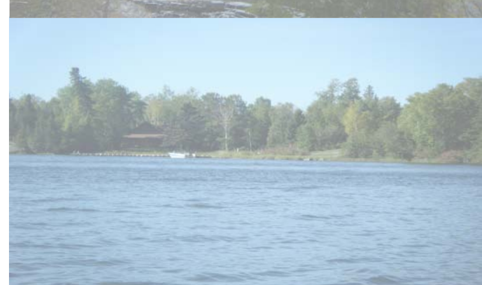


APPENDIX H

MODEL ASSUMPTIONS, EQUATIONS, ALGORITHMS AND WORKED EXAMPLE







APPENDIX H: MODEL ASSUMPTIONS, EQUATIONS, ALGORITHMS AND WORKED EXAMPLE

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APPENDIX H: MODEL ASSUMPTIONS, EQUATIONS, ALGORITHMS AND WORKED EXAMPLE

H-1.0 INTRODUCTION

This appendix provides technical information (*i.e.,* quantitative input parameters and equations) used in the assessment of exposure and related human health risk for the Flin Flon area Human Health Risk Assessment (HHRA). Refer to Chapter 3 (Problem Formulation) and Chapter 4 (Detailed Human Health Risk Assessment) of the main report for a detailed discussion regarding the rationale used to derive specific input parameters and exposure assumptions.

The Chemicals of Concern (COC) for the HHRA were: arsenic, cadmium, copper, lead, mercury, and selenium. The estimation of exposure to COC was based on the following parameters:

- The physical/chemical characteristics of COC which determine the interaction and behaviour of a chemical with its surrounding environment (*e.g.,* water solubility, volatility, tendency to bind to particles);
- The characteristics of the environmental compartments at the site (*e.g.,* air, soil, dust and water), as well as the quantities of chemicals entering the compartments from various sources, and their persistence in these compartments;
- The behavioural and lifestyle characteristics of the human receptors that determine the actual exposures through interactions of the receptors with the various pathways (*e.g.,* respiration rate, body weight); and,
- The equations and algorithms used to predict exposures to the receptors.

This Appendix has been divided into four components: i) human receptor selection and characteristics; ii) media-specific exposure point concentrations; iii) calculated exposure estimates; and, iv) health risk characterization.

H-2.0 HUMAN RECEPTOR SELECTION AND CHARACTERISTICS

H-2.1 Receptor Selection

A human receptor is a hypothetical person (*i.e.,* an infant, toddler, child, teen, or adult) who may reside, spend leisure time and/or work in the area being investigated and is, or could potentially be, exposed to the chemicals identified as being of COC. General physical and behavioural characteristics specific to the receptor type (*e.g.*, body weight, breathing rate, food consumption rate, *etc*.) are used to approximate the amount of chemical exposure received by each receptor. Due to differences in physiological characteristics and activity patterns between children and adults, the exposures received by a child and an adult will be different. Consequently, the potential risks estimated for the same COC will differ depending on the receptor chosen for evaluation.

For chemicals considered to be carcinogenic, it is common to assess exposure over a lifetime, as development of cancer is a long-term process that may take many years to manifest itself. For this reason, a special type of receptor called a “lifetime” or “composite” receptor is selected for evaluation of potential carcinogenic risks. This receptor is a “composite” of all relevant life stages for which exposure will be evaluated. Health risks associated with exposure to carcinogenic compounds are usually expressed as an estimate of excess or incremental lifetime cancer risk (ILCR) resulting from exposures to a particular source. Thus, risks associated with carcinogenic compounds are predicted using the average daily dose over a human receptor's entire life span.

In order to allow a comprehensive assessment of COC, all five age classes will be evaluated in the study (as per Health Canada, 2006):

i. Infant (0 to 6 months);
ii. Preschool child or toddler (7 months to 4 years);
iii. Child (5 years to 11 years);
iv. Adolescent or teen (12 to 19 years); and,
v. Adult (20 years and over).

In order to evaluate potential exposures, it is necessary to characterize the physiological and behavioural characteristics of each receptor group. Several published resources were considered in the selection of these parameters, including:

- *Federal Contaminated Sites Risk Assessment in Canada. PART I: Guidance on Human Health Risk Preliminary Quantitative Risk Assessment (PQRA).* (Health Canada, 2006);
- *Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc. 1155-2720 Queensview Dr., Ottawa, Ontario.* (Richardson, 1997);
- *Human Health Risk Assessment for Priority Substances: Canadian Environmental Protection Act: ISBN 0-662-22126-5; (*Health Canada, 1994);
- *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. EPA/540//R/99/005. July, 2004*. (U.S. EPA, 2004);
- *Users Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows Version – 32 Bit Version. Office of Solid Waste and Emergency Response U.S. Environmental Protection Agency Washington, DC 2046. May 2002. EPA 540-K-01-005.* (U.S. EPA, 2002)*; and,*
- *The U.S. EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. (U.S. EPA, 2005).

These sources have been used in numerous HHRAs that have been critically reviewed and accepted by regulatory agencies across Canada and the United States. Both the Compendium of Canadian Human Exposure Factors for Risk Assessment (Richardson, 1997) and Health Canada (2006) rely on data from published and reliable Canadian sources, such as Health Canada, Statistics Canada, and the Canadian Fitness and Lifestyles Research Institute. Where insufficient data are available in these sources to appropriately characterize relevant activity patterns and/or behavioural/physiological characteristics of a certain receptor group, other appropriate sources such as the U.S. EPA *Exposure Factors Handbook* (U.S. EPA, 1997) were used to supplement the receptor parameter dataset. In addition to the published resources listed above, site-specific information gathered as part of past and current programs including the local food consumption survey will be used to characterize receptor parameters.

H-2.2 Receptor Characteristics

Receptor characteristics reflective of a Central Tendency Estimate (CTE) were selected for use in the HHRA. A list of parameters and assumptions describing the physiological and behavioural characteristics of each receptor evaluated in the HHRA is provided in Tables H-1 to H-5.

As discussed in Chapter 3 of the main report, data from Richardson (1997) was used to characterize assumptions for each of the assessed life stages. Receptor-specific ingestion rates for specific food groups taken from Richardson (1997) were based upon the original Nutrition Canada survey (1970 to 1972), and has been peer reviewed both by Nutrition Canada (prior to its release to Health Canada) and Health Canada itself.

Table H-1 Receptor Characteristics and Assumptions for the Infant Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Exposure duration	yr	0.5	-	Health Canada (2006)
Exposure frequency – residential	days/yr	182	-	Health Canada (2006)
Body weight	kg	8.2	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	2.1	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	0.3	Arithmetic mean	Richardson (1997); Health Canada (2006)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	320	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	550	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	910	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	3620	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	15	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	37	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	468	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	0	-	Richardson (1997)
Fats and Oils	g/day	0	-	Richardson (1997)
Formula	g/day	113	Arithmetic mean	Richardson (1997)
Fruits and Juices	g/day	99	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	22	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	0	-	Richardson (1997)
Root Vegetables	g/day	8.8	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	30	Arithmetic mean	Richardson (1997)

Table H-1 Receptor Characteristics and Assumptions for the Infant Receptor				
Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Local Food Consumption Rates				
Fish	g/day	0	-	Assumed
Blueberries	g/day	0.61	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0	-	Assumed
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table H-2 Receptor Characteristics and Assumptions for the Toddler Receptor				
Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Exposure duration	yr	4.5	-	Health Canada (2006)
Exposure frequency –residential	days/yr	365	-	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90^{th} percentile	U.S. EPA (2003); based on the 90^{th} percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	2.3	50^{th} percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for children 5-11 from U.S. EPA (1997)
Body weight	kg	16.5	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	9.3	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	0.6	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.08	-	Health Canada (2006)
Surface area – hands	cm^2	430	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	890	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	1,690	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	6,130	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	77	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	167	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	579	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	4.7	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	21	Arithmetic mean	Richardson (1997)
Formula	g/day	3.3	Arithmetic mean	Richardson (1997)
Fruits and Juices	g/day	179	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	48	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	2.79	Arithmetic mean	Richardson (1997)

Table H-2 Receptor Characteristics and Assumptions for the Toddler Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Root Vegetables	g/day	79	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	46	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	11	-	Local Food Survey
Blueberries	g/day	1.2	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.1	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table H-3 Receptor Characteristics and Assumptions for the Child Receptor

Description	*Units*	*Value*	*Statistic*	*Reference*
Exposure duration	yr	7.0	-	Health Canada (2006)
Exposure frequency – residential	days/yr	365	-	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90^{th} percentile	U.S. EPA (2003); based on the 90^{th} percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	2.3	50^{th} percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for children 5-11 from U.S. EPA (1997)
Body weight	kg	32.9	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	14.5	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	0.8	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	590	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	1,480	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	3,070	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	10,140	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	115	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	264	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	591	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	10	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	37	Arithmetic mean	Richardson (1997)
Formula	g/day	0	-	Richardson (1997)
Fruits and Juices	g/day	197	Arithmetic mean	Richardson (1997)

Table H-3 Receptor Characteristics and Assumptions for the Child Receptor				
Description	***Units***	***Value***	***Statistic***	***Reference***
Other vegetables	g/day	80	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	7.27	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	132	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	66	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	22	-	Local Food Survey
Blueberries	g/day	2.4	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.13	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table H-4 Receptor Characteristics and Assumptions for the Teen Receptor				
Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Exposure duration	yr	8.0	-	Health Canada (2006)
Exposure frequency – residential	days/yr	365	-	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90^{th} percentile	U.S. EPA (2003); based on the 90^{th} percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	1.7	50^{th} percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for children 12-17 from U.S. EPA (1997)
Body weight	kg	59.7	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	15.8	Arithmetic mean	Richardson, 1997; recommended by Health Canada (2006)
Water intake rate	L/day	1.0	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	800	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	2,230	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	4,970	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – whole body	cm^2	15,470	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	158	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	280	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	545	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	12	Arithmetic mean	Richardson (1997)

Table H-4 Receptor Characteristics and Assumptions for the Teen Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Fats and Oils	g/day	49	Arithmetic mean	Richardson (1997)
Formula	g/day	0	-	Richardson (1997)
Fruits and Juices	g/day	163	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	95	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	7.52	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	185	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	71	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	40	-	Local Food Survey
Blueberries	g/day	4.4	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.17	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

Table H-5 Receptor Characteristics and Assumptions for the Adult Receptor

Description	*Units*	*Value*	*Statistic*	*Reference/Comment*
Exposure duration	yr	60	-	Health Canada (2006)
Exposure frequency - residential	days/yr	365	-	Health Canada (2006)
Exposure frequency - commercial	days/yr	240	Mean	Health Canada (2006)
Exposure frequency - commercial	hrs/day	10	Mean	Health Canada (2006)
Swim events per year - recreational	events/yr	30	90^{th} percentile	U.S. EPA (2003); based on the 90^{th} percentile swim events per month from U.S. EPA (1997) for 3 months per year
Duration of swim event - recreational	hrs/event	1.3	50^{th} percentile	U.S. EPA (2003); recommended exposure duration for long-term exposure for adults from U.S. EPA (1997)
Body weight	kg	70.7	Arithmetic mean	Richardson (1997); Health Canada (2006)
Breathing rate	m^3/day	15.8	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water intake rate	L/day	1.5	Arithmetic mean	Richardson (1997); Health Canada (2006)
Water ingestion while swimming	L/hrs	0.05	-	U.S. EPA (1989)
Soil/dust intake rate	g/day	0.02	-	Health Canada (2006)
Surface area – hands	cm^2	890	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – arms	cm^2	2,500	Arithmetic mean	Richardson (1997); Health Canada (2006)
Surface area – legs	cm^2	5,720	Arithmetic mean	Richardson (1997); Health Canada (2006)

Table H-5 Receptor Characteristics and Assumptions for the Adult Receptor				
Description	***Units***	***Value***	***Statistic***	***Reference/Comment***
Surface area – whole body	cm^2	17,640	Arithmetic mean	Richardson (1997)
Market Basket Food Consumption Rates				
Meat and Eggs	g/day	158	Arithmetic mean	Richardson (1997)
Cereals and Grains	g/day	219	Arithmetic mean	Richardson (1997)
Milk and Dairy	g/day	265	Arithmetic mean	Richardson (1997)
Fish and Shellfish	g/day	16	Arithmetic mean	Richardson (1997)
Fats and Oils	g/day	44	Arithmetic mean	Richardson (1997)
Formula	g/day	0	-	Richardson (1997)
Fruits and Juices	g/day	168	Arithmetic mean	Richardson (1997)
Other vegetables	g/day	109	Arithmetic mean	Richardson (1997)
Nuts and Seeds	g/day	2.93	Arithmetic mean	Richardson (1997)
Root Vegetables	g/day	153	Arithmetic mean	Richardson (1997)
Sugars and Sweets	g/day	58	Arithmetic mean	Richardson (1997)
Local Food Consumption Rates				
Fish	g/day	48	-	Local Food Survey
Blueberries	g/day	5.2	Mean + SE	U.S. EPA (1997)
Wild Game (fraction of market basket meat and eggs)	unitless	0.20	-	Local Food Survey
Home Garden Root Vegetables (fraction of market basket rate)	unitless	0.018	Mean	U.S. EPA (1997)
Home Garden Other Vegetables (fraction of market basket rate)	unitless	0.062	Mean	U.S. EPA (1997)

H-3.0 SUMMARY OF EXPOSURE POINT CONCENTRATIONS

Table H-6 provides a summary of the exposure point concentration (EPC) data used in the current assessment. Refer to Chapters 3 and 4 for detailed information on the derivation of these EPC values.

Table H-6 Summary of Exposure Point Concentrations used in the HHRA						
	Arsenic[a]	***Cadmium***[b]	***Copper***	***Lead***	***Mercury***[c]	***Selenium***
Soil Concentrations µg/g						
West Flin Flon	77	28	2,800	370	130	39
East Flin Flon	17	16	870	160	7.2	4.6
Creighton	88	16	850	250	8.9	7.2
Channing	22	14	510	160	4.1	2.6
Typical Background	2.5	0.2	26	5	0.14	0.2
Dust Concentrations (calculated)[d] µg/g						
West Flin Flon	68	22	2,300	260	5.8	10
East Flin Flon	42	17	1,600	320	1.7	4.4
Creighton	71	17	1,600	260	1.8	4.9
Channing	46	17	1,400	320	1.6	4.1

Table H-6 Summary of Exposure Point Concentrations used in the HHRA						
	Arsenic [a]	***Cadmium*** [b]	***Copper***	***Lead***	***Mercury*** [c]	***Selenium***
Typical Background [e]	2.5	0.2	26	5	0.1	0.2
Air Concentrations (outdoor and indoor) µg/m^3						
West Flin Flon	0.084	0.07	0.84	0.34	0.016	0.052
East Flin Flon	0.040	0.026	0.22	0.10	0.000094	0.014
Creighton	0.0085	0.0046	0.058	0.034	0.0013	0.0042
Channing	0.040	0.026	0.22	0.10	0.000094	0.014
Typical Background	0.001	0.0055	0.009	0.0026	NA	0.0018
Drinking Water µg/L						
West Flin Flon	3	1.3	520	4.6	0.056	1.8
East Flin Flon	3	1.3	520	4.6	0.056	1.8
Creighton	2.2	0.89	124	3.1	0.052	1.1
Channing	3	1.3	520	4.6	0.056	1.8
Typical Background	3.0	NA	41	1.9	0.01	1.6
Home Garden – Below Ground Vegetables µg/g wet weight						
All Communities	0.012	0.051	1.6	0.033	0.0025	0.3
Home Garden - Above Ground Vegetables µg/g wet weight						
All Communities	0.014	0.24	2.0	0.28	0.0082	0.3
Fish, Wild Game, and Blueberries µg/g wet weight						
Wild Game	0.00017	0.079	2	0.025	0.0068	0.37
Fish	0.0097	0.0084	0.31	0.031	0.45	1.6
Wild Blueberries	0.035	0.048	2.1	0.51	0.01	0.1
Surface Water µg/L	8.0	2.2	19	1.0	0.024	5.0
Sediment µg/g	110	150	2,600	630	2.6	100
Snow µg/L	96	113	3,000	483	1	2
Market Basket µg/g wet weight						
Dairy Products	0.0032	-	0.2	0.006	0.00071	0.038
Meat, Poultry and Eggs (without organ meats)	0.00046	-	1.0	0.0066	0.0011	0.17
Fish and Shellfish	0.0049	-	1.3	0.0069	0.29	0.31
Bakery Goods and Cereals	0.0032	-	1.4	0.012	0.00034	0.17
Root Vegetables	0.0043	-	1.1	0.0073	0.00022	0.014
Other Vegetables	0.0093	-	0.9	0.005	0.0059	0.016
Fruit and Fruit Juices	0.0019	-	0.85	0.014	0.00024	0.0083
Fats and Oils	0.0091	-	0.25	0.00038	0.00019	0.012
Nuts and Seeds	0.0073	-	14	0.014	0.001	0.34

Table H-6	Summary of Exposure Point Concentrations used in the HHRA					
	Arsenic [a]	***Cadmium*** [b]	***Copper***	***Lead***	***Mercury*** [c]	***Selenium***
Sugar and Candies	0.0077	-	1.4	0.04	0.00019	0.010
Infant Formula	0.0000072	-	0.9	0.0023	0.00023	0.012

NA Not available

[a] The arsenic exposure point concentration for all food products (*i.e.*, home garden, local produce, fish and wild game, and market basket foods) were adjusted to represent only the inorganic arsenic fraction content of the food (on which the TRV is based), as follows: all vegetable produce: 0.59, fruits and berries: 0.41, wild game: 0.01, market basket fish: 0.024, local fish: 0.068, infant formula: 0.56 (based upon whole milk), dairy: 0.47, meat and eggs: 0.03, cereals and grains: 0.21, sugars and sweets: 0.34; fats and oils: 0.34, and nuts and seeds: 0.34. Refer to Chapter 4, section 4.1.3 for further discussion of these factor adjustments, and Table 4-27 for the adjustment factors for each specific food grouping.

[b] Insufficient literature-based data on cadmium content in individual market basket foods were available. Therefore, the total food EDI recommended by CCME was used in the HHRA (refer to Table 4-28).

[c] Exposure point concentrations represent total mercury concentrations. For the purposes of exposure and risk calculations, total mercury measured in soil, dust, home garden produce, blueberries, wild game, sediment and all market basket foods other than fish was assumed to be 100% inorganic mercury; methyl mercury was assumed to be 100% of the total mercury in market basket fish, 25% of the total mercury in drinking water, and 20% of the total mercury measured in ambient air.

[d] Indoor dust concentrations were calculated based upon regression equations developed from paired soil and indoor dust data collected during the indoor dust survey except for lead. The EPC indoor dust concentration for lead is based on measured indoor dust data.

[e] Background indoor dust concentrations were not identified in the literature. The typical background soil concentrations were used as surrogate values.

H-4.0 EQUATIONS AND ALGORITHMS USED TO ESTIMATE HUMAN EXPOSURE RATES

The purpose of the following section is to provide a worked example outlining how exposure and human health risk estimates were calculated for the current assessment.

The following is a worked example based on a toddler residing in the community of West Flin Flon while being exposed to media-specific lead concentrations provided in Table H-6, through a number of exposure scenarios, using the receptor assumptions provided in Table H-2. All exposure values are provided in units of µg of lead per kilogram receptor bodyweight per day of exposure (µg/kg/day).

H-4.1 Exposure through Inhalation of Outdoor and Indoor Air

Exposure to COC in outdoor and indoor air was assessed through the inhalation of the PM_{10} fraction of airborne particulate matter. Given that it was assumed that concentrations of COC in indoor air were equal to concentrations measured in outdoor air, the amount of time spent indoors and outdoors was not relevant to predict exposure *via* inhalation. The relative absorption factor for each COC *via* inhalation was assumed to be 100%. The exposure of a toddler living in West Flin Flon to lead in outdoor air was calculated as follows:

Residential Inhalation of Fine Particulates in Air

$$EXP_{Inh} = \frac{C_{air} * EF * BR * RAF_{Inh}}{BW * DPY}$$

where:

EXP_{Inh}	=	exposure *via* inhalation (µg/kg/day)
C_{air}	=	exposure point concentration of COC in air (0.34 µg/m^3)
EF	=	exposure frequency (365 days/year)
BR	=	breathing rate (9.3 m^3/day)
RAF_{Inh}	=	relative absorption factor *via* inhalation (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through the inhalation of air is 1.9x10^{-1} µg/kg/day.

H-4.2 Estimate of Exposure from Dermal Contact with Soil/Dust

To estimate exposure *via* dermal contact with soil and dust under the residential exposure scenario, assumptions must be made regarding the time spent indoors and outdoors and the surface area of exposed skin throughout the year. It was assumed that for four months (122 days) of the year, winter snow cover would prevent direct exposure to outdoor soil. In addition, a limited amount of skin is assumed to be left exposed when spending time outdoors during this time thereby significantly limiting any potential dermal contact with soils. All dermal exposure during this time was assumed to be from contact with indoor dust. During time spent indoors on these colder months, it was assumed that arms and hands would be exposed and be available for dermal uptake of COC found in indoor dust. For the remaining eight months (243 days) of the year, dermal exposure was assumed to occur from direct contact with outdoor soil. During time spent outdoors on these warmer months, it was conservatively assumed that the hands, arms, and legs would be exposed and be available for dermal uptake of COC in outdoor soil.

On a daily basis, it is assumed that a single dermal exposure event occurs which is a function of the surface area of exposed skin and the soil/dust adherence to this skin. This will produce an estimate of the mass of COC adhered to the skin on a daily basis. Since route-specific TRVs are not available for dermal exposure, the dermal exposure must be compared to the oral TRV. The insoluble nature of most metals in soil/dust limits their potential for uptake through the skin. Available data on dermal uptake of metals indicate that uptake rates are low (Paustenbach, 2000). Since dermal absorption of the COC are low relative to oral absorption, the dermal exposure was adjusted by applying a relative dermal absorption factor (RAF_{Dermal}) to account for the relative difference in absorption between the oral and dermal routes. Therefore, the estimated mass value is multiplied by a chemical-specific RAF_{Dermal} to yield the soil/dust dermal exposure estimate in µg/kg body weight/day. The RAF_{Dermal} were those recommended by Health Canada (2008) and RAIS (2008) (Table H-7).

Table H-7 Relative Dermal Absorption Factors

COC	RAF_{Dermal}	*Reference*
Arsenic	0.03	Health Canada, 2008; RAIS, 2008
Cadmium	0.001	RAIS, 2008
Copper	0.001	Health Canada, 2008
Lead	0.006	Health Canada, 2008
Mercury	0.05	Health Canada, 2008

Table H-7 Relative Dermal Absorption Factors		
COC	***RAF_{Dermal}***	***Reference***
Selenium	0.002	Health Canada, 2008

The exposure of a toddler living in West Flin Flon to lead in outdoor soil *via* dermal contact was calculated as follows:

Residential Dermal Contact with Outdoor Soil

$$EXP_{Dermal\ Soil} = \frac{EF_S * EPD * C_{soil} * RAF_{Dermal} * [(SA_{hands} * AF_{hands}) + (SA_{AL} * AF_{other})]}{BW * DPY}$$

where:

$EXP_{Dermal\ Soil}$	=	dermal exposure *via* direct contact with soil (µg/kg/day)
EF_S	=	exposure frequency for summer months (243 days/year)
EPD	=	exposure events per day (1 event/day)
C_{soil}	=	exposure point concentration of COC in soil (370 µg/g)
RAF_{Dermal}	=	chemical-specific relative dermal absorption factor (0.006 unitless)
SA_{hands}	=	surface area of hands (0.043 m^2)
AF_{hands}	=	soil adherence factor for hands (1 g/m^2/event)
SA_{AL}	=	surface area of arms and legs (0.258 m^2)
AF_{other}	=	soil adherence factor for area other than hands (0.1 g/m^2/event)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through dermal contact with outdoor soil is 6.2×10^{-3} µg/kg/day.

The exposure of a toddler living in West Flin Flon to lead in indoor dust *via* dermal contact was calculated as follows:

Residential Dermal Contact with Indoor Dust

$$EXP_{Dermal\ Dust} = \frac{C_{dust} * RAF_{Dermal} * [(EF_w * EPD * ((SA_{hands} * AF_{hands}) + (SA_{Arms} * AF_{other})))]}{BW * DPY}$$

where:

$EXP_{Dermal\ Dust}$	=	dermal exposure *via* direct contact with indoor dust (µg/kg/day)
C_{dust}	=	exposure point concentration of COC in indoor dust (265 µg/g)
RAF_{Dermal}	=	chemical-specific relative dermal absorption factor (0.006 unitless)
EF_W	=	exposure frequency for winter months (122 days/year)
EPD	=	exposure events per day (1 event/day)
SA_{hands}	=	surface area of hands (0.043 m^2)
AF_{hands}	=	soil adherence factor for hands (1 g/m^2/event)
AF_{other}	=	soil adherence factor for area other than hands (0.1 g/m^2/event)
SA_{arms}	=	surface area of arms (0.089 m^2)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through dermal contact with indoor dust is 1.7×10^{-3} µg/kg/day.

H-4.3 Estimate of Exposure from Incidental Ingestion of Soil/Dust

Under the residential exposure scenario, it was assumed that for four months (122 days) of the year, winter snow cover would prevent direct exposure to outdoor soil. Therefore, during this time, 100% of the recommended daily soil/dust ingestion was assumed to be from ingestion of indoor dust. For the remaining eight months (243 days), 100% of the recommended daily soil/dust ingestion was assumed to be from ingestion of outdoor soil.

The effective intake of COC from soil/dust ingestion is dependent upon the amount of chemical released from the soil/dust during digestion. This is especially the case for metals. Only metals that are released in soluble form from soil/dust particles into the stomach or intestines during digestion are considered to be available for uptake. Metals not released from soil/dust are excreted in the feces and do not have the opportunity to cause adverse health effects. Therefore, in assessing exposure and potential human health risks from soil/dust ingestion, it is necessary to consider the amount of chemical that is actually released from the soil/dust into the gut and small intestine, and not just the total amount that is ingested within the soil/dust. Under ambient conditions in soil/dust, most metals are generally insoluble in water and tend to remain bound to soil/dust particles under neutral conditions (pH 6 to pH 8). However, the solubility of most metals increases under acidic conditions. Therefore, given the acidic conditions of the stomach, it is reasonable to expect that a portion of bound metals will be released and become bioaccessible. Results of the site-specific bioaccessibility study for arsenic and lead were used to determine the bioaccessibility of these COC from soil relative to the medium used to derive the toxicological criterion. For all other COC, the oral bioaccessibity was conservatively assumed to be 100% (Table H-8). Refer to Appendix G for a discussion on the results of the bioaccessibility study.

Table H-8	Relative Absorption Factors for Oral Exposure to Soil and Dust			
COC	RAF_{Soil}	***Source***	RAF_{dust}	***Source***
Arsenic	0.33	Site-Specific Study	0.33	Assumed
Cadmium	1.0	Assumed	1.0	Assumed
Copper	1.0	Assumed	1.0	Assumed
Lead	0.58	Site-Specific Study	0.58	Assumed
Mercury	1.0	Assumed	1.0	Assumed
Selenium	1.0	Assumed	1.0	Assumed

The exposure of a toddler living in West Flin Flon to lead in outdoor soil *via* ingestion was calculated as follows:

Residential Ingestion of Outdoor Soil

$$EXP_{Ing\ Soil} = \frac{EF_S * C_{Soil} * SIR * RAF_{Soil}}{BW * DPY}$$

where:

$EXP_{Ing\ Soil}$	=	exposure *via* incidental ingestion of soil (µg/kg/day)
EFs	=	exposure frequency during summer (243 days/year)
C_{Soil}	=	exposure point concentration of COC in soil (370 µg/g)
SIR	=	soil/dust ingestion rate (0.08 g/day)
RAF_{Soil}	=	relative absorption factor for ingested soil (0.58 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of outdoor soil is 6.9×10^{-1} µg/kg/day.

The exposure of a toddler living in West Flin Flon to lead in indoor dust *via* ingestion was calculated as follows:

Residential Ingestion of Indoor Dust

$$EXP_{Ing\ Dust} = \frac{EF_W * C_{Dust} * SIR * RAF_{Dust}}{BW * DPY}$$

where:

$EXP_{Ing\ Dust}$	=	exposure *via* incidental ingestion of dust (µg/kg/day)
EFw	=	exposure frequency during winter (122 days/year)
C_{Dust}	=	exposure point concentration of COC in dust (265 µg/g)
SIR	=	soil/dust ingestion rate (0.08 g/day)
RAF_{Dust}	=	relative absorption factor for ingested dust (0.58 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of indoor dust is 2.5×10^{-1} µg/kg/day.

H-4.4 Estimate of Exposure from Consumption of Drinking Water

Exposure to COC *via* the ingestion of municipal drinking water was assessed using EPCs derived for all communities in Flin Flon (*i.e*., East Flin Flon, West Flin Flon, and Channing) and for Creighton based on the ongoing drinking water monitoring program and the short-term multiple location sample event completed by Jaques Whitford Limited. Age-specific water intake rates are those recommend by Health Canada (2006). The relative absorption factor for each COC *via* consumption of drinking water was assumed to be 100%.

The exposure of a toddler living in West Flin Flon to lead *via* ingestion of drinking water was calculated as follows:

Ingestion of Drinking Water

$$EXP_{DW} = \frac{C_{DW} * IR_{DW} * EF * RAF_{DW}}{BW * DPY}$$

where:

EXP_{DW}	=	exposure *via* consumption of drinking water (µg/kg/day)
C_{DW}	=	exposure point concentration of COC in drinking water (4.6 µg/L)
IR_{DW}	=	intake rate of drinking water (0.6 L/day)
EF	=	exposure frequency (365 days/year)
RAF_{DW}	=	relative absorption factor for drinking water (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of drinking water is 1.7×10^{-1} µg/kg/day.

H-4.5 Estimate of Exposure from Consumption of Home Garden Vegetables

Exposure to COC was assessed *via* the consumption of vegetables grown in home gardens in the study area under the residential exposure scenario. The results of the Manitoba Conservation home garden study was used to characterize concentrations of each COC in aboveground and root vegetables. The consumption rates of home garden vegetables is based on the recommended daily intake rates for root and aboveground vegetables (Richardson, 1997) for each age class and the application of a generic fraction of total intake represented by home produced vegetables as recommended by U.S. EPA (1997). Table 13-71 of the U.S. EPA *Exposure Factors Handbook* indicates that for the northeast region, 6.2% of all aboveground vegetables and 1.8% of all root vegetables consumed are derived from home gardens. The relative absorption factor for each COC *via* consumption of home-grown vegetables was assumed to be 100%.

The exposure of a toddler living in West Flin Flon to lead *via* ingestion of home garden root vegetables was calculated as follows:

Ingestion of Home-grown Root Vegetables

$$EXP_{RV} = \frac{C_{RV} * CR_{RV} * EF * Fr_{HGRV} * RAF_{Food}}{BW * DPY}$$

where:

EXP_{RV}	=	exposure from ingestion of home-grown root vegetables (µg/kg/day)
C_{RV}	=	exposure point concentration of COC in home-grown root vegetables (0.033 µg/g ww)
CR_{RV}	=	consumption rate of root vegetables (79 g/day)
EF	=	exposure frequency (365 days/year)
Fr_{HGRV}	=	fraction of root vegetables consumed derived from home gardens (0.018 unitless)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of home garden root vegetables is 2.8×10^{-3} µg/kg/day.

The exposure of a toddler living in West Flin Flon to lead *via* ingestion of home garden above-ground vegetables was calculated as follows:

Ingestion of Home-grown Above Ground Vegetables

$$EXP_{AGV} = \frac{C_{AGV} * CR_{AGV} * EF * Fr_{HGAGV} * RAF_{Food}}{BW * DPY}$$

where:

EXP_{AGV}	=	exposure from ingestion of home-grown above ground vegetables (µg/kg/day)
C_{AGV}	=	exposure point concentration of COC in home-grown above ground vegetables (0.28 µg/g ww)
CR_{AGV}	=	consumption rate of above ground vegetables (48 g/day)
EF	=	exposure frequency (365 days/year)
Fr_{HGAGV}	=	fraction of above ground vegetables consumed derived from home gardens (0.062 unitless)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of home garden above-ground vegetables is 5.0×10^{-2} µg/kg/day.

H-4.6 Estimate of Exposure from Consumption of Local Wild Blueberries

Exposure to COC was assessed *via* the consumption of local wild blueberries under the residential exposure scenario. The results of the Stantec (2009) local blueberry sampling study were used to characterize concentrations of COC in blueberries collected in the study area.

Since there is an abundance of blueberries in the area, rather than deriving a consumption rate that is based on a typical fruit or berry consumption rate and allocating a fraction of this to local berries, it was conservatively assumed that consumption of wild blueberries would be a separate consumption rate in addition to the consumption of market basket berries. The U.S. EPA (1997; Table 13-49) lists an average consumer-only consumption rate of homegrown "other berries" of 0.48 g/kg/day and a standard error of 0.042. Using a consumption rate equal to the average plus the standard error (*i.e.*, 0.52 g/kg/day), this represents a local blueberry ingestion rate of 37 g/day for a 70.7 kg adult. It was conservatively assumed that receptors would freeze blueberries and consume them one day per week throughout the entire year. Therefore, the average daily consumption rate over the course of the year is 0.074 g/kg/day, or 5.2 g/day for an adult. This equates to an annual consumption rate of 1.9 kg/year (or 4.2 pounds/year) for an adult. Receptors of all age categories were assumed to consume local berries at a rate of 0.074 g/kg/day (Table H-9).

Table H-9 Rates for the Consumption of Local Blueberries

Receptor	***Consumption Rate (g/kg/day)***	***Consumption (g/day)***
Infant	0.074	0.61
Toddler	0.074	1.2
Child	0.074	2.4
Teen	0.074	4.4
Adult	0.074	5.2

The relative absorption factor for each COC *via* consumption of local blueberries was assumed to be 100%. The exposure of a toddler living in West Flin Flon to lead *via* ingestion of local wild blueberries was calculated as follows:

Ingestion of Local Wild Blueberries

$$EXP_{WB} = \frac{C_{WB} * CR_{WB} * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{WB}	=	exposure from ingestion of local wild blue berries (µg/kg/day)
C_{WB}	=	exposure point concentration of COC in local wild blue berries (0.51 µg/g ww)
CR_{WB}	=	wild berry consumption rate (1.2 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of local wild blueberries is 3.7×10^{-2} µg/kg/day.

H-4.7 Estimate of Exposure from Consumption of Local Wild Game

Exposure to COC was assessed *via* the consumption of local wild game under the residential exposure scenario. Since it is unrealistic to assume that residents would be consuming local wild game meat in addition to the Health Canada recommended total meat intake represented within the market basket assessment, the consumption of market basket meats was adjusted by subtracting the fraction represented by local wild game consumption (H-10). The relative absorption factor for each COC *via* consumption of local wild game was assumed to be 100%.

Table H-10 Rates for the Consumption of Local Wild Game			
Receptor	**Consumption Rate (g/kg/day)**	**Consumption (g/day)**	**Fraction of Total Meats Consumed that is Wild Game**
Infant	-	-	0
Toddler	0.46	7.6	0.10
Child	0.46	15	0.13
Teen	0.46	27	0.17
Adult	0.46	32	0.20

The exposure of a toddler living in West Flin Flon to lead *via* ingestion of local wild game was calculated as follows:

Ingestion of Local Wild Game

$$EXP_{LWG} = \frac{C_{LWG} * CR_{ME} * Fr_{LWG} * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{LWG}	=	exposure from ingestion of local wild game (µg/kg/day)
C_{LWG}	=	exposure point concentration of COC in local wild game (0.025 µg/g ww)
CR_{ME}	=	consumption rate of meats and eggs (77 g/day)
Fr_{LWG}	=	fraction of total meats and eggs consumed that is local wild game (0.1 unitless)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of local wild game is 1.2×10^{-2} µg/kg/day.

H-4.8 Estimate of Exposure from Consumption of Local Fish

Exposure to COC was assessed *via* the consumption of local fish under the residential exposure scenario. It should be noted that the consumption of local fish was considered to be a distinct dietary source in addition to the consumption of fish obtained from local supermarkets which is assessed in the market basket exposure calculations (Table H-11). The relative absorption factor for each COC *via* consumption of local fish was assumed to be 100%. This pathway was considered under the residential exposure scenario.

Table H-11 Rates for the Consumption of Local Fish		
Receptor	**Consumption Rate (g/kg/day)**	**Consumption (g/day)**
Infant	-	-
Toddler	0.68	11
Child	0.68	22
Teen	0.68	40
Adult	0.68	48

The exposure of a toddler living in West Flin Flon to lead *via* ingestion of local fish was calculated as follows:

Ingestion of Local Fish

$$EXP_{LF} = \frac{CR_{LF} * C_{LF} * EF * RAF_{ORAL}}{BW * DPY}$$

where:

EXP_{LF}	=	daily exposure to COC from ingestion of local fish (µg/kg/day)
CR_{LF}	=	consumption rate of local fish (11 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{ORAL}	=	relative absorption factor for ingestion of COC (1.0 unitless)
C_{LF}	=	exposure point concentration of COC in local fish tissue (0.031 µg/g ww)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through ingestion of local fish is 2.1×10^{-2} µg/kg/day.

H-4.9 Estimate of Exposure from Consumption of Market Basket Food Products

Exposure to COC was assessed through the consumption of supermarket (market basket) food items within a number of food categories as follows:

Ingestion of Market Basket Food Products

$$EXP_{MB} = EXP_D + EXP_B + EXP_F + EXP_{RV} + EXP_{LV} + EXP_{FJ} + EXP_C + EXP_{SS} + EXP_{FO} + EXP_{NS}$$

where:

EXP_{MB}	=	exposure from ingestion of all market basket products (µg/kg/day)
EXP_D	=	exposure from ingestion of market milk and dairy (2.1×10^{-1} µg/kg/day)
EXP_B	=	exposure from ingestion of market meat and eggs (2.8×10^{-2} µg/kg/day)
EXP_F	=	exposure from ingestion of market fish and shellfish (2.0×10^{-3} µg/kg/day)
EXP_{RV}	=	exposure from ingestion of market root vegetables (3.4×10^{-2} µg/kg/day)
EXP_{LV}	=	exposure from ingestion of market above ground (leafy) vegetables (1.4×10^{-2} µg/kg/day)
EXP_{FJ}	=	exposure from ingestion of market fruits and fruit juices (1.5×10^{-1} µg/kg/day)
EXP_C	=	exposure from ingestion of market cereals and grains (1.2×10^{-1} µg/kg/day)
EXP_{SS}	=	exposure from ingestion of market sugar and sweets (1.1×10^{-1} µg/kg/day)
EXP_{FO}	=	exposure from ingestion of market fats and oils (4.8×10^{-4} µg/kg/day)
EXP_{NS}	=	exposure from ingestion of market nuts and seeds (2.4×10^{-3} µg/kg/day)

Therefore, for the current assessment, the total exposure to lead through ingestion of all market basket products for the toddler is 0.68 µg/kg/day.

Exposure to lead through the consumption of foods from individual food categories are shown below.

Ingestion of Market Milk and Dairy

$$EXP_D = \frac{C_D * DIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_D	=	exposure from ingestion of market milk and dairy (µg/kg/day)
C_D	=	concentration of lead in market milk and dairy (0.006 µg/g ww)
DIR	=	Canadian per capita dairy intake rate (579 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket milk and dairy products is $2.1x10^{-1}$ µg/kg/day.

Ingestion of Market Meat and Eggs

$$EXP_{ME} = \frac{C_{ME} * MEIR * Fr_{MBME} * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{ME}	=	exposure from ingestion of market meat and eggs (µg/kg/day)
C_{ME}	=	concentration of lead in market meat and eggs (0.0066 µg/g ww)
MEIR	=	Canadian per capita total meat and egg intake rate (77 g/day)
Fr_{MBME}	=	fraction of total meat and eggs consumed represented by market basket meat and eggs (0.9)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket meat and eggs is $2.8x10^{-2}$ µg/kg/day.

Ingestion of Market Fish and Shellfish

$$EXP_F = \frac{C_F * FIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_F	=	exposure from ingestion of market fish and shellfish (µg/kg/day)
C_F	=	concentration of lead in market fish and shellfish (0.0069 µg/g ww)
FIR	=	Canadian per capita fish intake rate (4.7 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket fish and shellfish is 2.0×10^{-3} µg/kg/day.

Ingestion of Market Root Vegetables

$$EXP_{RV} = \frac{C_{RV} * RVIR * Fr_{MBRV} * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{RV}	=	exposure from ingestion of market root vegetables (µg/kg/day)
C_{RV}	=	concentration of lead in market root vegetables (0.0073 µg/g ww)
RVIR	=	Canadian per capita root vegetable intake rate (79 g/day)
Fr_{MBRV}	=	fraction of root vegetables consumed represented by market basket root vegetables (0.982)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket root vegetables is 3.4×10^{-2} µg/kg/day.

Ingestion of Market Aboveground (Leafy) Vegetables

$$EXP_{LV} = \frac{C_{LV} * LVIR * Fr_{MBLV} * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{LV}	=	exposure from ingestion of market above ground (leafy) vegetables (µg/kg/day)
C_{LV}	=	concentration of lead in market leafy vegetables (0.005µg/g ww)
LVIR	=	Canadian per capita leafy vegetable intake rate (48 g/day)
Fr_{MBLV}	=	fraction of leafy vegetables consumed represented by market basket leafy vegetables (0.938)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket above ground (leafy) vegetables is 1.4×10^{-2} µg/kg/day.

Ingestion of Market Fruits and Fruit Juices

$$EXP_{FJ} = \frac{C_{FJ} * FVIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{FJ}	=	exposure from ingestion of market fruits and fruit juices (µg/kg/day)
C_{FJ}	=	concentration of lead in market fruits and fruit juice (0.014 µg/g ww)
FJIR	=	Canadian per capita fruit intake rate (179 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket fruits and juices is 1.5×10^{-1} µg/kg/day.

Ingestion of Market Cereals and Grains

$$EXP_C = \frac{C_C * CIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_C	=	exposure from ingestion of market cereals and grains (µg/kg/day)
C_C	=	concentration of lead in market cereals and grains (0.012 µg/g ww)
CIR	=	Canadian per capita cereals and grains intake rate (167 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket cereals and grains is 1.2×10^{-1} µg/kg/day.

Ingestion of Market Sugar and Sweets

$$EXP_{SS} = \frac{C_{SS} * SSIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{SS}	=	exposure from ingestion of market sugar and sweets (µg/kg/day)
C_{SS}	=	concentration of contaminant in market sugar and sweets (0.04 µg/g ww)
SSIR	=	Canadian per capita sugar and sweets intake rate (46 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket sugar and sweets is 1.1×10^{-1} µg/kg/day.

Ingestion of Market Fats and Oils

$$EXP_{FO} = \frac{C_{FO} * FOIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{FO}	=	exposure from ingestion of market fats and oils (µg/kg/day)
C_{FO}	=	concentration of lead in market fats and oils (0.00038 µg/g ww)
FOIR	=	Canadian per capita fats and oils intake rate (21 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket fats and oils is 4.8×10^{-4} µg/kg/day.

Ingestion of Market Nuts and Seeds

$$EXP_{NS} = \frac{C_{NS} * NSIR * EF * RAF_{Food}}{BW * DPY}$$

where:

EXP_{NS}	=	exposure from ingestion of market nuts and seeds (µg/kg/day)
C_{NS}	=	concentration of lead in market nuts and seeds (0.014 µg/g ww)
NSIR	=	Canadian per capita nuts and seeds intake rate (2.79 g/day)
EF	=	exposure frequency (365 days/year)
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0 unitless)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler through ingestion of market basket nuts and seeds is 2.4×10^{-3} µg/kg/day.

H-4.10 Exposure through all Dermal Pathways

Exposure to lead through dermal contact with soil and dust was calculated as follows:

Exposure through all Dermal Pathways

$$EXP_{Dermal\ Total} = EXP_{Dermal\ Soil} + EXP_{Dermal\ Dust}$$

where:

$EXP_{Dermal\ Total}$	=	total exposure *via* all dermal pathways (µg/kg/day)
$EXP_{Dermal\ Soil}$	=	dermal exposure *via* direct contact with soil (6.2×10^{-3} µg/kg/day)
$EXP_{Dermal\ Dust}$	=	dermal exposure *via* direct contact with dust (1.7×10^{-3} µg/kg/day)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through all dermal pathways is 7.9×10^{-3} µg/kg/day.

H-4.11 Exposure through all Oral Pathways

Exposure to lead through all oral pathways, including ingestion of dietary items, drinking water, and incidental ingestion of soil and dust, was calculated as follows:

Exposure through all Oral Pathways

$$EXP_{Oral\ Total} = EXP_{IngSoil} + EXP_{Ing\ Dust} + EXP_{DW} + EXP_{HP} + EXP_{WB} + EXP_{LWG} + EXP_{LF} + EXP_{MB}$$

where:

$EXP_{Oral\ Total}$	=	exposure *via* all oral pathways (µg/kg/day)
$EXP_{Ing\ Soil}$	=	exposure *via* incidental ingestion of soil (6.9×10^{-1} µg/kg/day)
$EXP_{Ing\ Dust}$	=	exposure *via* incidental ingestion of dust (2.5×10^{-1} µg/kg/day)
EXP_{DW}	=	exposure *via* consumption of drinking water (1.7×10^{-1} µg/kg/day)
EXP_{HP}	=	exposure *via* ingestion of homegrown produce (5.3×10^{-2} µg/kg/day)
EXP_{WB}	=	exposure *via* ingestion of local wild blueberries (3.7×10^{-2} µg/kg/day)
EXP_{LWG}	=	exposure *via* ingestion of local wild game (1.2×10^{-2} µg/kg/day)
EXP_{LF}	=	exposure *via* ingestion of local fish (2.1×10^{-2} µg/kg/day)
EXP_{MB}	=	exposure *via* ingestion of market basket products (6.8×10^{-1} µg/kg/day)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through all oral pathways is 1.9 µg/kg/day.

H-4.12 Total Exposure

Total exposure to lead *via* all potential pathways was calculated as follows:

Total Exposure *via* all Pathways

$$EXP_{Total} = EXP_{Inh\ Total} + EXP_{Dermal\ Total} + EXP_{Oral\ Total}$$

where:

EXP_{Total}	=	total exposure *via* all pathways (µg/kg/day)
$EXP_{Inh\ Total}$	=	total exposure *via* all inhalation pathways (1.9×10^{-1} µg/kg/day)
$EXP_{Dermal\ Total}$	=	total exposure *via* all dermal pathways (7.9×10^{-3} µg/kg/day)
$EXP_{Oral\ Total}$	=	total exposure *via* all oral pathways (1.9 µg/kg/day)

Therefore, for the current assessment, the total exposure to lead for the toddler living in West Flin Flon through all pathways is 2.1 µg/kg/day.

H-4.13 Additional Recreational Exposure Pathways

Under a supplemental recreational assessment, it was assumed that receptors may spend a significant portion of the summer months swimming in local lakes. Exposure to COC was assumed to occur *via* incidental ingestion of surface water and sediment, as well as dermal contact of surface water with all skin. The method used to predict dermal absorption was that recommended by the U.S. EPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E: Supplemental Guidance for Dermal Risk Assessment) (U.S. EPA, 2004).

The exposure of a toddler to lead *via* dermal exposure to surface water while swimming was calculated as follows:

Dermal Exposure While Swimming

$$EXP_{Derm\,SW} = \frac{DA_{event} * SA * EV * EF}{BW * DPY}$$

where:

$EXP_{Derm\,SW}$	=	daily dermal exposure *via* direct contact with surface water (µg/kg/day)
DA_{event}	=	absorbed dose per event (2.3×10^{-6} µg/cm^2-event)
SA	=	exposed surface area (6,130 cm^2)
EV	=	event frequency (1 event/day)
EF	=	exposure frequency (30 days/year)
BW	=	body weight (16.5 kg)
DPY	=	averaging time (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler *via* dermal exposure from surface water while swimming is 7.0×10^{-5} µg/kg/day.

In the above equation, the DA_{event} term was calculated as follows:

Absorbed Dose per Swimming Event

$$DA_{event} = K_P * C_{SW} * CF_1 * t_{event} * CF_2$$

where:

DA_{event}	=	absorbed dose per event (2.3×10^{-6} µg/cm^2-event)
K_p	=	dermal permeability coefficient of lead in water (0.001 cm/hr)
C_{sw}	=	exposure point concentration of lead in surface water (1.0 µg/L)
CF_1	=	conversion factor for µg/L to mg/cm^3 (1.0×10^{-6})
t_{event}	=	duration of swimming event (2.3 hr event)
CF_2	=	conversion factor for mg/cm^2-event to µg/cm^2-event (1,000)

The dermal permeability coefficient (Kp) foreach COC was 0.001 cm/hr (U.S. EPA, 2004).

The exposure of a toddler to lead *via* incidental ingestion of surface water while swimming was calculated as follows:

Incidental Ingestion While Swimming

$$EXP_{oral\ SW} = \frac{IR_{SW} * C_{SW} * ED * EF}{BW * DPY}$$

where:

$EXP_{Oral\ SW}$	=	daily oral exposure *via* incidental ingestion of surface water (µg/kg/day)
IR_{SW}	=	incidental ingestion rate of surface water while swimming (0.05 L/hour)
C_{SW}	=	exposure point concentration in surface water (1.0 µg/L)
ED	=	event duration (2.3 hours/day)
EF	=	exposure frequency (30 days/year)
BW	=	body weight (16.5 kg)
AT	=	averaging time (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler *via* incidental ingestion of surface water while swimming is 5.7×10^{-4} µg/kg/day.

To predict exposure *via* incidental ingestion of sediment while swimming, the ingestion rate for sediment was assumed to be equal to the daily soil ingestion rate. The relative absorption factors were also assumed to be equivalent to those selected for soil.

Incidental Ingestion of Sediment While Swimming

$$EXP_{oral\ Sed} = \frac{IR_{Sed} * C_{Sed} * RAF_{Sed} * EF}{BW * DPY}$$

where:

$EXP_{Oral\ Sed}$	=	daily oral exposure *via* incidental ingestion of sediment (µg/kg/day)
IR_{Sed}	=	incidental ingestion rate of sediment while swimming (0.08 µg/g)
C_{Sed}	=	exposure point concentration in sediment (630 µg/g)
RAF_{Sed}	=	chemical-specific relative absorption factor for sediment (0.58 unitless)
EF	=	exposure frequency (30 days/year)
BW	=	body weight (16.5 kg)
DPY	=	days per year (365 days/year)

Therefore, for the current assessment, the total exposure to lead for the toddler *via* incidental ingestion of sediment while swimming is 1.4×10^{-1} µg/kg/day.

H.5.0 RISK CHARACTERIZATION

Typically, the risk characterization stage of a human health risk assessment consists of a comparison between estimated exposures and the acceptable or "safe" intake level for each chemical of concern or acceptable daily dose.

Risk Calculation for Non-Carcinogens

For COC which act through a threshold-based mechanism of toxicological action, the numerical value associated with this comparison is called the Hazard Quotient (HQ) and is calculated as follows:

$$\text{Hazard Quotient (HQ)} = \frac{\text{Estimated Exposure (µg/kg/day)}}{\text{Exposure Limit (µg/kg/day)}}$$

The Hazard Quotient is an indicator used to:

- Identify situations where the exposure received by a human receptor under a specified set of conditions is greater than the maximum allowable dose;
- Compare potential adverse human health effects between different exposure scenarios and receptors; and,
- Simplify the presentation of the human health risk assessment results so that the reader may have a clear understanding of these results, and an appreciation of their significance.

Risk Calculation for Carcinogens

In the case of direct acting, non-threshold carcinogenic chemicals, ILCR levels were used to communicate the estimated additional lifetime cancer risk associated with on-site exposure estimates as follows:

$$\begin{array}{c}\text{Incremental Lifetime}\\ \text{Cancer Risk (ILCR)}\end{array} = \text{Estimated Exposure}\,(\mu\text{g/kg/day}) \times \text{Cancer Slope Factor}\,(\mu\text{g/kg/day})^{-1}$$

H-5.1 Human Health Risk Estimates

Since the RfD for lead is based on the protection of a blood lead level of concern resulting from all routes of exposure (*i.e.*, oral, dermal, and inhalation), the total predicted exposure is compared to the RfD of 3.6 µg/kg/day to produce one HQ as follows:

HQ from Total Exposure to Lead

$$HQ = \frac{EXP_{Total}}{EXP\ Limit}$$

where:

HQ	=	Hazard Quotient (unitless)
EXP_{Total}	=	Total exposure to lead (2.1 µg/kg/day)
EXPLimit	=	exposure limit for lead (3.6 µg/kg/day)

Therefore, for the current assessment, the HQ resulting from total exposure to lead for the toddler living in West Flin Flon at the community-based EPCs is 0.58.

For non-carcinogenic chemicals where inhalation exposure elicits a direct effect on respiratory tissues, risks *via* the inhalation pathway were assessed through a direct comparison of the ambient air concentration to the reference concentration (RfC) to produce a concentration ratio (CR). This is illustrated below for inhalation exposure to copper in West Flin Flon:

CR from Inhalation Exposure to Copper

$$CR = \frac{C_{Air}}{RfC}$$

where:

CR	=	Concentration ratio (unitless)
C_{Air}	=	Concentration of copper in ambient air in West Flin Flon (0.84 µg/m^3)
RfC	=	Reference concentration for copper in air (1 µg/m^3)

Therefore, for the current assessment, the CR resulting from inhalation exposure to copper for a residential receptor living in West Flin Flon at the community-based EPC is 0.84.

Since the inhalation exposure pathway can also contribute to the total internal dose, the exposure *via* inhalation was also added to the total oral and dermal exposure for comparison to the oral RfD.

For carcinogenic chemicals where inhalation exposure elicits a direct effect on respiratory tissues, risks *via* the inhalation pathway were assessed by multiplying the ambient air concentration by the unit risk value to produce an ILCR. This is illustrated below for inhalation exposure to cadmium in West Flin Flon:

ILCR from Inhalation Exposure to Cadmium

$$ILCR = C_{Air} * UR$$

where:

ILCR	=	Incremental Lifetime Cancer Risk Level (unitless)
C_{Air}	=	Concentration of cadmium in ambient air in West Flin Flon (0.070 µg/m^3)
UR	=	Unit risk value for cadmium in air (0.0098 (µg/m^3)$^{-1}$)

Therefore, for the current assessment, the ILCR resulting from inhalation exposure to cadmium for a residential receptor living in West Flin Flon at the community-based EPC is 6.9x10^{-4}.

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