Sudbury Area Risk Assessment
Volume II

Appendix B:

Model Assumptions, Equations, Algorithms and a Worked Example

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SUDBURY AREA RISK ASSESSMENT
VOLUME II

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

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

B-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 Sudbury Human Health Risk Assessment (HHRA). Refer to Chapter 2 (Problem Formulation) and Chapter 4 (Detailed Human Health Risk Assessment) of the Volume II 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 Sudbury HHRA were: arsenic (As); cobalt (Co); copper (Cu); lead (Pb); nickel (Ni); and, selenium (Se). 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, subsurface soil 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.

B-2.0 HUMAN RECEPTOR SELECTION AND CHARACTERISTICS

B-2.1 Receptor Selection

For the current risk assessment, male and female receptors in five life stages (infant, preschool child, child, teen, and adult) were evaluated to predict risks associated with exposure to COC. Two of the COC, As and Ni, have mechanisms of toxicity which are considered carcinogenic. To conservatively assess potential incremental lifetime cancer risks to these carcinogenic chemicals, a lifetime or composite receptor for each gender was also considered. The composite receptor incorporates all receptor life stages, from birth to 70 years of age.

The characteristics of each human receptor are outlined in Tables B.1 through B.5. Receptor parameter information is presented in the form of the mean and standard deviation of the parameter data. As well, *Central Tendancy Estimate* (CTE) and *Reasonably Maximally Exposed* (RME) values were calculated for each parameter for use in the HHRA. Finally, a description of the type of distribution (*i.e.*, normal, lognormal, or max extreme) used to represent the underlying shape of the probability distribution function (PDF). Refer to Sections 2.0 and 3.0 of the Volume II main report for further information on the calculation of this information.

Receptor characteristics were based primarily on data provided by:

- U.S. EPA. 2002. Child-Specific Exposure Factors Handbook. National Center for Environmental Assessment – Washington, DC. EPA-600-P-00-002B. September, 2002.
- U.S. EPA. 1997. Exposure Factors Handbook. Volume I – General Factors. Office of Research and Development. United States Environmental Protection Agency. EPA/600/P-95/002Fa. August, 1997.
- Richardson, G.M. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc. 1155-2720 Queensview Dr., Ottawa, Ontario.
- Health Canada (2005, pers. comm.). The complete Health Canada receptor database on which the *Compendium of Canadian Human Exposure Factors for Risk Assessment* was developed.
- Burmaster, D.E. 1998. Lognormal distributions of skin area as a function of body weight. Risk Anal 18(1):27-32.

B-2.2 Receptor Characteristics

Physical and behavioral characteristics of male and female receptors at each life stage are presented in Tables B.1 to B.5. The ages associated with each receptor life stage are as follows:

- Infant 0 to <6 months
- Preschool Child 6 months to <5 years
- Child 5 to 11 years
- Teen 12 to 19 years
- Adult 20 to 70+ years

As discussed in Chapter 2 of the Volume II main report, data from Richardson (1997) was used to characterize assumptions for each of the assessed life stages. However, as insufficient detail was available in the Richardson (1997) document to properly calculate the necessary statistical parameters for a number of the assumptions, the full data set used to develop the information presented in Richardson (1997) was obtained from Mark Richardson of Health Canada (2005, pers. comm.). This dataset is based upon the original Nutrition Canada survey (1970-1972), and has been peer reviewed both by Nutrition Canada (prior to its release to Health Canada) and Health Canada itself. Use of this complete dataset, rather than the statistical summaries provided in Richardson (1997), allows the current assessment to account for bodyweight adjustments on an individual basis, rather than as an overall receptor age group. This allows for a more accurate and precise characterization of receptor assumptions, and reduces the overall uncertainty inherent in each particular modeled receptor characteristic.

Table B.1 Receptor Characteristics – Infant (0 to 6 months)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [e]	8.2	2.9	8.2	8.2	L	8.2	2.9	8.2	8.2	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	2.1	0.60	2.0	2.9	L	2.1	0.60	2.0	2.9	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	0.43	0.43	na	na	na	0.43	0.43	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	0.3	0.2	0.25	0.54	L	0.3	0.2	0.25	0.54	L	Richardson, 1997
Amount of Formula Consumed (g/kg/day)	82.0	45.9	63.2	101.6	N	53.3	30.8	50.0	65.9	N	Health Canada, 2005 pers. comm.
Amount of Milk and Dairy Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	na	na	na	na	N	na	na	na	na	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable
\- Not provided
[a] Whole body surface area was calculated using body weight from Richardson (1997) and the univariate model developed by Burmaster (1998) as described below.
[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.
[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.
[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.*, 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.
[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.
[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil.

Table B.2 Receptor Characteristics – Preschool Child (7 months to 4 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [f]	16.4	4.5	16.4	16.4	L	16.5	4.6	16.5	16.5	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	8.8	2.4	8.5	11.9	L	9.7	2.7	9.4	13.3	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.036	na	0.036	0.036	na	0.036	na	0.036	0.036	na	Health Canada (2004) [e]
Amount of Dust Ingested (g/day)	0.044	na	0.044	0.044	na	0.044	na	0.044	0.044	na	Health Canada (2004) [e]
Total Skin Surface Area (m^2)	na	na	0.69	0.69	na	na	na	0.69	0.69	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	0.6	0.4	0.5	1.09	L	0.6	0.4	0.5	1.09	L	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	44.5	38.8	28.7	46.7	N	45.1	30.0	38.1	47.2	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	6.2	5.2	5.7	6.5	N	6.2	5.8	5.1	6.6	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	3.0	2.6	2.5	3.8	N	4.4	4.4	2.6	5.5	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	7.4	5.3	7.1	9.5	N	7.9	6.9	5.90	8.5	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	4.7	2.9	5.3	6.3	N	4.8	5.2	3.1	6.3	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	17.8	13.6	14.5	20.8	N	16.9	12.8	14.2	17.9	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	11.7	8.7	9.6	13.5	N	12.2	10.6	9.1	13.4	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	4.0	1.8	4.6	6.7	N	3.7	4.9	1.9	4.4	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	1.8	1.1	2.1	2.4	N	0.87	0.79	0.7	1.2	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	1.0	0.7	0.9	1.4	N	0.9	0.79	0.7	1.2	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	Na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	Na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable

\- Not provided

[a] Whole body surface area was calculated using body weight from Richardson, 1997 and the univariate model developed by Burmaster (1998) as described below.

[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.

[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.

[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.,* 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.

[e] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil.

[f] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.

Table B.3 Receptor Characteristics – Child (5 to 11 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [e]	33.6	9.3	33.6	33.6	L	32.2	8.0	32.2	32.2	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	14.0	3.0	13.7	17.9	L	15.1	3.4	14.7	19.6	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	1.1	1.1	na	na	na	1.1	1.1	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	0.8	0.4	0.72	1.3	L	0.8	0.4	0.72	1.3	0.8	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	22.1	15.6	19.5	24.3	N	24.5	17.4	21.6	26.9	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	4.2	3.0	3.5	4.4	N	4.8	3.9	4.1	5.3	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	3.5	4.6	2.2	4.2	N	3.5	3.9	2.1	5.1	3.5	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	5.3	5.3	4.3	6.5	N	6.6	5.8	5.2	7.8	6.6	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	3.4	3.5	2.3	3.6	N	3.7	4.5	2.2	4.4	3.7	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	9.6	8.9	7.4	10.9	N	10.8	9.5	7.7	12.3	10.8	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	9.2	7.7	6.9	10.6	N	10.6	7.9	8.3	11.9	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	2.5	3.6	1.5	2.8	N	2.8	3.5	1.6	3.1	2.8	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	1.4	1.9	0.9	1.5	N	1.4	1.7	0.9	1.5	1.4	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	0.8	0.7	0.6	0.9	N	0.8	0.82	0.6	0.9	0.8	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable
- Not provided

[a] Whole body surface area was calculated using body weight from Richardson, 1997 and the univariate model developed by Burmaster (1998) as described below.

[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.

[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50th percentile values to represent the central tendency.

[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.*, 90 to 95th percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.

[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.

Table B.3 Receptor Characteristics – Child (5 to 11 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	

[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil.

Table B.4 Receptor Characteristics – Teen (adolescent) (12 to 19 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	
Body weight (kg) [e]	56.2	10.2	56.2	56.2	L	63.1	15.3	63.1	63.1	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	14.0	2.9	13.7	17.8	L	17.7	4.1	17.2	23.1	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	1.6	1.6	na	na	na	1.7	1.7	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	1.0	0.6	0.9	1.7	L	1.0	0.6	0.9	1.7	L	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	10.2	9.1	8.1	11.9	N	12.7	10.5	10.4	14.8	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	2.8	1.9	2.4	2.9	N	3.7	2.5	3.0	3.9	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	1.9	1.7	1.3	2.1	N	2.2	2.1	1.6	2.5	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	3.9	3.3	3.2	4.6	N	5.1	4.2	4.1	5.8	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	2.4	2.8	1.6	2.9	N	2.3	2.8	1.5	2.9	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	5.3	5.0	4.0	6.4	N	5.0	4.8	3.5	5.8	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	4.8	4.8	3.5	5.4	N	6.5	5.3	5.0	7.2	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	1.4	1.9	0.8	1.7	N	1.8	2.3	1.0	2.2	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	1.1	1.6	0.7	1.2	N	1.0	1.2	0.6	1.2	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	0.5	0.6	0.3	0.7	N	0.6	0.8	0.4	0.9	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	na	229	243	na	243	na	229	243	na	Assumed
Exposure Frequency – Winter (days/ year)	122	na	122	122	na	122	na	122	122	na	Assumed
Time Spent Outdoors (min/day)	91	83	67.2	182.2	L	91	83	67.2	182.2	L	Richardson, 1997

na Not applicable
- Not provided
[a] Whole body surface area was calculated using body weight from Richardson, 1997and the univariate model developed by Burmaster (1998) as described below.
[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.
[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50^{th} percentile values to represent the central tendency.
[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.*, 90 to 95^{th} percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.
[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.
[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a

Table B.4 Receptor Characteristics – Teen (adolescent) (12 to 19 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE[c]	RME[d]	PDF[b]	Mean	SD	CTE[c]	RME[d]	PDF	

default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil.

Table B.5 Receptor Characteristics – Adult (>20 years)

Receptor Parameter	Female[a]					Male[a]					Reference
	Mean	SD	CTE	RME	PDF	Mean	SD	CTE	RME	PDF	
Body weight (kg) [e]	63.1	11.9	63.1	63.1	L	78.8	12.3	78.8	78.8	L	Richardson, 1997
Amount of Air Inhaled (m^3/day)	14.9	2.9	14.6	18.7	L	17.2	4.1	16.7	22.6	L	Richardson, 1997
Amount of Soil Ingested (g/day)	0.009	-	0.009	0.009	na	0.009	-	0.009	0.009	na	Health Canada (2004) [f]
Amount of Dust Ingested (g/day)	0.011	-	0.011	0.011	na	0.011	-	0.011	0.011	na	Health Canada (2004) [f]
Total Skin Surface Area (m^2)	na	na	1.7	1.7	na	na	na	2.0	2.0	na	Burmaster, 1998
Amount of Drinking Water Ingested (L/day)	1.5	0.8	1.3	2.5	L	1.5	0.8	1.3	2.5	L	Richardson, 1997
Amount of Milk and Dairy Consumed (g/kg/day)	4.1	4.4	2.6	4.5	N	4.8	5.1	3.1	5.4	N	Health Canada, 2005 pers. comm.
Amount of Meat and Eggs Consumed (g/kg/day)	2.2	1.6	1.8	2.2	N	4.8	5.1	3.1	5.4	N	Health Canada, 2005 pers. comm.
Amount of Fish and Shellfish Consumed (g/kg/day)	1.7	1.8	1.3	2.1	N	1.7	1.6	1.2	2.0	N	Health Canada, 2005 pers. comm.
Amount of Root Vegetables Consumed (g/kg/day)	2.6	2.3	2.1	2.8	N	3.2	2.6	2.6	3.5	N	Health Canada, 2005 pers. comm.
Amount of Other Vegetables Consumed (g/kg/day)	2.1	2.0	1.6	2.2	N	2.0	2.1	1.4	2.3	N	Health Canada, 2005 pers. comm.
Amount of Fruits and Juices Consumed (g/kg/day)	3.9	3.3	3.1	4.2	N	3.5	3.0	2.7	3.8	N	Health Canada, 2005 pers. comm.
Amount of Cereal and Grains Consumed (g/kg/day)	3.0	2.8	2.3	3.2	N	3.9	3.0	3.1	4.1	N	Health Canada, 2005 pers. comm.
Amount of Sugar and Sweets Consumed (g/kg/day)	1.0	1.1	0.6	1.1	N	1.1	1.3	0.7	1.2	N	Health Canada, 2005 pers. comm.
Amount of Fats and Oils Consumed (g/kg/day)	0.8	0.9	0.5	0.8	N	0.7	0.7	0.4	0.7	N	Health Canada, 2005 pers. comm.
Amount of Nuts and Seeds Consumed (g/kg/day)	0.3	0.4	0.2	0.4	N	0.3	0.6	0.2	0.4	N	Health Canada, 2005 pers. comm.
Exposure Frequency – Summer (days/ year)	243	-	229	243	-	243	-	229	243	-	Assumed
Exposure Frequency – Winter (days/ year)	122	-	122	122	-	122	-	122	122	-	Assumed
Time Spent Outdoors (min/day)	91.0	83.0	67.2	182.2	L	91.0	83.0	67.2	182.2	L	Richardson, 1997

na Not applicable

- Not provided

[a] Whole body surface area was calculated using body weight from Richardson, 1997 and the univariate model developed by Burmaster (1998) as described below.

[b] N- Normal PDF, L- Lognormal PDF, ME- Max Extreme (Truncated). Normal PDFs represent uncertainty around the arithmetic mean and all other PDFs represent variability of the sample population.

[c] With the exception of body weight, all parameters representing the *central tendancy estimate* (CTE) were characterized using 50^{th} percentile values to represent the central tendency.

[d] With the exception of body weight and food intake rates, all parameters representing the *reasonably maximally exposed* (RME) individual were characterized using upper percentile (*i.e.*, 90 to 95^{th} percentile) values. The upper 95 percent confidence limit (95 UCL) on the arithmetic mean was used to characterize chronic food intake rates.

[e] Equivalent average body weights (arithmetic mean values reported by Richardson, 1997) were used for both CTE and RME exposure scenarios, as recommended by the U.S. EPA (1989) for the derivation of a reasonable maximum exposure (RME) scenario.

[f] Default data used by the U.S EPA's IEUBK model (U.S. EPA 1994a) was employed to develop outdoor soil and indoor dust ingestion rates. The IEUBK model uses a default outdoor:indoor 45/55 split which applies 55% of the total soil and dust ingestion rate to indoor dust with the remaining 45% being applied to soil.

B-2.2.1 Calculation of Receptor Surface Areas

Total body surface area for each receptor type was calculated by using a univariate model as a function of body weight developed by Burmaster (1998). Using a dataset of 401 individuals cited by the U.S. EPA (1997) covering all life stages for males and females, Burmaster developed an equation that could be used to predict lognormal distributions for surface area that are in strong agreement with more complicated bivariate models used by the U.S. EPA. Total surface area for each receptor was calculated as:

$$SA = aBW^{c}$$

where:

SA	=	total body surface area (m^2);
a	=	0.1025 (unitless);
BW	=	body weight (kg); and,
c	=	0.6821 (unitless).

This approach was used to calculate all receptor surface areas presented in tables B.1 through B.5. Note, total surface body area (SA) is a function of body weight (BW) and, therefore, changes with in accordance with the BW parameter.

B-2.2.2 Fraction of Dietary Items Derived from Local Sources

A number of dietary items consumed by receptors within the study area may be derived from local sources. This includes fruits and vegetables produced by local agriculture or home gardens, blue berries collected from the wild, and fish and wild game from the local environment. Since these dietary items are derived from environments affected by smelter emissions, they may potentially contain higher concentrations of COC than similar market basket food items. To account for this local influence, a fraction of receptor's diets was considered to be composed of these local food items and their associated COC concentrations. Table B.6 provides the fractions of the daily intake of dietary items that is derived from local sources. Refer to the methodology (Appendix B) and the Problem Formulation (Chapter 2) for a detailed discussion on how these fractions were derived.

Table B.6 Fraction of Average Daily Intake of Dietary Items from Local Sources

Local Food Items	CTE	RME
Fraction of root vegetables grown locally	0.018	0.11
Fraction of other vegetable grown locally	0.062	0.23
Fraction of fruit grown locally	0.044	0.082
Fraction of fish caught locally[2]	0.59/2.53	1.88/4.7
Fraction of meat which is local wild game[2]	0.031/0.13	0.033/0.15
Fraction of fruit which is local wild berries	0.057	0.093

[2] two sets of values have been provided for the fraction of fish and meat that is local wild game. These data were used to represent the general GSA population and a sub-population of avid anglers and hunters.

Of the fraction of fruits and vegetables that were considered to be derived from local sources, 25% of these amounts were assumed to be derived from home gardens, while the remaining 75% was assumed to be from local agriculture. Fruits and vegetables produced in home gardens in each of the five regions assessed contained levels of COC that may differ from region to region and from those measured from local agriculture. The concentrations of COC in home garden produce were measured in the Sudbury 2003 Garden survey, which is provided in Appendix E.

B-3.0 SUMMARY OF EXPOSURE POINT CONCENTRATION DATA

Table B.7 provides a summary of the exposure point concentration (EPC) data used in the current assessment. Refer to Chapters 2, 3, and 4 for detailed information on the derivation of these EPC values.

Table B.7 Summary of 95% UCLM values for all Exposure Point Concentrations (EPCs) used in the HHRA

Community of Interest	As [a]	Co	Cu	Pb	Ni	Se
Soil Concentrations			µg/g			
Coniston	12	19	320	52	433	1.3
Copper Cliff	19	33	1370	98	976	7.5
Falconbridge	79	57	1010	82	1070	3.1
Hanmer	4.3	6.6	67	19	68	0.68
Sudbury Centre	7.2	11	204	36	210	1.3
Typical Ontario Resident	17	21	85	43	120	1.9
Dust Concentrations (calculated)[b]			µg/g			
Coniston	87	98	204	127	221	49
Copper Cliff	98	113	298	150	273	77
Falconbridge	142	130	276	143	280	61
Hanmer	67	74	136	98	137	41
Sudbury Centre	76	85	182	116	183	49
Typical Ontario Resident	95	101	145	121	158	54
Air Concentrations (outdoor and indoor)			µg/m^3			
Coniston	0.0024	0.00087	0.016	0.0080	0.012	0.0034
Copper Cliff	0.0050	0.0025	0.081	0.022	0.059	0.0055
Falconbridge	0.0024	0.0025	0.026	0.015	0.028	0.0034
Hanmer	0.0056	0.00066	0.099	0.0098	0.012	0.0040
Sudbury Centre						
Combined data (2 stations)	0.0061	0.0097	0.17	0.025	0.095	0.0092
Travers Street only	0.0090	0.018	0.20	0.031	0.26	0.014
Typical Ontario Resident	0.001	0.0019	0.0091	0.0080	0.0014	0.0019
Drinking Water			µg/L			
Coniston	1.1	0.2	45	0.31	53	1.3
Copper Cliff	2.5	0.05	170	1.4	49	3
Falconbridge	2.6	0.2	30	0.97	32	2.5
Hanmer	1.5	0.06	65	0.49	0.8	1.3
Sudbury Centre	1.1	0.2	45	0.31	53	1.3
Typical Ontario Resident	0.64	0.088	0.41	2.2	1.9	1.6
Home Garden – Below Ground Vegetables			µg/g wet weight			
Coniston	0.0069	0.024	0.81	0.26	0.56	0.029
Copper Cliff	0.0088	0.019	1.2	0.13	1.7	0.42
Falconbridge	0.025	0.13	1.2	0.23	3.7	0.016
Hanmer	0.042	0.10	1.1	0.25	0.31	0.10
Sudbury Centre	0.0075	0.017	1.1	0.075	0.79	0.040

Table B.7 Summary of 95% UCLM values for all Exposure Point Concentrations (EPCs) used in the HHRA

Community of Interest	As [a]	Co	Cu	Pb	Ni	Se
Home Garden - Above Ground Vegetables			**µg/g wet weight**			
Coniston	0.0069	0.21	0.54	0.095	0.57	0.030
Copper Cliff	0.016	0.13	0.92	0.13	1.8	0.68
Falconbridge	0.052	0.11	0.75	0.038	2.0	0.02
Hanmer	0.0046	0.0074	0.46	0.089	0.28	0.0083
Sudbury Centre	0.0067	0.027	0.75	0.094	0.75	0.059
Home Garden – Fruits			**µg/g wet weight**			
All COI	0.0063	0.019	0.90	0.046	2.7	0.058
Wild Berries			**µg/g wet weight**			
All COI	0.0052	0.016	0.68	0.074	0.71	0.016
Local Commercial Produce			**µg/g wet weight**			
Root Vegetables	0.0086	0.037	1.0	0.11	0.91	0.13
Above Ground Vegetables	0.0079	0.038	0.71	0.078	1.1	0.10
Fruit	0.0061	0.035	0.65	0.042	1.5	0.024
Fish and Wild Game			**µg/g wet weight**			
Wild Game	0.00013	0.040	0.68	0.0040	0.62	1.4
Fish	0.00022	0.019	0.52	0.30	0.032	2.0
Market Basket Foods - TEDIs			**µg/g**			
Infant Formula	7.2×10^{-6}	0.0046	0.90	0.0023	0.011	0.020
Dairy	0.0032	0.010	0.36	0.0060	0.015	0.072
Meat and Eggs	0.00046	0.011	1.1	0.0066	0.022	0.25
Fish	0.00041	0.0093	1.3	0.0069	0.037	0.43
Root Vegetables	0.0043	0.033	1.1	0.0073	0.075	0.014
Other Vegetables	0.0093	0.013	1.2	0.0050	0.28	0.023
Fruits	0.0022	0.025	1.7	0.014	0.080	0.0092
Cereals and Grain	0.0059	0.025	1.8	0.012	0.17	0.13
Sugar and Sweets	0.0077	0.024	1.4	0.040	0.27	0.021
Fats and Oils	0.0091	0.022	0.25	0.00038	0.057	0.025
Nuts and Seeds	0.0073	0.063	14	0.014	2.0	0.32

[a] The arsenic exposure point concentration (see highlighted entries) 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: 0.42, fruits and berries: 0.33, wild game: 0.028, fish: 0.002, infant formula: 0.55 (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 Section 4.1.3 in Chapter 4 for further discussion of these factor adjustments, and Table 4.22 in Chapter 4 for the adjustment factors for each specific food grouping.

[b] Indoor dust concentrations calculated based upon regression equation developed from paired soil and indoor dust data collected during the Sudbury indoor dust survey. Refer to Chapter 3 for a summary of the indoor dust survey, and Appendix M for the detailed indoor dust survey report.

B-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 female preschool child residing in the Sudbury Centre COI while being exposed to media-specific nickel concentrations provided in Table B.7, through a number of exposure scenarios, using the Reasonably Maximally Exposed (RME) receptor assumptions provided in Tables B.1 through B.5. All exposure values are provided in units of µg of nickel per kilogram receptor bodyweight per day of exposure (µg/kg/day).

B-4.1 Estimate of Exposure from Inhalation of Fine Particulates

Exposure to fine particulates was assessed through inhalation routes in both indoor and outdoor environments as follows:

<u>Inhalation of Fine Particulates - Outdoors</u>

Inhalation of Fine Particulates in Outdoor Air

$$EXP_{Inh\ OA} = \frac{\lfloor C_{Outdoorair} * BR * RAF_{Inh} * (TSO \div CF) * EF_S * ED \rfloor + \lfloor C_{Outdoorair} * BR * RAF_{Inh} * (TSO \div CF) * EF_W * ED \rfloor}{AT * BW}$$

where:

$EXP_{Inh\ OA}$	=	inhalation exposure *via* outdoor air (µg/kg/day);
$C_{outdoor\ air}$	=	concentration of contaminants in outdoor air (9.5×10^{-2} mg/m^3);
BR	=	breathing rate (8.8 m^3/day);
RAF_{Inh}	=	relative absorption factor *via* inhalation (1.0 unitless);
TSO	=	time spent outdoors (91 mins/day);
CF	=	conversion factor (1,440; 60 mins/hr x 24 hrs/day);
EF_S	=	exposure frequency during summer months (243 days/year);
EF_W	=	exposure frequency during winter months (122 days/year);
ED	=	exposure duration (4.5 years (length of life stage));
AT	=	averaging time (1,642.5 days); and,
BW	=	body weight (16.4 kg).

Therefore, for the current assessment, the total exposure to nickel for the female preschool child living in Sudbury (centre) through inhalation of outdoor air is 3.21×10^{-3} µg/kg/day.

Inhalation of Fine Particulates - Indoors

Inhalation of Fine Particulates in Indoor Air

$$EXP_{Inh\ IA} = \frac{\lfloor C_{Indoorair} * BR * RAF_{Inh} * (TSI \div CF) * EF_S * ED \rfloor + \lfloor C_{Indoorair} * BR * RAF_{Inh} * (TSI \div CF) * EF_W * ED \rfloor}{AT * BW}$$

where:

$EXP_{Inh\ IA}$	=	inhalation exposure *via* indoor air (µg/kg/day);
$C_{Indoor\ air}$	=	concentration of contaminants in indoor air (9.5x10^{-2} mg/m^3);
BR	=	breathing rate (8.8 m^3/day);
RAF_{Inh}	=	relative absorption factor *via* inhalation (1.0 unitless);
TSI	=	time spent indoors (1,349 mins/day);
CF	=	conversion factor (1,440; 60 mins/hr x 24 hrs/day);
EF_S	=	exposure frequency during summer months (243 days/year);
EF_W	=	exposure frequency during winter months (122 days/year);
ED	=	exposure duration (4.5 years (length of life stage));
AT	=	averaging time (1,642.5 days); and,
BW	=	body weight (16.4 kg).

Therefore, for the current assessment, the total exposure to nickel for the female preschool child living in Sudbury (centre) through inhalation of indoor air is 4.76x10^{-2} µg/kg/day.

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

Exposure to chemicals in soil and dust is estimated separately for indoor and outdoor scenarios. However, the fraction of exposed skin is assumed to be equal for indoor and outdoor conditions during each season. Table B.8 shows the fraction of skin that is exposed during each season and the number of days within each season.

Table B.8 Fraction of Exposed Skin

Units	Spring	Summer	Fall	Winter[1]	Prorated
Fraction	0.150	0.250	0.150	0.050	0.142
Days	61.0	92.0	91.0	121.0	365.0

[1] Winter was defined as times of the year where direct soil contact would be reduce due to snow cover and/or frozen earth.

The prorated fraction of exposed skin is calculated as factor of the number of days per year for each season and the fraction of skin that is exposed during each season as follows:

$$FR_{Prorated} = \frac{(Fr_{Spring} * Days_{Spring}) + (Fr_{Summer} * Days_{Summer}) + (Fr_{Fall} * Days_{Fall}) + (Fr_{Winter} * Days_{Winter})}{365}$$

The surface area of exposed skin is calculated by multiplying the prorated fraction of exposed skin (or the annualized fraction of exposed skin) by the receptor-specific total body surface area and a conversion factor to convert m^2 to cm^2.

$$SA_{Exp} = Fr_{Exp} * SA * CF$$

where:

SA_{Exp}	=	Surface area of skin in contact with soil (cm^2/event)
Fr_{Exp}	=	Fraction of total surface area that is exposed to soil (0.142 per exposure event)
SA	=	Total surface area of female preschool child (0.69 m^2)
CF	=	Conversion factor (10,000 cm^2/m^2)

Therefore, the surface area of the female preschool child's skin available for contact with soil is 979.8 cm^2/event.

The soil adherence factor (outdoors) is calculated separately from the dust adherence factor (indoors) using the values presented in Table B.9.

Table B.9 Dermal Loading Factors and Body Surface Areas

Receptor Age Class		Percentage of Total Body Surface Area				Indoor Dust Loading (mg/cm^2)				Outdoor Soil Loading (mg/cm^2)			
		Hands	Arms	Legs	Feet	Hands	Arms	Legs	Feet	Hands	Arms	Legs	Feet
Female	Infant	5.3	13.7	20.6	6.54	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Female	Preschool child	6.07	14.4	26.8	7.21	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Female	Child	5.3	12.3	28.7	7.58	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Female	Teen	5.68	13.1	33.6	6.93	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Female	Adult	5.2	14.1	31.2	7.0	0.006	0.002	0.002	0.002	0.045	0.014	0.001	0.018
Male	Infant	5.3	13.7	20.6	6.54	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Male	Preschool child	6.07	14.4	26.8	7.21	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Male	Child	5.3	12.3	28.7	7.58	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Male	Teen	5.68	13.1	33.6	6.93	0.014	0.004	0.003	0.009	0.11	0.011	0.031	0.018
Male	Adult	5.2	14.1	31.2	7.0	0.006	0.002	0.002	0.002	0.045	0.014	0.001	0.018

The Area Weighted Outdoor Soil Adherence Factor (AF_{soil}) for the female preschool child is calculated as follows:

$$AF_{soil} = (FR_{SA-Hands} * OSL_{Hands}) + (FR_{SA-Arms} * OSL_{Arms}) + (FR_{SA-Legs} * OSL_{Legs}) + (FR_{SA-Feet} * OSL_{Feet})$$

where:

AF_{soil} = Area weighted soil adherence factor (mg/cm^2)
$Fr_{SA-Hands}$ = Fraction of total surface area represented by hands (0.0607)
OSL_{Hands} = Outdoor soil loading for hands (0.11 mg/cm^2)
$Fr_{SA-Arms}$ = Fraction of total surface area represented by arms (0.144)
OSL_{Arms} = Outdoor soil loading for arms (0.011 mg/cm^2)
$Fr_{SA-Legs}$ = Fraction of total surface area represented by legs (0.268)
OSL_{Legs} = Outdoor soil loading for legs (0.031 mg/cm^2)
$Fr_{SA-Feet}$ = Fraction of total surface area represented by feet (0.0721)
OSL_{Feet} = Outdoor soil loading for feet (0.018 mg/cm^2).

Therefore, the area weighted soil adherence factor for the female preschool child is 1.79×10^{-2} mg/cm^2.

Using the values presented in Table B.9, the Area Weighted Indoor Dust Adherence Factor (AF_{dust}) for the female preschool child is calculated as follows:

$$AF_{dust} = (FR_{SA-Hands} * IDL_{Hands}) + (FR_{SA-Arms} * IDL_{Arms}) + (FR_{SA-Legs} * IDL_{Legs}) + (FR_{SA-Feet} * IDL_{Feet})$$

where:

AF_{soil}	=	Area weighted soil adherence factor (mg/cm^2);
$Fr_{SA\text{-}Hands}$	=	Fraction of total surface area represented by hands (0.0607);
ODL_{Hands}	=	Indoor dust loading for hands (0.014 mg/cm^2);
$Fr_{SA\text{-}Arms}$	=	Fraction of total surface area represented by arms (0.144);
ODL_{Arms}	=	Indoor dust loading for arms (0.004 mg/cm^2);
$Fr_{SA\text{-}Legs}$	=	Fraction of total surface area represented by legs (0.268);
ODL_{Legs}	=	Indoor dust loading for legs (0.003 mg/cm^2);
$Fr_{SA\text{-}Feet}$	=	Fraction of total surface area represented by feet (0.0721); and,
ODL_{Feet}	=	Indoor dust loading for feet (0.009 mg/cm^2).

Therefore, the area weighted dust adherence factor for the female preschool child is 2.88×10^{-3} mg/cm^2.

Dermal Exposure to Outdoor Soil

Dermal Contact with Outdoor Soil

$$EXP_{Dermal\ Soil} = \frac{C_{soil} * SA/BW * AF_{soil} * CF * EF * ED * ABS}{AT}$$

where:

$EXP_{Dermal\ Soil}$	=	dermal exposure *via* direct contact with soil (µg/kg/day);
C_{soil}	=	concentration of contaminant in soil ($2.10 \times 10^{+2}$ µg/g);
SA_{Exp}	=	surface area of the skin that contacts the soil (979.8 cm^2/event);
BW	=	body weight (16.4 kg);
AF_{soil}	=	adherence factor for soil (1.79×10^{-2} mg/cm^2)
CF	=	conversion factor (1×10^{-3} g/mg);
EF	=	exposure frequency (243 events/year);
ED	=	exposure duration (4.5 years (length of life stage));
ABS	=	absorption fraction (0.001); this value is chemical-specific; and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through direct dermal contact with outdoor soil for the female preschool child living in Sudbury (centre) is 1.50×10^{-4} µg/kg/day.

Dermal Exposure to Indoor Dust

Dermal Contact with Indoor Dust

$$EXP_{Dermal\ Dust} = \frac{C_{dust} * \ SA/BW \ * \ AF_{dust} \ * CF \ * \ EF \ * \ ED * ABS}{AT}$$

where:

$EXP_{Dermal\ Dust}$	=	dermal exposure *via* direct contact with dust (µg/kg/day);
C_{Dust}	=	concentration of contaminant in dust ($5.15x10^{+2}$ µg/g);
SA	=	surface area of the skin that contacts the dust (979.8 cm^2/event);
BW	=	body weight (16.4 kg);
AF_{dust}	=	adherence factor for dust ($2.88x10^{-3}$ mg/cm^2)
CF	=	conversion factor ($1x10^{-3}$ g/mg);
EF	=	exposure frequency (365 events/year);
ED	=	exposure duration (4.5 years (length of life stage));
ABS	=	absorption fraction (0.001); this value is chemical-specific; and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through direct contact with indoor dust for the female preschool child living in Sudbury (centre) is $9.03x10^{-5}$ µg/kg/day.

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

Exposure to COC was assessed through the incidental ingestion of soil in outdoor environments or the incidental ingestion of dusts in indoor environments as follows:

Incidental Ingestion of Outdoor Soil

Ingestion of Outdoor Soil

$$EXP_{Ing\ Soil} = \frac{C_{Soil} * \ SIR_A \ * RAF_{Soil}}{BW}$$

where:

$EXP_{Ing\ Soil}$	=	exposure *via* incidental ingestion of soil (µg/kg/day);
C_{Soil}	=	concentration of contaminants in soil ($2.10x10^{+2}$ µg/g);
SIR_A	=	annualized soil intake rate ($6.40x10^{-2}$ g/day);
RAF_{Soil}	=	relative absorption factor for ingested soil (0.44 unitless); and ,
BW	=	body weight (16.4 kg).

The annualized soil intake rate used above is calculated by combining the summer and winter soil intake rates as follows:

$$SIR_A = SIR_{Summer} + SIR_{Winter}$$

where:

SIR$_A$ = annualized soil intake rate (6.40x10^{-2} g/day);
SIR$_{Summer}$ = soil intake rate for summer months (0.06 g/day); and,
SIR$_{Winter}$ = soil intake rate for winter months (0.003 g/day).

The season-specific soil intake rates are calculated based on the Canadian per capita soil intake rates and the exposure frequencies for the summer and winter months as follows:

$$SIR_{Summer} = \frac{SIR_{per\ capita} * EF_S * ED}{AT}$$

where:

SIR$_{Summer}$ = soil intake rate during summer months (2.4x10^{-2} g/day);
SIR$_{per\ capita}$ = Canadian per capita soil intake rate (3.6x10^{-2} g/day);
EF$_s$ = exposure frequency for summer months (243 days/year);
ED = exposure duration (4.5 years (length of life stage)); and,
AT = averaging time (1,642.5 days).

$$SIR_{Winter} = \frac{SIR_{per\ capita} * EF_W * ED * WA}{AT}$$

where:

SIR$_{Winter}$ = soil intake rate during winter months (1.2x10^{-3} g/day);
SIR$_{per\ capita}$ = Canadian per capita soil intake rate (3.6x10^{-1} g/day);
EF$_W$ = exposure frequency for winter months (122 days/year);
ED = exposure duration (4.5 years (length of life stage));
WA = winter accessibility factor (0.1); and,
AT = averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through incidental ingestion of soil for the female preschool child living in Sudbury (centre) is 2.52x10^{-2} μg/kg/day.

Incidental Ingestion of Indoor Dust

Ingestion of Indoor Dust

$$EXP_{Ing\ Dust} = \frac{C_{Dust} * DIR_{per\ capita} * (EF_S + EF_W) * ED * RAF_{Dust}}{AT * BW}$$

where:

$EXP_{Ing\ Dust}$	=	exposure *via* incidental ingestion of dust (µg/kg/day);
C_{Dust}	=	concentration of contaminants in dust ($5.2x10^{+2}$ µg/g);
DIR_A	=	Canadian per capita dust intake rate ($4.4x10^{-2}$ g/day);
EF_S	=	exposure frequency for summer months (243 days/year);
EF_W	=	exposure frequency for winter months (122 days/year);
ED	=	exposure duration (4.5 years (length of life stage));
RAF_{Dust}	=	relative absorption factor for ingested dust ($3.0x10^{-1}$ unitless);
AT	=	averaging time (1,642.5 days); and,
BW	=	body weight (16.4 kg).

Therefore, for the current assessment, the exposure to nickel through incidental ingestion of indoor dust for the female preschool child living in Sudbury (centre) is $4.1x10^{-1}$ µg/kg/day.

B-4.4 Estimate of Exposure from Consumption of Drinking Water

Exposure to COC through the consumption of local drinking water was assessed as follows:

Ingestion of Drinking Water

$$EXP_{DW} = \frac{C_{DW} * WIR * (EF_S + EF_W) * ED * RAF_{DW}}{AT * BW}$$

where:

EXP_{DW}	=	exposure *via* consumption of drinking water (µg/kg/day);
C_{DW}	=	concentration of contaminant in drinking water (52.8µg/L);
WIR	=	intake rate of drinking water ($6.0x10^{-1}$ L/day);
EF_S	=	exposure frequency for summer months (243 days/year);
EF_W	=	exposure frequency for winter months (122 days/year);
ED	=	exposure duration (4.5years (length of life stage));
RAF_{DW}	=	relative absorption factor for drinking water (1.0);
AT	=	averaging time (1,642.5 days); and,
BW	=	body weight (16.4 kg).

Therefore, for the current assessment, the exposure to nickel through ingestion of drinking water for the female preschool child living in Sudbury (centre) is 1.9 µg/kg/day.

B.4.5 Estimate of Exposure from Consumption of Home Produced Fruits and Vegetables

Exposure to COC was assessed through the consumption of produce grown in home gardens. This includes exposure related to the consumption of root vegetables, aboveground (or leafy) vegetables, and fruits, as follows:

Ingestion of Homegrown Fruits and Vegetables

$$EXP_{HP} = \frac{(EXP_{RV} + EXP_{AGV} + EXP_{F}) * EF * ED}{AT}$$

where:

EXP_{HP}	=	exposure from ingestion of homegrown produce (µg/kg/day);
EXP_{RV}	=	exposure from ingestion of homegrown root vegetables (1.17×10^{-1} µg/kg/day);
EXP_{AGV}	=	exposure from ingestion of homegrown aboveground vegetables (1.46×10^{-1} µg/kg/day)
EXP_{F}	=	exposure from ingestion of homegrown fruits (7.71×10^{-1} µg/kg/day);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of home grown fruits and vegetables for the female preschool child living in Sudbury (centre) is 1.03 µg/kg/day.

Calculation of exposure via consumption of home grown root vegetables, aboveground vegetables, and fruits are shown below.

Ingestion of Homegrown Root Vegetables

$$EXP_{RV} = C_{RV} * (1 - FPLF) * RVIR * Fr_{RVL} * Fr_{LFH} * RAF_{Food}$$

where:

EXP_{RV}	=	exposure from ingestion of homegrown root vegetables (µg/kg/day);
C_{RV}	=	concentration of contaminant in homegrown root vegetables ($7.9x10^{-1}$ µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$RVIR$	=	Canadian per capita root vegetable intake rate (5.56 g/kg/day);
Fr_{RVL}	=	fraction of root vegetables grown locally (0.106);
Fr_{LFH}	=	fraction of local foods from home garden (0.25); and,
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0).

Therefore, for the current assessment, the exposure to nickel through ingestion of home grown root vegetables for the female preschool child living in Sudbury (centre) is $1.17x10^{-1}$ µg/kg/day.

In the above calculation, the Canadian per capita root vegetable intake rate was calculated from the intake rate reported for only those individuals who consumed root vegetables during the time of the survey, and assuming that 75% of the total Canadian population consumes root vegetables, as shown below:

$$RVIR = CORVIR * 0.75$$

where:

RVIR	=	Canadian per capita root vegetable intake rate (5.6 g/kg/day);
CORVIR	=	consumers only root vegetable intake rate (7.17 g/kg/day); and,
0.75	=	per capita adjustment factor for consumption of root vegetables.

Ingestion of Homegrown Aboveground Vegetables

$$EXP_{AGV} = C_{AGV} * (1 - FPLF) * AGVIR * Fr_{AGVL} * Fr_{LFH} * RAF_{Food}$$

where:

EXP_{AGV}	=	exposure from ingestion of homegrown aboveground vegetables (µg/kg/day);
C_{AGV}	=	concentration of contaminant in homegrown aboveground vegetables ($7.5x10^{-1}$ µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$AGVIR$	=	Canadian per capita aboveground vegetables intake rate (3.33 g/kg/day);
Fr_{AGVL}	=	fraction of aboveground vegetables grown locally (0.233);
Fr_{LFH}	=	fraction of local foods from home garden (0.25); and,
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0).

Therefore, for the current assessment, the exposure to nickel through ingestion of home grown aboveground vegetables for the female preschool child living in Sudbury (centre) is 1.46×10^{-1} μg/kg/day.

In the above calculation, the Canadian per capita aboveground vegetable intake rate was calculated from the intake rate reported for only those individuals who consumed aboveground vegetables during the time of the survey, and assuming that 75% of the total Canadian population consumes aboveground vegetables, as shown below:

$$AGVIR = COAGVIR * 0.71$$

where:

AGVIR	=	Canadian per capita aboveground vegetable intake rate (4.50 g/kg/day);
COAGVIR	=	consumers only aboveground vegetable intake rate (6.34 g/kg/day); and,
0.71	=	per capita adjustment factor for consumption of aboveground vegetables.

Ingestion of Homegrown Fruits

$$EXP_F = C_F * (1 - FPLF) * FVIR * Fr_{FL} * Fr_{LFH} * RAF_{Food}$$

where:

EXP_F	=	exposure from ingestion of homegrown fruits (μg/kg/day);
C_F	=	concentration of contaminant in homegrown fruits (2.70μg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$FVIR$	=	Canadian per capita fruit intake rate (14 g/kg/day);
Fr_{FL}	=	fraction of fruits grown locally (0.082);
Fr_{LFH}	=	fraction of local foods from home garden (0.25); and,
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0).

Therefore, for the current assessment, the exposure to nickel through ingestion of home grown fruits for the female preschool child living in Sudbury (centre) is 7.71×10^{-1} μg/kg/day.

In the above calculation, the Canadian per capita fruit intake rate was calculated from the intake rate reported for only those individuals who consumed fruit during the time of the survey, and assuming that 75% of the total Canadian population consumes fruit, as shown below:

$$FVIR = COFVIR * 0.77$$

where:

FVIR	=	Canadian per capita fruit intake rate (16 g/kg/day);
COFVIR	=	consumers only fruit intake rate (20.8 g/kg/day); and,
0.77	=	per capita adjustment factor for consumption of fruit.

B-4.6 Estimate of Exposure from Consumption of Locally Produced Fruits and Vegetables

Exposure to COC was assessed through the consumption of produce derived from local agriculture. This includes exposure related to the consumption of root vegetables, aboveground (or leafy) vegetables, and fruits, as follows:

Ingestion of Locally-Grown Fruits and Vegetables

$$EXP_{LP} = \frac{(EXP_{LRV} + EXP_{LAGV} + EXP_{LF}) * EF * ED}{AT}$$

where:

EXP_{LP}	=	exposure from ingestion of local produce (µg/kg/day);
EXP_{LRV}	=	exposure from ingestion of local root vegetables (4.04x10^{-1} µg/kg/day);
EXP_{LAGV}	=	exposure from ingestion of local aboveground vegetables (6.26x10^{-1} µg/kg/day)
EXP_{LF}	=	exposure from ingestion of local fruits (1.25 µg/kg/day);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of local fruits and vegetables for the female preschool child is 2.28 µg/kg/day.

Calculation of exposure *via* consumption of local root vegetables, aboveground vegetables, and fruits are shown below.

Ingestion of Local Root Vegetables

$$EXP_{LRV} = C_{RVL} * (1 - FPLF) * RVIR * Fr_{RVL} * (1 - Fr_{LFH}) * RAF_{Food}$$

where:

EXP_{LRV}	=	exposure from ingestion of local root vegetables (µg/kg/day);
C_{RVL}	=	concentration of contaminant in local root vegetables (0.914 µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$RVIR$	=	Canadian per capita root vegetable intake rate (5.56 g/kg/day);
Fr_{RVL}	=	fraction of root vegetables grown locally (0.106);
Fr_{LFH}	=	fraction of local foods from home garden (0.25); and,
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0).

It should be noted that "1-Fr_{LFH}" represents the fraction of total root vegetables that are commercially grown local foods. Therefore, for the current assessment, the exposure to nickel through ingestion of local root vegetables for the female preschool child is 4.04×10^{-1} µg/kg/day.

Ingestion of Local Aboveground (Leafy) Vegetables

$$EXP_{LAGV} = C_{LVL} * (1 - FPLF) * LVIR * Fr_{LVL} * (1 - Fr_{LFH}) * RAF_{Food}$$

where:

EXP_{LAGV}	=	exposure from ingestion of local aboveground (leafy) vegetables (µg/kg/day);
C_{LVL}	=	concentration of contaminant in local aboveground vegetables (1.076 µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$LVIR$	=	Canadian per capita aboveground vegetables intake rate (3.33 g/kg/day);
Fr_{LVL}	=	fraction of aboveground vegetables grown locally (0.233);
Fr_{LFH}	=	fraction of local foods from home garden (0.25); and,
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0).

Therefore, for the current assessment, the exposure to nickel through ingestion of local aboveground (leafy) vegetables for the female preschool child is 6.26×10^{-1} µg/kg/day.

Ingestion of Local Fruits

$$EXP_{LF} = C_{FL} * (1 - FPLF) * FVIR * Fr_{FVL} * (1 - Fr_{LFVH}) * RAF_{Food}$$

where:

EXP_{LF}	=	exposure from ingestion of local fruits (µg/kg/day);
C_{FL}	=	concentration of contaminant in local fruits (1.489µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$FVIR$	=	Canadian per capita fruit intake rate (14 g/kg/day);
Fr_{FVL}	=	fraction of fruits grown locally (0.082);
Fr_{LFH}	=	fraction of local foods from home garden (0.25); and,
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0).

Therefore, for the current assessment, the exposure to nickel through ingestion of local fruits for the female preschool child is 1.25 µg/kg/day.

B-4.7 Estimate of Exposure from Consumption of Local Wild Blueberries

Exposure to COC was assessed through the consumption of wild blue berries collected from within the Greater Sudbury area as follows:

Ingestion of Local Wild Blueberries

$$EXP_{WB} = \frac{C_{WB} * (1 - FPLF) * FVIR * Fr_{WB} * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{WB}	=	exposure from ingestion of local wild blue berries (µg/kg/day);
C_{WB}	=	concentration of contaminant in local wild blue berries (0.706µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$FVIR$	=	Canadian per capita fruit intake rate (14 g/kg/day);
Fr_{WB}	=	fraction of fruits consumed represented by local wild blue berries (0.093);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of local wild blue berries for the female preschool child is 8.89×10^{-1} µg/kg/day.

B-4.8 Estimate of Exposure from Consumption of Local Wild Game

Exposure to COC was assessed through the consumption of wild game caught from the Greater Sudbury Area as follows:

Ingestion of Local Wild Game

$$EXP_{LWG} = \frac{CL_{WG} * (1 - FPLF) * BIR * Fr_{LWG} * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{LWG}	=	exposure from ingestion of local wild game (µg/kg/day);
C_{LWG}	=	concentration of contaminant in local wild game (0.624 µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
BIR	=	Canadian per capita beef intake rate (5.57 g/kg/day);
Fr_{LWG}	=	fraction of meat consumed represented by local wild game (0.033);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

In the above calculation, the Canadian per capita beef intake rate was calculated from the intake rate reported for only those individuals who consumed beef during the time of the survey, and assuming that 90% of the total Canadian population consumes beef, as shown below:

$$BIR = COBIR * 0.90$$

where:

BIR	=	Canadian per capita beef intake rate (5.57 g/kg/day);
COBIR	=	consumers only beef intake rate (6.19 g/kg/day); and,
0.90	=	per capita adjustment factor for consumption of beef.

Therefore, for the current assessment, the exposure to nickel through ingestion of local wild game for the female preschool child is 1.17×10^{-1} µg/kg/day.

B-4.9 Estimate of Exposure from Consumption of Local Fish

Exposure to COC was assessed through the consumption of fish caught from the Greater Sudbury Area as follows:

Ingestion of Impacted Local Fish

$$EXP_{LF} = \frac{C_{LF} * (1 - FPLF) * FIR * Fr_{LF} * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{LF}	=	exposure from ingestion of local fish (µg/kg/day);
C_{LF}	=	concentration of contaminant in local fish (0.032 µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
FIR	=	Canadian per capita fish intake rate (0.242 g/kg/day);
Fr_{LF}	=	fraction of fish consumed represented by local fish (1.88);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

In the above calculation, the Canadian per capita fish intake rate was calculated from the intake rate reported for only those individuals who consumed fish during the time of the survey, and assuming that 8% of the total Canadian population consumes fish, as shown below:

$$FIR = COFIR * 0.08$$

where:

FIR	=	Canadian per capita fish intake rate (0.242 g/kg/day);
COFIR	=	consumers only fish intake rate (3.02 g/kg/day); and,
0.08	=	per capita adjustment factor for consumption of fish.

Therefore, for the current assessment, the exposure to nickel through ingestion of local fish for the female preschool child is 1.46×10^{-2} µg/kg/day. In order to calculate a total fish intake rate that was equivalent to the local consumption survey data, the 'fraction of fish consumed represented by local fish' had to be adjusted accordingly.

B.4-10 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

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

where:

EXP_{MB}	=	exposure from ingestion of all market basket products (µg/kg/day);
EXP_D	=	exposure from ingestion of market milk and dairy ($6.54x10^{-1}$ µg/kg/day);
EXP_B	=	exposure from ingestion of market meat and eggs ($1.21x10^{-1}$ µg/kg/day);
EXP_F	=	exposure from ingestion of market fish and shellfish ($9.0\ x10^{-3}$ µg/kg/day);
EXP_{RV}	=	exposure from ingestion of market root vegetables ($3.73x10^{-1}$ µg/kg/day);
EXP_{LV}	=	exposure from ingestion of market above ground (leafy) vegetables ($7.15x10^{-1}$ µg/kg/day);
EXP_{FV}	=	exposure from ingestion of market fruits and fruit juices (1.02 µg/kg/day);
EXP_C	=	exposure from ingestion of market cereals and grains (1.93 µg/kg/day);
EXP_{SS}	=	exposure from ingestion of market sugar and sweets ($9.59\ x10^{-1}$ µg/kg/day);
EXP_{FO}	=	exposure from ingestion of market fats and oils ($8.87x10^{-2}$ µg/kg/day); and,
EXP_{NS}	=	exposure from ingestion of market nuts and seeds ($4.36x10^{-1}$ µg/kg/day).

Therefore, for the current assessment, the total exposure to nickel through ingestion of all market basket products for the female preschool child is approximately 6.40 µg/kg/day. It is noted that in some instances when local fish consumption exceeds market basket fish and shellfish consumption, it was assumed that local fish consumption was the only source of this type of food.

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

Ingestion of Market Milk and Dairy

$$EXP_D = \frac{C_D * (1 - FPLF) * DIR * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_D	=	exposure from ingestion of market milk and dairy (µg/kg/day);
C_D	=	concentration of contaminant in market milk and dairy ($1.50x10^{-2}$µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
DIR	=	Canadian per capita dairy intake rate (43.6 g/kg/day);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market milk and dairy for the female preschool child is 6.54x10^{-1} µg/kg/day.

Ingestion of Market Meat and Eggs

$$EXP_B = \frac{C_B * (1 - FPLF) * [\ BIR - (BIR * Fr_{LWG})\ ] * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_B	=	exposure from ingestion of market meat and eggs (µg/kg/day);
C_B	=	concentration of contaminant in market meat and eggs (2.24x10^{-2}µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
BIR	=	Canadian per capita meat and eggs intake rate (5.57 g/kg/day);
Fr_{LWG}	=	fraction of meat consumed represented by local wild game (0.031);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market meat and eggs for the female preschool child is 1.21x10^{-1} µg/kg/day.

Ingestion of Market Fish and Shellfish

$$EXP_F = \frac{C_F * (1 - FPLF) * [\ FIR - (FIR * Fr_{LF})\ ] * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_F	=	exposure from ingestion of market fish and shellfish (µg/kg/day);
C_F	=	concentration of contaminant in market fish and shellfish (3.70x10^{-2}µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
FIR	=	Canadian per capita fish intake rate (0.305 g/kg/day);
Fr_{LF}	=	fraction of fish consumed represented by local fish (0.22);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market fish and shellfish for the female preschool child is 8.80x10^{-3} µg/kg/day. As previously indicated, if local fish consumption rates exceeded the intake rate of market fish and shellfish (from supermarket stores), it was assumed that local fish alone comprised this food group.

Ingestion of Market Root Vegetables
$$EXP_{RV} = \frac{C_{RV} * (1 - FPLF) * [\ RVIR - (\ RVIR * Fr_{RVL}\ )\ ] * RAF_{Food} * EF * ED}{AT}$$
where:
EXP_{RV} = exposure from ingestion of market root vegetables (µg/kg/day);
C_{RV} = concentration of contaminant in market root vegetables ($7.50\text{x}10^{-2}$ µg/g fresh weight);
$FPLF$ = food preparation loss factor (0);
$RVIR$ = Canadian per capita root vegetable intake rate (5.56 g/kg/day);
Fr_{RVL} = fraction of root vegetables consumed represented by local root vegetables (0.106);
RAF_{Food} = chemical-specific relative absorption factor for food (1.0);
EF = exposure frequency (365 days/year);
ED = exposure duration (4.5 years (length of life stage); and,
AT = averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market root vegetables for the female preschool child is $3.73\text{x}10^{-1}$ µg/kg/day.

Ingestion of Market Aboveground (Leafy) Vegetables
$$EXP_{LV} = \frac{C_{LV} * (1 - FPLF) * [\ LVIR - (\ LVIR * Fr_{LVL}\ )\ ] * RAF_{Food} * EF * ED}{AT}$$
where:
EXP_{LV} = exposure from ingestion of market above ground (leafy) vegetables (µg/kg/day);
C_{LV} = concentration of contaminant in market leafy vegetables ($2.80\text{x}10^{-1}$ µg/g fresh weight);
$FPLF$ = food preparation loss factor (0);
$LVIR$ = Canadian per capita leafy vegetable intake rate (3.33 g/kg/day);
Fr_{LVL} = fraction of leafy vegetables consumed represented by local leafy vegetables (0.233);
RAF_{Food} = chemical-specific relative absorption factor for food (1.0);
EF = exposure frequency (365 days/year);
ED = exposure duration (4.5 years (length of life stage); and,
AT = averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market above ground (leafy) vegetables for the female preschool child is $7.15\text{x}10^{-1}$ µg/kg/day.

Ingestion of Market Fruits and Fruit Juices

$$EXP_{FV} = \frac{C_{FV} * (1 - FPLF) * [FVIR - (FVIR * Fr_{FVL})] * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{FV}	=	exposure from ingestion of market fruits and fruit juices (µg/kg/day);
C_{FV}	=	concentration of contaminant in market fruits and fruit juices (7.95×10^{-2} µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$FVIR$	=	Canadian per capita fruit intake rate (13.7 g/kg/day);
Fr_{FVL}	=	fraction of fruits consumed represented by local fruits (0.053);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market fruits and fruit juices for the female preschool child is 1.02 µg/kg/day.

Ingestion of Market Cereals and Grains

$$EXP_{C} = \frac{C_{C} * (1 - FPLF) * CIR * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{C}	=	exposure from ingestion of market cereals and grains (µg/kg/day);
C_{C}	=	concentration of contaminant in market cereals and grains (1.65×10^{-1} µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
CIR	=	Canadian per capita cereals and grains intake rate (11.7 g/kg/day);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market cereals and grains for the female preschool child is 1.93 µg/kg/day.

Ingestion of Market Sugar and Sweets

$$EXP_{SS} = \frac{C_{SS} * (1 - FPLF) * SSIR * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{SS}	=	exposure from ingestion of market sugar and sweets (µg/kg/day);
C_{SS}	=	concentration of contaminant in market sugar and sweets (2.72×10^{-1}µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$SSIR$	=	Canadian per capita sugar and sweets intake rate (3.54 g/kg/day);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market sugar and sweets for the female preschool child is 0.96 µg/kg/day.

Ingestion of Market Fats and Oils

$$EXP_{FO} = \frac{C_{FO} * (1 - FPLF) * FOIR * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{FO}	=	exposure from ingestion of market fats and oils (µg/kg/day);
C_{FO}	=	concentration of contaminant in market fats and oils (5.70×10^{-2}µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$FOIR$	=	Canadian per capita fats and oils intake rate (1.54 g/kg/day);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the total exposure to nickel through ingestion of market fats and oils for the female preschool child is 8.87×10^{-2} µg/kg/day.

Ingestion of Market Nuts and Seeds

$$EXP_{NS} = \frac{C_{NS} * (1 - FPLF) * NSIR * RAF_{Food} * EF * ED}{AT}$$

where:

EXP_{NS}	=	exposure from ingestion of market nuts and seeds (µg/kg/day);
C_{NS}	=	concentration of contaminant in market nuts and seeds (2.00µg/g fresh weight);
$FPLF$	=	food preparation loss factor (0);
$NSIR$	=	Canadian per capita nuts and seeds intake rate (0.218 g/kg/day);
RAF_{Food}	=	chemical-specific relative absorption factor for food (1.0);
EF	=	exposure frequency (365 days/year);
ED	=	exposure duration (4.5 years (length of life stage); and,
AT	=	averaging time (1,642.5 days).

Therefore, for the current assessment, the exposure to nickel through ingestion of market nuts and seeds for the female preschool child is 4.36×10^{-1} µg/kg/day.

B-4.11 Exposure through all Inhalation Pathways

Exposure to nickel through the inhalation of particulates in indoor and outdoor air was calculated as follows:

Inhalation of Fine Particulates in Outdoor and Indoor Air

$$EXP_{Inh\ Total} = EXP_{Inh\ OA} + EXP_{Inh\ IA}$$

where:

$EXP_{Inh\ Total}$	=	total inhalation exposure (µg/kg/day);
$EXP_{Inh\ OA}$	=	inhalation exposure *via* outdoor air (3.21×10^{-3} µg/kg/day); and,
$EXP_{Inh\ IA}$	=	inhalation exposure *via* indoor air (4.76×10^{-2} µg/kg/day).

Therefore, for the current assessment, the total exposure to nickel for the female preschool child living in Sudbury (centre) through all inhalation pathways is 5.08×10^{-2} µg/kg/day.

B-4.12 Exposure through all Dermal Pathways

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

Exposure through all Dermal Pathways

$$EXP_{DermalTotal} = EXP_{DermalSoil} + EXP_{DermalDust}$$

where:

$EXP_{Dermal\ Total}$	=	total exposure *via* all dermal pathways (µg/kg/day);
$EXP_{Dermal\ Soil}$	=	dermal exposure *via* direct contact with soil (1.50×10^{-4} µg/kg/day); and,
$EXP_{Dermal\ Dust}$	=	dermal exposure *via* direct contact with dust (9.03×10^{-5} µg/kg/day).

Therefore, for the current assessment, the total exposure to nickel for the female preschool child living in Sudbury (centre) through all dermal pathways is 2.40×10^{-4} µg/kg/day.

B.4.13 Exposure through all Oral Pathways

Exposure to nickel 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

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

where:

$EXP_{Oral\ Total}$	=	exposure *via* all oral pathways (µg/kg/day);
$EXP_{Ing\ Soil}$	=	exposure *via* incidental ingestion of soil (2.52×10^{-2} µg/kg/day);
$EXP_{Ing\ Dust}$	=	exposure *via* incidental ingestion of dust (4.1×10^{-1} µg/kg/day);
EXP_{DW}	=	exposure *via* consumption of drinking water (1.9 µg/kg/day);
EXP_{HP}	=	exposure *via* ingestion of homegrown produce (1.03 µg/kg/day);
EXP_{LP}	=	exposure *via* ingestion of local produce (2.28 µg/kg/day);
EXP_{WB}	=	exposure *via* ingestion of local wild berries (8.89×10^{-1} µg/kg/day);
EXP_{LWG}	=	exposure *via* ingestion of local wild game (1.17×10^{-1} µg/kg/day);
EXP_{LF}	=	exposure *via* ingestion of local fish (1.46×10^{-2} µg/kg/day); and,
EXP_{MB}	=	exposure *via* ingestion of market basket products (6.30 µg/kg/day).

Therefore, for the current assessment, the total exposure to nickel for the female preschool child living in Sudbury (centre) through all oral pathways is 13.1 µg/kg/day.

B-4.14 Total Exposure

Total exposure to nickel *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 (5.08x10^{-2} µg/kg/day);
$EXP_{Dermal\ Total}$	=	total exposure *via* all dermal pathways (2.40x10^{-4} µg/kg/day); and,
$EXP_{Oral\ Total}$	=	total exposure *via* all oral pathways (13.3 µg/kg/day).

Therefore, for the current assessment, the total exposure to nickel for the female preschool child living in Sudbury (centre) through all exposure pathways is 13.2 µg/kg/day.

B.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:

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

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, Incremental Lifetime Cancer Risk (ILCR) levels were used to communicate the estimated additional lifetime cancer risk associated with on-site exposure estimates as follows:

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

B-5.1 Human Health Risks Associated with Oral and Dermal Exposure

Since nickel does not act as a carcinogen through oral or dermal exposure, a hazard quotient was calculated for exposure to nickel *via* all oral and dermal pathways as follows:

$$HQ = \frac{EXP_{Dermal\ Total} + EXP_{Oral\ Total}}{EXP\ Limit_{Oral}}$$

where:

HQ	=	Hazard Quotient (unitless);
$EXP_{Dermal\ Total}$	=	Total dermal exposure ($2.40\text{x}10^{-4}$ µg/kg/day);
$EXP_{Oral\ Total}$	=	Total oral exposure (13.1 µg/kg/day); and,
$EXPLimit_{oral}$	=	Oral exposure limit for nickel (20 µg/kg/day).

Therefore, for the current assessment, the HQ for exposure to nickel for the female preschool child living in Sudbury (centre) through all oral and dermal pathways is 0.66, below the acceptable HQ benchmark of 1.0 (*i.e.*, exposure does not exceed the acceptable daily intake for nickel). As such, low or no health risk to the female preschool child living in Sudbury (centre) is predicted from exposure to nickel *via* these pathways.

B-5.2 Human Health Risks Associated with Inhalation Exposure

The model runs conducted for nickel via inhalation assumed a non-carcinogenic end-point of concern and, therefore, a hazard quotient (HQ) value was estimated for this route of exposure.

$$HQ = \frac{EXP_{Inh\ Total}}{EXP\ Limit_{Inh}}$$

where:

HQ	=	Hazard Quotient (unitless);
$EXP_{Inh\ Total}$	=	Total inhalation exposure ($5.08\text{x}10^{-2}$ µg/kg/day); and,
$EXPLimit_{Inh}$	=	Inhalation exposure limit for nickel ($5.71\text{x}10^{-3}$ µg/kg/day).

The nickel inhalation HQ estimate for the female preschool child living in Sudbury (centre) via inhalation was approximately 8.9. Refer to Chapter 5 for a detailed discussion of the nickel inhalation results.

B-6.0 REFERENCES

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