Evaluation of Trail Homegrown Produce Consumption Final Draft

Prepared for:
Teck Metals Ltd.
25 Aldridge Avenue
PO Box 1000
Trail, B.C. V1R 4L8
Canada

Prepared by:
ENVIRON International Corporation
Seattle, Washington

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ENVIRON

Contents

Acronyms and Abbreviations

$ADD_{produce}$:	Average daily dose from consumption of produce (mg/kg-day)
ALS:	ALS Laboratory in Vancouver, BC
ANOVA:	Statistical Analysis of Variance
AT:	Averaging time (days)
BW:	Body weight (kg)
CARO:	CARO Analytical Services in Richmond, BC
CCME:	Canadian Council of Ministers of the Environment
CF:	Unit conversion factor (1,000 g/kg)
$C_{fruiting}$:	Concentration of cadmium in the fruiting parts of vegetables and in fruits (mg/kg ww)
C_{leafy}:	Concentration of chemical in leafy vegetables (mg/kg ww)
C_{root}:	Concentration of chemical in root vegetables (mg/kg ww)
ED:	Exposure duration (years)
EF:	Exposure frequency (days/year)
FI:	Fractional intake from homegrown sources (unitless)
HHRA:	Phase 4 Human Health Risk Assessment
HQ:	Hazard Quotient
I:	Estimated Average Daily Intake
$IR_{fruitingadj}$:	Fruiting vegetables and fruit consumption rate adjusted for lifetime intake (g-year/kg-day)
$IR_{leafyadj:}$	Leafy vegetable consumption rate adjusted for lifetime intake (g-year/kg-day)
$IR_{rootadj}$:	Root vegetable consumption rate adjusted for lifetime intake (g-year/kg-day)
NHANES:	National Health and Nutrition Examination Survey
NOAEL:	No Observed Adverse Effect Level
RfD:	Reference Dose
TDI:	Tolerable Daily Intake
TRV:	Toxicity Reference Values
USEPA:	United States Environmental Protection Agency
USEPA IRIS:	United States Environmental Protection Agency - Integrated Risk Information System
US FDA:	United States Food and Drug Administration
UCLM:	Upper Confidence Limits on the Mean Concentration
WHO:	World Health Organization

1 Introduction

This assessment was conducted for Teck Metals Limited (Teck) to update calculations in the Phase 4 *Human Health Risk Assessment (HHRA) for Offsite Impacts from Trail, B.C., Smelter* (Integral 2008, hereafter "the Phase 4 HHRA") and has three main objectives:

- Incorporating cadmium and thallium concentrations from recently collected homegrown produce samples,
- Re-evaluating consumption rates for various produce types (i.e., rooting, fruiting vegetables, and leafy vegetables) including consideration of high rates of produce consumption,
- Evaluating the relative contribution from consumption of homegrown produce to the overall intake of cadmium and thallium.

The prior evaluation of exposure to metals in homegrown produce in the Phase 4 HHRA indicated that hazards associated with cadmium are well below a threshold of concern. Noncancer hazard indices calculated in the Phase 4 HHRA for thallium slightly exceeded the acceptable hazard index of 1.0 for the child scenario considering combined exposures to thallium in soil, dust, and homegrown produce based on data for East Trail, Rivervale, Tadanac, and West Trail neighborhoods. Biomonitoring for thallium conducted in 2001 on 50 residents from Trail indicated that Trail residents might have slightly higher exposure than that in the typical United States (US) population, but that the levels were well below levels of concern. This biomonitoring provided biometric data which indicated that exposures were within safe levels. Teck's consultants have collected produce data subsequent to the Phase 4 HHRA, in part to assess the effectiveness of garden remediation. Teck desired an update to the Phase 4 HHRA produce risk estimates for cadmium and thallium using these additional data.

This document includes a data assessment that summarizes the produce cadmium and thallium data for samples collected from 2007 through 2013 and presents produce exposure point concentrations; an exposure assessment that describes the consumption rate estimates for produce types; and a risk estimate update. Produce cadmium and thallium concentrations in remediated vs. unremediated gardens are also assessed.

2 Data Assessment

Cadmium and thallium concentrations are available for soil and homegrown vegetables for areas defined in the Phase 4 HHRA as near the Teck Smelter and those defined as far away, with "near" including East Trail, Glenmerry, Shaver's Bench, Sunningdale, Tadanac, West Trail and Rivervale and "far" including Casino, Oasis, Waneta, and Warfield[1]. Produce data for 2007 through 2013 were available for all of these areas except Warfield, Shavers Beach, and Casino. Most available produce data are from the "near" areas, which are the focus of this assessment.

[1] Warfield was considered a "near" area in the Phase 4 HHRA, but subsequent analysis has shown it is more consistent with the far areas. No data were collected from this area during the 2007 or 2010 produce collection efforts considered here so it is not considered in this assessment.

Produce sampling is described in Enns and McCormick (2014). Produce samples collected from 2010 to 2012 were analyzed by ALS Laboratory in Vancouver, BC (ALS). Samples collected in 2013 were analyzed by CARO Analytical Services in Richmond, BC (CARO). All samples were analyzed using USEPA method 203.6020A[2]. None of the cadmium samples were undetected. Thallium was undetected in 111 of the 205 samples and detection limits varied from 0.001 to 0.01 mg/kg wet weight. Undetected samples are included in the analysis as ½ the detection limit. The high frequency of undetected samples and the variability in detection limits lends uncertainty to the thallium sample data. Cadmium and thallium data analyses are discussed separately below.

The data files also indicate whether soils have been remediated or not. In order to assess whether there were variations in produce cadmium concentrations among "near" neighborhoods, an analysis of variance test was run to compare the means of the 2010-2013 datasets for Tadanac, West Trail and East Trail. It was determined that the means of these three groups are not statistically different, so they are treated here as one dataset for the "near" area. Data were also analyzed to determine whether there were significant differences between years during which produce samples were collected. A t-test was conducted to compare the means of the following groups for the data in the "near" areas:

- 2007 root cadmium data vs. 2010-2013 root cadmium data
- 2007 fruiting vegetable cadmium data vs. 2010-2013 fruiting vegetable cadmium
- 2007 leaf cadmium data vs. 2010-2013 leaf cadmium data

The only group that showed a significant difference between years was the fruiting vegetables. The fruiting vegetable concentrations were much lower than concentrations in leafy or root vegetables, so the difference in concentrations between time periods was judged not to be meaningful in terms of human exposure potential. Therefore the data were combined across all years from 2007-2013 for each of the three vegetable types.

Initial analyses were conducted with cadmium data to evaluate appropriate grouping of data for the risk assessment. Analyses of sample results by year and considerations of near and far areas were not conducted using thallium produce concentrations because thallium was frequently undetected in produce samples for all produce types limiting the ability to make meaningful statistical comparisons by year and by area.

Figures 1-3 below show concentrations of cadmium in individual produce samples within the neighborhoods where they were sampled and Figures 4-6 show these data for thallium. Cadmium concentrations in leafy produce are higher than those in root vegetables, while fruiting vegetables and fruits generally had the lowest concentrations. Thallium concentrations are also highest in leafy produce, with roots having much lower concentrations and fruits and fruiting

[2] ALS worksheet notes: "This method is adapted from US EPA Method 200.3 "Sample Procedures for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues" (1996). Tissue samples are homogenized and sub-sampled prior to hotblock digestion with nitric and hydrochloric acids, in combination with repeated additions of hydrogen peroxide. Analysis is by Inductively Coupled Plasma - Mass Spectrometry, adapted from US EPA Method 6020A. This digestion procedure was implemented on October 5, 2009"

vegetables having the lowest concentrations. Many thallium samples were undetected within each of the produce types. A single highly elevated sample of 78.9 mg/kg in kale sample from East Trail was considered to be unreliable because it was much higher than the next highest concentration of 4.1 and was considerably higher than the highest soil sample in East Trail reported in the Phase 4 HHRA of 6.6 mg/kg. Therefore, this sample was not included in subsequent analyses. Differences in concentration within produce types are taken into account in exposure and risk estimates presented in this report.

The figures also indicate whether the soil where the vegetable or fruit was collected was remediated or not. As indicated, produce concentrations within remediated soil areas are not strikingly different from those in unremediated soils. However, statistical evaluation of cadmium concentrations in produce from remediated and unremediated areas found that when all produce types were considered together as a group, produce grown on unremediated soils had slightly higher cadmium concentrations than those from remediated soils (Enns and McCormick 2014, Table 13). In other words, statistical analysis of variance (ANOVA) tests on produce concentration data within the three groups (root, fruiting vegetables and leafy) indicated small but statistically significant differences in cadmium concentrations in leafy vegetables grown in unremediated soils compared with those from remediated soils. However, as discussed in section 5.2, the counts and types of leafy vegetables sampled are very different for remediated and unremediated gardens, lending uncertainty to the interpretation. Given these findings, and to better address questions regarding the need for remediation of soils, the risk estimates for cadmium provided in this assessment are based on vegetables grown on unremediated soils. There were too few thallium samples in unremediated soils to serve as the basis for risk calculations and so thallium produce concentration for remediated and unremediated areas were grouped in exposure estimates.

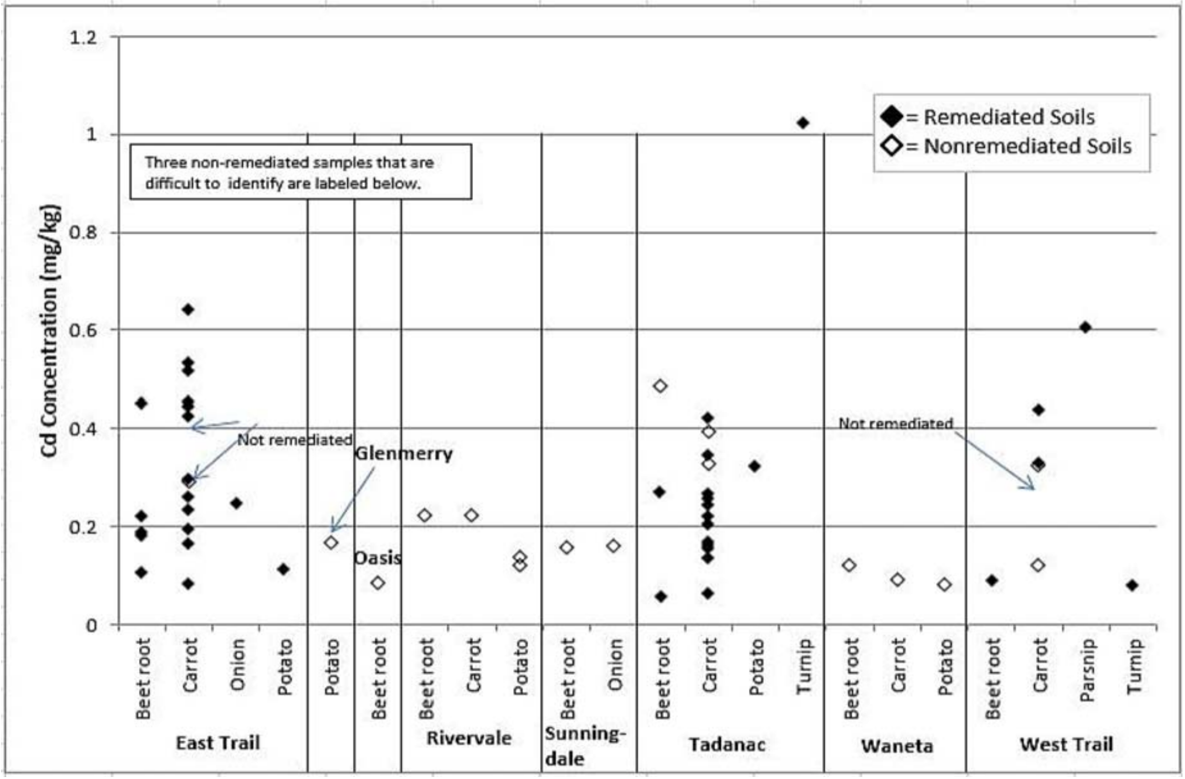

Figure 1. Cadmium in Root Vegetables Sampled in the Vicinity of the Trail Smelter (2007-2013)

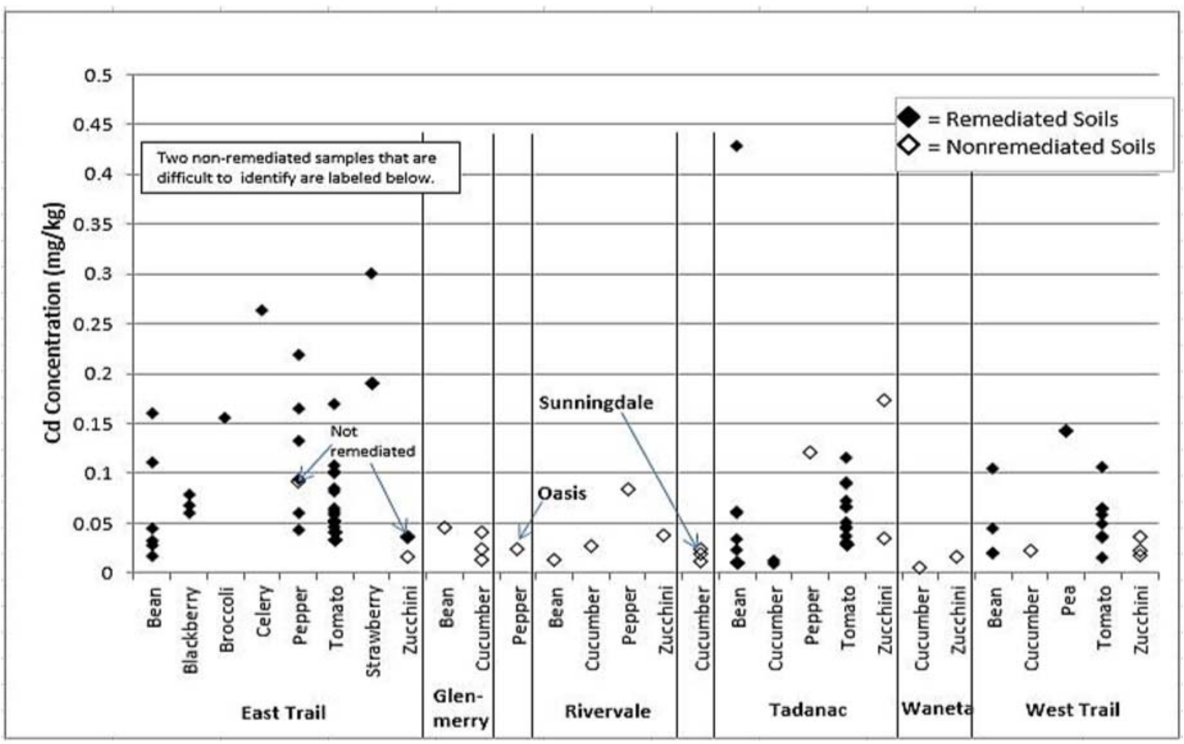

Figure 2. Cadmium in Fruit and Fruiting Vegetables Sampled in the Vicinity of the Trail Smelter (2007-2013)

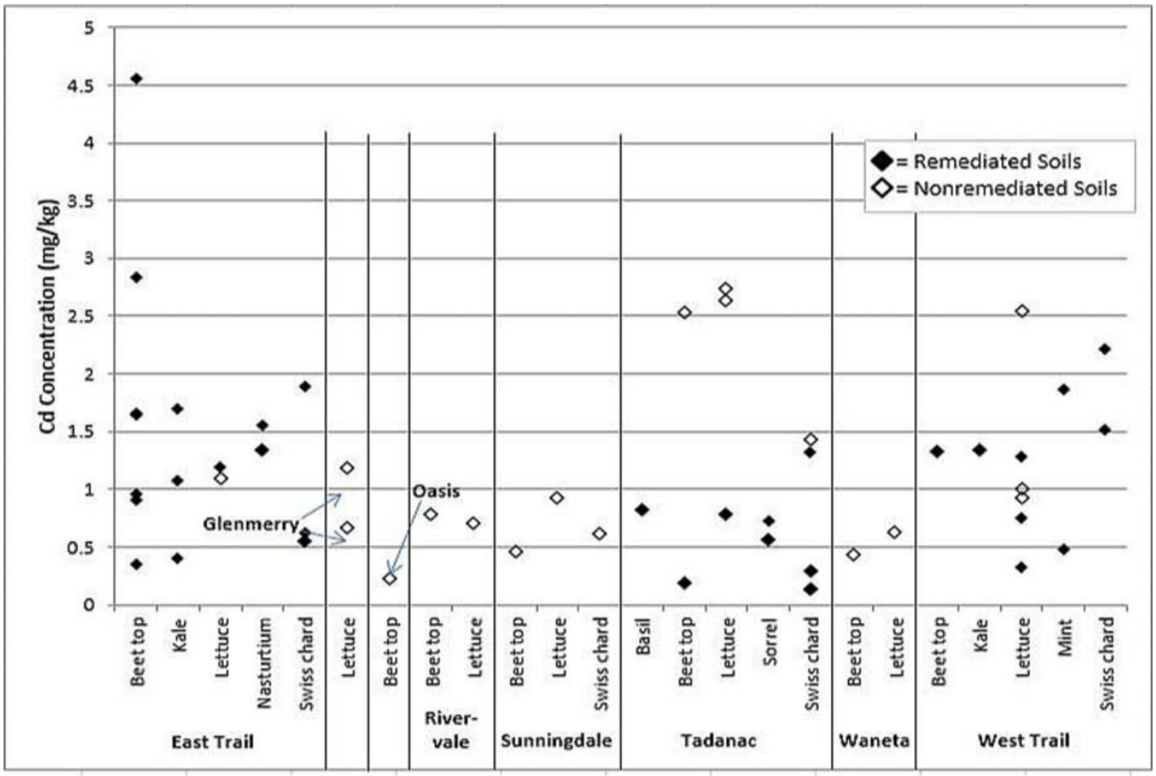

Figure 3. Cadmium in Leafy Vegetables Sampled in the Vicinity of the Trail Smelter (2007-2013)

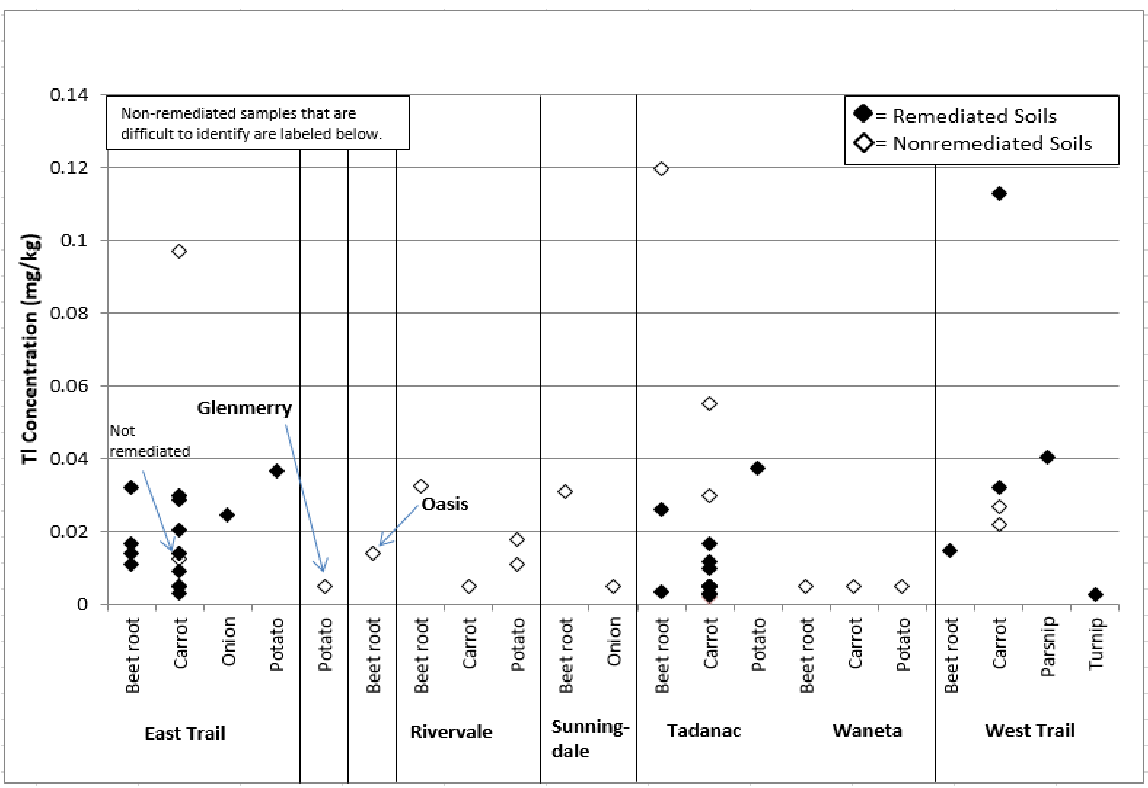

Figure 4: Thallium in Root Vegetables Sampled in the Vicinity of the Trail Smelter (2007-2013)

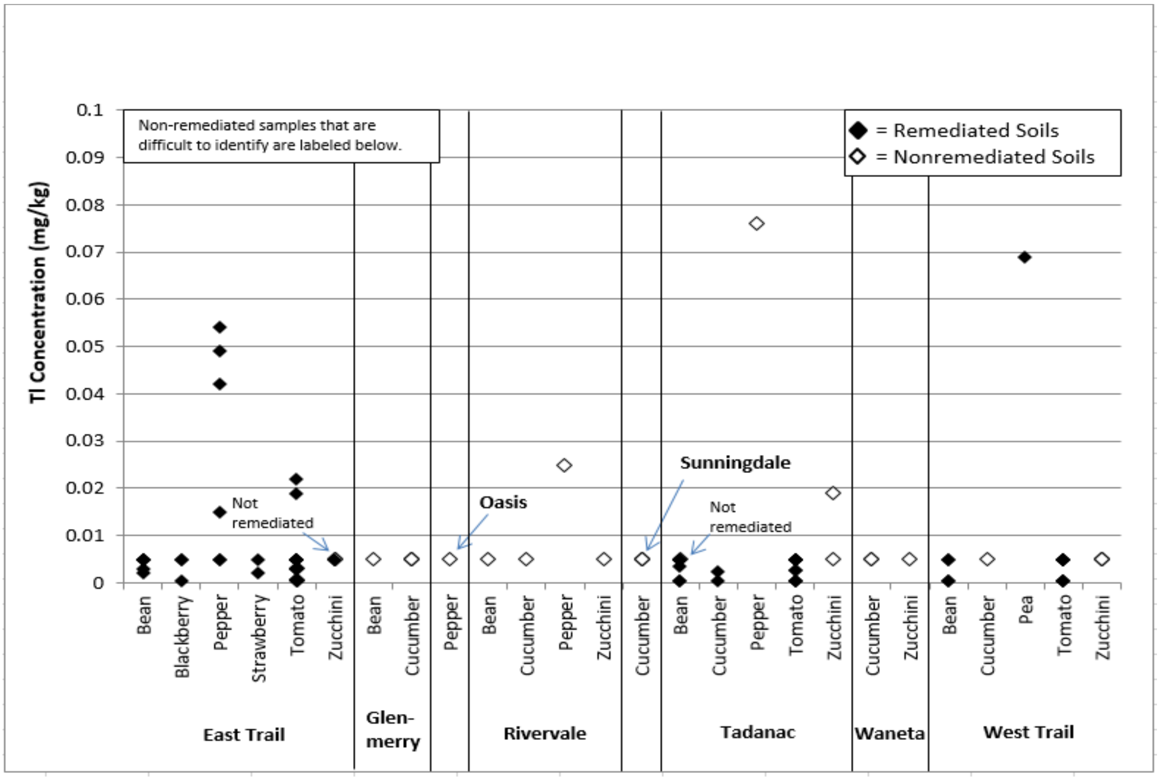

Figure 5 Thallium in Fruit and Fruiting Vegetables Sampled in the Vicinity of the Trail Smelter (2007-2013)

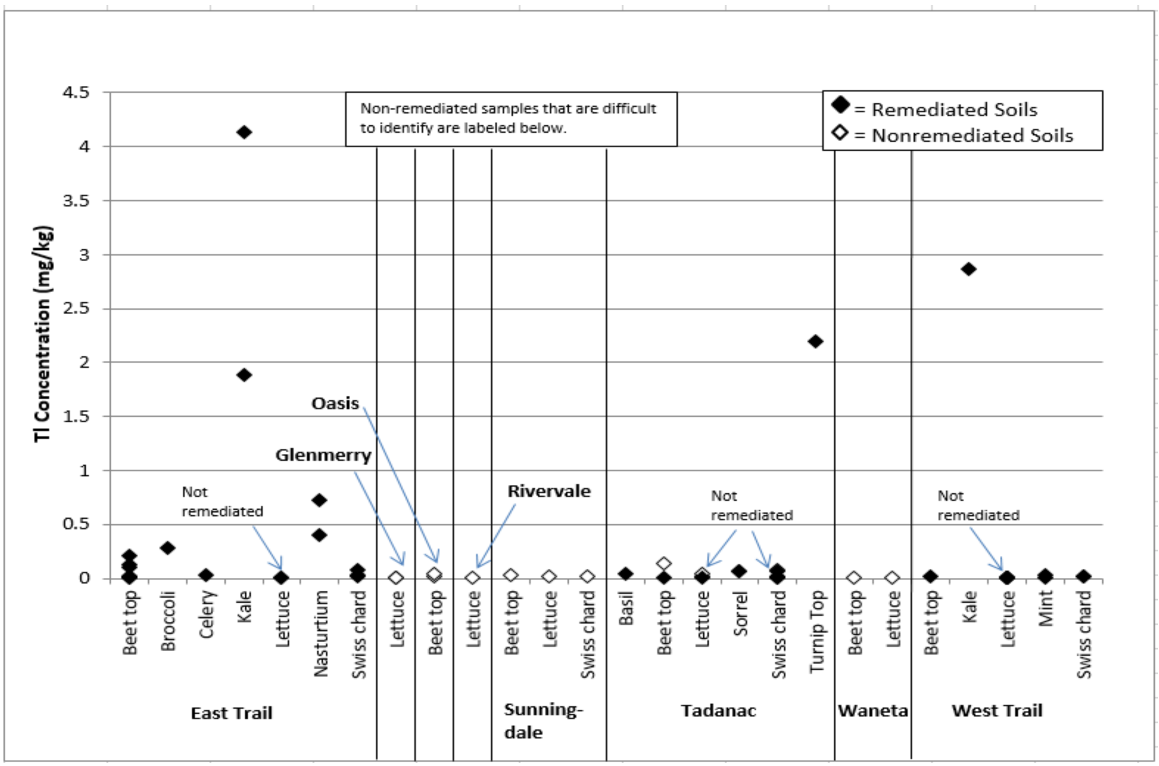

Figure 6. Thallium in Leafy Vegetables Sampled in the Vicinity of the Teck Smelter (2007-2013)*
***(Excludes sample of kale with concentration of 78.9 mg/kg, see text)**

Summary statistics are presented in Table 1 for produce data grouped into produce types and geographic areas for cadmium and thallium.

Table 1. Cadmium and Thallium Concentrations in Trail Homegrown Produce (mg/kg wet weight)

Dataset	%detected	N	Min	Max	Mean
Cadmium					
Near Root	100%	53	0.06	1.0	0.3
Far Root	100%	4	0.08	0.1	0.1
Near Fruiting	100%	89	0.009	0.4	0.07
Far Fruiting	100%	3	0.005	0.02	0.01
Near Leafy	100%	51	0.1	4.6	1.0
Far Leafy	100%	3	0.2	0.6	0.4
Thallium					
Dataset	**%detected**	**N**	**Min**	**Max[a]**	**Mean**
Near Root	69%	52	0.002	0.13	0.02
Far Root	25%	4	0.01	0.01	0.01
Near Fruiting	17%	90	0.001	0.09	0.01
Far Fruiting	0%	4	0.01	0.01	0.01
Near Leafy	76%	51	0.004	4	0.27
Far Leafy	67%	3	0.01	0.02	0.01

[a]Excludes outlier leafy sample with 78 mg/kg thallium.

In risk assessment, exposure point concentrations are calculated from available data to provide estimates of the average concentrations to which a person might be exposed over the expected exposure period (typically the number of years people are expected to live in a residence). Health Canada (2012) does not indicate a specific approach to derive exposure point concentrations, but does indicate that USEPA guidance can be used where representative guidance is not available. For this reason, the USEPA ProUCL Software program (USEPA 2013, Version 5) was used to derive the exposure point concentrations expressed as the 95 percent upper confidence limit on the mean concentration (UCLM) for each metal and produce type. An earlier version of this program was also used in the Phase 4 HHRA.

For cadmium exposure point concentrations were calculated for the “near” data in unremediated soils and used for exposure estimates (Table 2). Table 2 also shows exposure point concentrations for remediated soils for comparison. Data are too limited to make meaningful estimates of exposure for far areas. However, because concentrations in far areas are consistently lower than those in near areas, any estimates made for near areas will provide a protective means to consider risks in far areas and for produce grown on remediated soils.

Table 2. Cadmium Concentrations in Trail Produce from Areas Near the Smelter (mg/kg wet weight)

Dataset (Near)	N	Min	Max	Mean	Recommended UCLM
Root, Unremediated	14	0.12	0.5	0.26	0.32[a]
Root, Remediated	39	0.06	1.0	0.29	0.35[b]
Fruiting, Unremediated	21	0.01	0.2	0.04	0.06[c]
Fruiting, Remediated	68	0.009	0.4	0.08	0.09[d]
Leafy, Unremediated	15	0.5	2.7	1.4	1.9[b]
Leafy, Remediated	36	0.13	4.6	1.1	1.4[a]

Notes:
UCLM = upper confidence limit on the mean. Shaded UCLM row was value used in this HHRA.
[a] 95% Student's-t UCLM, [b] 95% adjusted gamma UCLM, [c] 95%H-UCLM, [d] 95% approximate gamma UCLM

For thallium exposure point concentrations are based on data for remediated and unremediated soils combined (Table 3). As shown in Figures 6 and 7 most leafy greens had thallium concentrations less than 1 mg/kg wet weight; however, a single kale sample from East Trail had a highly elevated concentration of 78.9 mg/kg and was judged to be an outlier. In addition, four other samples (three kale and one turnip top) also had elevated thallium concentrations. The few high thallium results had a large impact on the UCLM for thallium in leafy greens. For that reason, as well as and to illustrate the sensitivity of the interpretation to these few samples, Table 3 shows UCLMs calculated two ways. Specifically, Table 3 shows UCLMs calculated using all leafy results except the single highly elevated kale sample. A UCLM for leafy greens was also calculated excluding the same 78.9 mg/kg outlier sample in kale, as well as three additional kale samples and one turnip green sample.

Table 3. Thallium Concentrations in Trail Produce from Areas near the Smelter (mg/kg wet weight)

Dataset (Near)	N	% Detected	Min	Max	Mean[a]	Recommended UCLM
Root, Unremediated	14	79%	0.01	0.12	0.03	0.03[b]
Root, Remediated	38	66%	0.002	0.13	0.02	
Fruiting, Unremediated	22	18%	0.01	0.09	0.01	0.0095[c]
Fruiting, Remediated	68	16%	0.001	0.07	0.007	
Leafy values excluding 1 outlier result						
Leafy, Unremediated	15	53%	0.01	0.14	0.03	0.96[d,e]
Leafy, Remediated[d]	36	86%	0.004	4.1	0.38	
Leafy values excluding 4 high sample results						
Leafy, Unremediated	15	53%	0.01	0.14	0.03	0.14[e,f]
Leafy Remediated[f] (Excluding 5 samples)	32	84%	0.004	0.7	0.08	

Notes:
UCLM = upper confidence limit on the mean. Thallium UCLM calculated for unremediated and remediated soils combined due to limited data for produce from unremediated soils. Shaded UCLM row was value used in this HHRA.
[a]Mean calculated with values below the detection limit equal to half of the detection limit
[b] UCLM represents 95% Kaplan-Meier (KM) bias-corrected accelerated bootstrap method
[c] UCLM represents 95% KM (t)
[d]Excludes outlier leafy sample with 78 mg/kg thallium
[e] UCLM represents 97.5% KM (Chebyshev)
[f] Excludes outlier leafy sample with 78 mg/kg thallium and also 4 other leafy samples greater than 1 mg/kg.

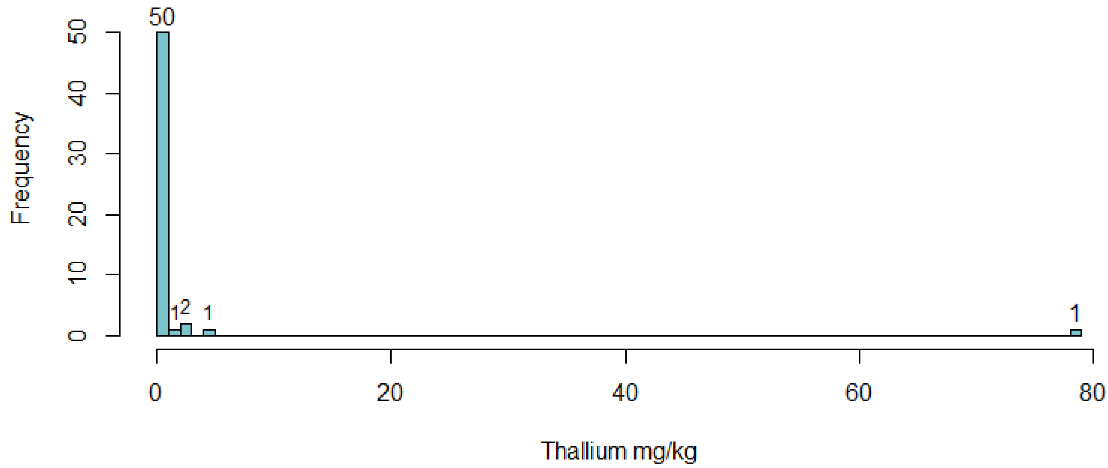

Figure 7. Histogram of Thallium in Leafy Vegetables Sampled in the Vicinity of the Trail Smelter (2007-2013)

3 Exposure Assessment

This section describes revised assumptions applied to estimate exposure to cadmium and thallium in homegrown produce. Changes in these assumptions from those used in the Phase 4 HHRA were needed due to updates on dietary consumption rates and due to particular questions associated with consumption of leafy greens. The Phase 4 HHRA only distinguished between root and non-root vegetables; however, the leafy green vegetables continue to have higher cadmium and thallium concentrations than do the other non-root produce, making it necessary to break out this grouping to address questions related to ongoing exposures.

Discussion is provided below for values selected for age groups considered, produce consumption rates, fractional intake, and exposure frequency and body weights. Guidance applied in the exposure assessment includes updated exposure assessment guidance from Health Canada (2012, 2010a,b), Richardson and Stantec (2013), and the U.S. Environmental Protection Agency (USEPA) Exposure Factors Handbook (2011), as well as the older guidance from Richardson (1997) relied upon in the Phase 4 HHRA. The algorithms and assumptions for quantifying consumption of homegrown produce are presented in Exhibit 3-1.

Exhibit 3-1: Consumption of Homegrown Produce

$$ADD_{produce} = \frac{[(C_{root} \times IR_{rootadj}) + (C_{fruiting} \times IR_{fruitingadj}) + (C_{leafy} \times IR_{leafyadj})] \times EF \times ED \times FI}{AT \times CF}$$

Where:

$ADD_{produce}$	=	Average daily dose from consumption of produce (mg/kg-day)
C_{root}	=	Concentration of cadmium or thallium in root vegetables (mg/kg ww)
$IR_{rootadj}$	=	Root vegetable consumption rate adjusted for lifetime intake (g-year/kg-day)
$C_{fruiting}$	=	Concentration of cadmium or thallium in the fruiting parts of vegetables and in fruits (mg/kg ww)
$IR_{fruitingadj}$	=	Fruiting vegetables and fruit consumption rate adjusted for lifetime intake (g-year/kg-day)
C_{leafy}	=	Concentration of cadmium or thallium in leafy vegetables (mg/kg ww)
$IR_{leafyadj}$	=	Leafy vegetable consumption rate adjusted for lifetime intake (g-year/kg-day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
FI	=	Fractional intake from homegrown sources (unitless)
AT	=	Averaging time (days)
BW	=	Body weight (kg)
CF	=	Unit conversion factor (1,000 g/kg)

Exposure parameter values are provided in Table 4.

Table 4. Exposure Parameters Used In Hazard Quotients

Parameter	Parameter Definition	Units	Adult	Toddler	Adult +Child*	Reference
C_{root}	Cadmium and thallium in root vegetables	mg/kg	Tables 2 and 3			
$C_{fruiting}$	Cadmium and thallium in fruiting vegetables & fruit	mg/kg	Tables 2 and 3			
C_{leafy}	Cadmium and thallium in leafy vegetables	mg/kg	Tables 2 and 3			
IR_{root}	Ingestion rate root vegetables	g/day	30 mean 189 95th	10 mean 70 95th	13 mean 80 95th	NHANES
$IR_{fruiting}$	Ingestion rate fruiting vegetables & fruit	g/day	49 mean 244 95th	18 mean 127 95th	21 mean 111 95th	NHANES
IR_{leafy}	Ingestion rate leafy vegetables	g/day	25 mean 131 95th	3.3 mean 21 95th	9.4mean 50 95th	NHANES
EF	Exposure frequency	days/yr	365	365	365	USEPA 2013
ED	Exposure duration	yrs	27	3	30	USEPA 2013
FI	Fractional intake	--	0.1	0.1	0.1	CCME 2006
CF	Conversion factor	g/mg	0.001	0.001	0.001	USEPA 1989
BW	Body weight	kg	76.6	15.4	--	Richardson 2013
AT	Averaging time	days	9,855	1,085	10,950[1]	USEPA 2013

Notes:
[1] Consistent with toxicity study basis, exposure estimates for cadmium were calculated for the lifetime by deriving time weighted intake rates per kg body weight as follows:

$$IR_{adj} \text{ in g-year/kg-day} = IR_{adj} = \frac{(IR_{child} \times ED_{child})}{BW_{child}} + \frac{(IR_{adult} \times ED_{adult})}{BW_{adult}}$$

The exposure variables were used to estimate intakes as lifetime average daily doses (ADD) in mg/kg-day using the algorithm in Exhibit 3-1. These exposure variables are described further in the following sections.

3.1 Age Groups Considered

Consistent with the approach applied in the Phase 4 HHRA, exposure estimates were calculated for both adults and young children. For this assessment, age groups were selected from current Health Canada (2012) guidance and include a young child (toddler) aged 1 to <4 weighing 15.4 kg and an adult weighing 76.6 kg.

3.2 Produce Consumption Rates

The Phase 4 HHRA applied homegrown produce consumption rates for root and non-root vegetables drawn from Richardson (1997), which provided food (including produce) consumption rate distributions based on Canadian national data. Mean values for root produce consumption were 105 g/day for children and 196 g/day for adults. Consumption of non-root produce was assumed to average 67 g/day for children and 143 g/day for adults as shown in Table 5. These consumption rates represent a wide variety of foods from all sources including the grocery store. Consistent with guidance from the Canadian Council of Ministers of the Environment (CCME 2006) and the approach in the Phase 4 HHRA a fractional intake of 0.1 is then applied to represent amounts consumed as homegrown produce.

Table 5. Average Vegetable Consumption Rates in Richardson (1997)

Age Group	Root		Non-root	Totals
Toddler 1 to < 4 yr	105	--	67	172
Adult 20 to < 65	196	--	143	339

The consumption rates in Richardson (1997) are still recommended in guidance from Health Canada (2012). However, Richardson (1997) did not provide separate intake rates for fruiting or leafy vegetables. To better estimate consumption of homegrown produce by food group, updates to the 1997 Canadian consumption rate reference were sought. Although there is an update to the 1997 Richardson guidance (Richardson and Stantec 2013), the more recent guidance does not provide updated food consumption recommendations. Health Canada (2010a) recommends Richardson (1997) as basis for assumed consumption of homegrown foods in non-aboriginal populations, but notes that these consumption rate data in may be somewhat out of data. Health Canada indicates that more recent surveys of food consumption have been conducted in all provinces, but that compiled and published data are only available for Nova Scotia and Quebec. Health Canada also recommends that U.S. risk assessment resources should be used where representative Canadian data are not available.

The USEPA Exposure Factors Handbook (USEPA 2011) provides intake rates for produce based on U.S. dietary intake as reported from the National Health and Nutrition Examination Survey (NHANES). However, the Exposure Factors Handbook consumption rates are not collated by the food groups of interest in Trail and do not allow for separate consideration of leafy produce which has higher cadmium and thallium concentrations. Thus, in order to provide representative consumption rates for produce grown in Trail, ENVIRON queried the NHANES data for years 2007-8 and 2009-10 directly and assembled consumption rate data consistent with foods considered by Richardson (1997) and also consistent with those grown in Trail.

Dietary consumption data in the NHANES database is based on a compilation of intakes for a broad listing of foods people regularly consume. These lists may specify how the foods are prepared, meaning that multiple variations on a single raw food may need to be identified and complied to obtain the total intake of that food (e.g., fresh, frozen and creamed spinach). For the purposes of this assessment, foods likely to be grown in Trail gardens were identified and NHANES consumption rate data were compiled, as illustrated below:

- Root produce – including, but not limited to, carrots, onions, rutabagas, turnip, beets, potatoes (including raw, boiled, canned, French fries, and chips).
- Fruiting produce – Fruits and fruiting vegetables were combined to derive estimates for fruiting vegetables, including but not limited to corn, celery, green peppers, cauliflower, broccoli, green beans, peas, tomatoes (including fresh or canned and tomato-based

condiments), mushrooms, cucumbers (including fresh and cucumber-based condiments), baby food vegetables, asparagus, rhubarb, squash, popcorn, and beans. Fruits included were only those judged to be potentially grown in British Columbia (i.e., no tropical or citrus fruits were included).

- Leafy produce – including, but not limited to, cabbage (including coleslaw) and various types of greens.

The most recent NHANES estimates are 1-day consumption rate estimates and are provided on a per capita basis (termed "all respondents") and as rates among people who ate those specific foods on the survey day (termed "consumers only"). The per capita basis data for "all respondents" are more appropriate for estimating long-term exposure in a population and are used here to derive consumption rates for homegrown foods. The USEPA Exposure Factors Handbook notes that using data from only people who consumed the foods on the survey day (i.e., "consumers only") from short-term intake studies such as the 1-day recall data available from NHANEs will not be representative of long-term consumption of foods. USEPA also notes that the limitations of such data are particularly significant in evaluating fruits and vegetables that have seasonal variability in availability (USEPA 2011) stating:

> *Day-to-day variation in intake among individuals will be high for fruits and vegetables that are highly seasonal and for fruits and vegetables that are eaten year-round, but that are not typically eaten every day. For these fruits and vegetables, the intake distribution generated from short-term data will not be a good reflection of the long-term distribution.*

USEPA goes on to state:

> *Because of the increased variability of the short-term distribution, the short-term upper percentiles shown here may overestimate the corresponding percentiles of the long-term distribution.*

Resulting estimates of consumption rates by food group are shown in Table 6 and additional detail on the assumptions used to derive intake estimates for fruiting vegetables and fruit is provided in Table 7.

Mean and 95th percentile consumption rates were derived from NHANES data for the homegrown produce groups (rooting, fruits and fruiting, and leafy vegetables). Although the means and 95th percentiles from these groups are shown both individually and as a summed total of the mean and of the 95th percentile estimate, it should be noted that the summed 95th percentile estimates likely represent a substantial overestimate of intake for any one individual. This is because each of the 95th percentile estimates are representative of the high end consumers for that specific group of foods and any one individual is unlikely to fall in the 95th percentile for all foods considered here. Nevertheless, a summed 95th percentile intake estimate is provided here to provide a high-end estimate of consumption and for comparison with the Phase 4 HHRA.

Table 6. Vegetable and Fruit Consumption by Age Group from NHANES 2007-8 and 2009-10[1] (grams/day)

Age Group	Root Vegetables		Fruiting Vegetables & Fruits		Leafy Vegetables		Totals (Summed mean and Summed 95th)	
	Mean	95th	Mean	95th	Mean	95th	Mean	95th
Toddler 1 to < 4 yr	10	70	18	127	3	21	32	218[2]
Adult 20 to < 65	30	189	49	244	25	131	104	563[2]

Notes:
[1] Based on 'per capita' data for all respondents.
[2] Summed 95th percentile values likely substantially overestimate intake, but are provided here as a high-end estimate of consumption and for comparison with the Phase 4 HHRA.

Table 7. Derivation of Consumption Rates by Age Group for Fruits and Fruiting Vegetables

Age Group	N	Fruits		Fruit of Vegetable		Fruiting Vegetables and Fruit	
		mean	95th	mean	95th	Mean	95th
Toddler 1 to < 4 yr	1,484	5	42	13	85	18	127
Adult 20 to < 65	8,406	6	36	43	208	49	244

The total mean produce consumption rates in Table 6 are lower than those assumed in the Phase 4 HHRA, but the 95th percentile values are higher than consumption rates used in that assessment. The 95th percentile estimates provide the basis for a high end estimate to address concerns about high produce consumers. As described above, when consumption rates are added together they represent a value that is likely substantially more conservative than the 95th percentile for any one individual.

3.3 Fractional Intake

The produce consumption rates derived from the NHANES data encompass both commercial and homegrown sources. The Canadian Council of Ministers of the Environment (CCME 2006) assumes that 10 percent of produce comes from homegrown sources; therefore, a fractional intake of 0.10 was applied to this scenario consistent with the approach applied in the Phase 4 HHRA. This fractional intake assumption has not been changed in the more recent guidance (Health Canada 2012).

The fractional intake used in this HHRA is more protective than the applicable fractional intakes identified in the USEPA Exposure Factor's Handbook (USEPA 2011) for consumption of homegrown vegetables. USEPA includes data for the Northeast, Midwest, South, and West regions in the United States with fractional intakes ranging from 1 percent to 14 percent for relevant foods homegrown in the US[3]. Based on the assumption that garden yields are related

[3] Data for the fraction of household consumption that is homegrown within the US is shown in EFH 2011 Table 13-68 and ranges from 1% for exposed fruit in the Northeast to 14% for exposed vegetables in the Midwest. Protected

to regional plant hardiness classifications, we compared the Trail classification with that of US regions for which homegrown produce consumption estimates were available. Trail is identified as being in hardiness zone 7a (Plantmaps.com 2014) and a large area within the southern US is within zone 7a (National Gardening Association 2014). The fraction of household intake represented by homegrown produce ranged from 4 percent to 9 percent in those data. Similarly, fractional intake was considered in an evaluation of exposure to metals in produce at Deloro Village for the Ontario Ministry of Environment (CANTOX 1999). In that assessment, fractional intakes of 2.7 percent and 7.4 percent for fruits and vegetables, respectively, were applied to account for the fraction of the fruits and vegetables consumed by a family of four that could be homegrown in a garden. This estimate incorporated 1991 intake data from Statistics Canada adjusted to reflect fruits that could be grown in the area (apples, blueberries, cherries, plums, raspberries, strawberries) and assumed all vegetables could be homegrown. The assessment also integrated a typical home garden yield and garden size estimated by Ontario Ministry of Environment of 42 kg/year.

The fractional intake estimate of 0.1 can also be considered in light of the 95th percentile consumption rate for leafy greens of 131 g/day, which is quite high. If one assumes a two cup serving of leafy greens and an average g per meal of 80 g for two cups[4], this represents nearly 600 meals of leafy greens per year[5]. Assuming 10 percent of the leafy greens are homegrown the 95th percentile estimate represents approximately 60 homegrown meals per year of leafy greens. This high resulting consumption estimate together with the basis used in the USEPA Exposure Factors Handbook and in the Deloro risk assessment all indicate that an assumed fractional intake of 10 percent is a protective assumption.

3.4 Exposure Frequency, Exposure Duration and Averaging Time

An exposure frequency value of 365 days/year was applied in estimates for consumption of homegrown produce because the consumption rates are generated as average daily values over a year. Exposure durations are consistent with the age groups i.e., 3 years for the 1 to <4 year olds and 27 years for the adults. As described in the Phase 4 HHRA, because cadmium toxicity values are based on effects that occur after an exposure period of more than 30 years, the exposure estimates integrate childhood and adult intake, and are considered over a 30 year combined adult and childhood exposure period.

4 Toxicity Assessment

This section reviews and updates the discussion of oral cadmium and thallium toxicity reference values (TRVs) from the Phase 4 HHRA.

The purpose of the toxicity assessment is to summarize health effects that may be associated with exposure to the chemicals included in the risk assessment and to identify doses that may

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fruits are not considered relevant for this evaluation. Fractions consumed in the Southern region included exposed vegetables (9.1%); protected vegetables (7.7%); root vegetables (4.2%); and exposed fruit (4%).

[4] The 80 gram average was calculated as the average of the grams per cup in kale, spinach, beet greens, lettuce and Swiss chard as reported by the United States Department of Agriculture.(USDA 2006)

[5] The estimate of approximately 600 meals was calculated as follows: 131 g/day x 365 days=47,702 g/year, divided by 80 g meals = 596 meals.

be associated with those effects. The focus is on effects associated with long-term exposures and on effects that could be associated with the chemical concentrations and pathways of exposure that are relevant in environmental settings. TRVs developed based on dose-response assessments for these relevant adverse effects are identified. TRVs are numerical expressions of chemical dose and response, and vary based on factors such as the route of exposure (e.g., oral or inhalation) and duration of exposure.

4.1 Cadmium Toxicity

Cadmium metal occurs naturally in the earth's crust and is widely distributed in soils, water and foods (ATSDR 2012). Cadmium exposure through consumption of food in the US has been estimated from the 2007 US FDA Total Diet Study for various age groups (Egan et al. 2007). For young adults the cadmium intakes ranged from 0.16 to 0.18 µg/kg-day. This estimate is similar to the Health Canada Total Diet Study 2007 result for Vancouver of 0.22 µg/kg-day (Health Canada 2014). USEPA (2012) used the Egan et al. (2007) data to estimate the average daily absorbed cadmium dose. Assuming 2.5 percent absorption of cadmium from food, the absorbed dose is estimated to be 0.0053 µg/kg-day. This recent estimate of dietary intake is very similar to that derived in the Trail Technical Memorandum 2.1 (Exponent 1998) of 0.0048 µg/kg/day based on Canadian data from Dabeka and McKenzie (1995) also assuming 2.5 percent absorption of cadmium in food. ATSDR (2012) indicates that cigarette smoking is a source of cadmium exposure and estimates those who smoke have about twice as much cadmium exposure as nonsmokers.

Kidney toxicity has long been recognized as a sensitive effect of long-term oral cadmium exposure. TRVs for use in risk assessment and risk management for cadmium derived by Health Canada, the World Health Organization and by USEPA are all based on significant proteinuria, which is an early indicator of renal tubular dysfunction. Numerous studies in humans and laboratory animals have demonstrated that proteinuria develops only when cadmium concentrations in the kidney exceed a critical level, established at 200 µg/g (ww) in the kidney cortex by USEPA (2012). Both the Health Canada tolerable daily intake (TDI) and the USEPA reference dose (RfD) are based on this critical cadmium concentration in the renal cortex.

Health Canada (2010b) derived a provisional TDI of 0.001 mg/kg-day based on the 1972 WHO provisional weekly tolerable level of 7 ug/kg-week (1 µg/kg-day). WHO derived this level through use of a multi-compartmental model for cadmium distribution in the body. The WHO level reflects an estimate of 0.1 percent of the population reaching the critical cadmium concentration of 200 µg/g in the renal cortex after 50 years (Kjellstrom and Nordberg 1978; WHO 1972). Although this Health Canada (2010a) TDI is the most current available, it is noteable that the WHO revised their tolerable intake in 2011 using the same basis as before, but indicated that it was to be applied as 25 µg/kg per month. WHO indicated that this change was to emphasize the importance of considering long-term exposure to cadmium. The Phase 4 HHRA applied a slightly more conservative TDI of 0.0008 mg/kg-day which was in place at that time (Health Canada 2007c; Health Canada 2007d) and had the same underlying basis as the current TDI.

The USEPA also used has used the same critical endpoint (critical cadmium concentration of 200 µg/g in the renal cortex after 50 years) as the basis in deriving an RfD values of 0.001 mg/kg-day for consideration of cadmium in food or soil. This value was derived through application of a toxicokinetic model that assumes that 0.01 percent of the total body burden of cadmium is eliminated per day. It also assumes 2.5 percent or 5 percent absorption of cadmium from food and water, respectively. The toxicokinetic model predicts a NOAEL for either food or water that would result in 200 µg/g ww cadmium in the human renal cortex. An uncertainty factor of 10 was applied to the NOAEL to account for intra-human variability (USEPA 20012).

This update uses the latest Health Canada TDI for cadmium of 1 µg/kg-day as the TRV.

4.2 Thallium Toxicity

Thallium metal occurs naturally and is widely distributed in trace amounts in the earth's crust (ATSDR 1992b) and consequently is present in air, water, soil and foods (ATSDR 1992b). Thallium concentrations in foods are generally less than 1 mg/kg dry weight (IPCS 1996 OEHHA 1991). The International Program on Chemical Safety (IPCS 1996) estimated daily thallium intakes ranging from 0.9 µg to 2.3 µg depending on whether the estimate was derived from measured levels of thallium in human urine or the thallium body burden, respectively, for populations residing in uncontaminated areas.[6] These daily intakes would yield intakes of 0.015-0.03 on a µg/kg-day basis. Health Canada (2014) reports much lower intakes from the diet in the 2007 Vancouver survey (0.004 µg/kg-day for "all ages" and for young adults). Cigarettes appear to be a source of human exposure: people who smoke cigarettes have been shown to excrete about twice as much thallium in their urine as nonsmokers (ATSDR 1992).

Rats exposed to 1.8 mg/kg-day thallium exhibited hair loss, atrophy of hair follicles and decrease in size of sebaceous glands (ATSDR 1992). People exposed to very high doses of thallium have also been reported to have hair loss (alopecia) with reduced hair on the body, scalp and beard, but the hair loss is temporary (USEPA 2009, ATSDR 1992). People exposed to higher exposure levels have had neurological effects (USEPA 2009).

No TRV is available for thallium from Health Canada. Moreover, both USEPA (2014) and ATSDR (1992) have determined that data are too limited to derive a chronic toxicity value for thallium. The Phase 4 HHRA applied an oral RfD of 9×10^{-5} mg/kg-day that had been derived by USEPA for thallium acetate and thallium nitrate and was on the USEPA IRIS site at that time. USEPA also derived an oral RfD of 8×10^{-5} mg/kg-day for thallium sulfate, thallium chloride and thallium carbonate. These RfDs are stated in terms of the compound molecular weight. Converting them to an RfD based on thallium alone yields an RfD of 7×10^{-5} mg/kg-day.

The oral RfDs were based on a 90-day (subchronic) study where thallium sulfate was administered by gavage to rats (MRI 1988) at doses of 0.01, 0.05, or 0.25 mg/kg. Alopecia (i.e., hair loss) and minor alternations in blood chemistry were reported in the study. However, the authors concluded that dose-related changes were minor and were not toxicologically

[6] The IPSC (1996) estimate based on thallium in urine was derived assuming that the total amount of thallium excreted under steady state conditions accurately reflects daily thallium intake. The estimate is then derived from a mean urinary concentration of 0.4 µg/L, a urinary volume of 1.5 L/day, and an assumption that renal excretion accounts for 70 percent of daily thallium excretion, to yield a daily intake of 0.9 µg thallium. To estimate daily intake from thallium body burdens, a linear relationship between the daily intake of thallium and the elimination rate constant was assumed. Beginning with an estimated body burden of 100 µg per 75 kg body weight and an elimination rate constant of 0.023 day–1, a daily intake of 2.3 µg was estimated.

significant. Consequently, MRI (1988) identified the highest dose, 0.25 mg/kg-day thallium (I) sulfate (0.20 mg/kg-day Tl), as a no-observed-adverse-effect level (NOAEL) (Integral 2008). In deriving a RfD in 1988 USEPA applied an uncertainty factor of 3,000 to the NOAEL to account for extrapolation from subchronic to chronic exposure, extrapolation across species, interspecies variability and lack of reproductive and chronic toxicity data.

USEPA (2009) relied on the same study to derive a draft revised RfD for soluble thallium salts of 1×10^{-5} mg thallium/kg body weight, identifying 0.01 mg/kg as the NOAEL reasoning that alopecia seen at 0.25 mg/kg-day represented a toxic effect. Comments submitted after the draft version of the USEPA thallium assessment was released contested USEPA's toxicological assumptions in changing the RfD (e.g., see Integral 2008). This lower RfD also represents a daily exposure level that is lower than background dietary intake. Specifically, the USEPA (2008) draft RfD of 1×10^{-5} mg/kg-day represents an intake of 0.7 ug thallium per day for a 70 kg individual, which is lower than the 0.9 ug/day intake rate estimated by IPCS (1996). USEPA (2009) ultimately determined that the data on repeated dose exposure to thallium, including data in MRI (1988) are too limited to derive an oral toxicity value and did not post the revised RfD to its Integrated Risk Information System (USEPA 2014).

Due to the absence of an accepted TRV, thallium risks should not be quantified. For this reason, thallium hazard indices are not included in the risk characterization here. However, in order to provide additional information to risk managers, , the RfD of 7×10^{-5} mg/kg-day is used here to derive hazard indicies within the Uncertainty Assessment. These estimates can be considered in comparison with the Phase 4 HHRA estimates and also relative to the findings of the biomonitoring for thallium described in the Phase 4 HHRA..

5 Risk Characterization

For adverse health effects other than cancer, health risks are characterized by comparing average estimated daily intake to the TRV. The resulting ratio is termed a hazard quotient (HQ). If the calculated value of the HQ is less than or equal to 1.0, no adverse health effects are expected. If the calculated value of the HQ is greater than 1.0, then further risk evaluation is needed. For the ingestion pathway, the HQ was calculated using the following equation:

$$HQ = \frac{I}{TDI}$$

Where:

HQ	=	Hazard quotient associated with exposure to the chemical via the specified exposure route (dimensionless)
I	=	Estimated average daily intake of the chemical via the specified exposure route (mg/kg-day)
TDI	=	Tolerable daily intake or Reference Dose (RfD) for the chemical (mg/kg-day)

The exposure estimates and the toxicity values described in the prior sections are combined to derive HQs for exposure to cadmium and thallium in produce and the resulting HQs are shown in Tables 8 and 9, respectively. Both mean and 95th percentile consumption rate estimates are used. Mean consumption rates are more representative for most individuals. However, in order to provide an estimate of potential exposure and risk for the highest produce consumers, 95th percentile estimates are also presented.

5.1 Risk Characterization for Cadmium

HQs for cadmium are shown in Table 8. As is indicated in Table 8, no HQs are greater than 1 for exposure to cadmium even when very high assumed consumption rates are applied. This indicates that adverse effects related to exposure to cadmium through consuming homegrown produce are not expected.

Table 8. Cadmium Hazard Quotients for Homegrown Produce Consumption

Hazard Quotients at mean intake rates					
Produce Type	Concentration (UCLM) (mg/kg)	Intake rate (g/day) Adult	Intake rate (g/day) Toddler	Average Daily Dose *(mg/kg-d)	Hazard Quotients
Root vegetables	0.32	30	10	1.0E-05	**0.01**
Fruiting vegetables & fruit	0.06	49	18	4E-06	**0.004**
Leafy vegetables	1.9	25	3	6E-05	**0.06**
			Total at mean intake	8E-05	**0.08**
Hazard Quotients at 95th percentile intake rates					
Produce Type	**Concentration (UCLM) (mg/kg)**	**Intake rate (g/day) Adult**	**Intake rate (g/day) Toddler**	**Average Daily Dose * (mg/kg-d)**	**Hazard Quotients**
Root vegetables	0.32	189	70	8E-05	**0.1**
Fruiting vegetables & fruit	0.06	244	127	2E-05	**0.02**
Leafy vegetables	1.9	131	21	3E-04	**0.3**
			Total at 95th percentile intake	8.0E-04	**0.4**

Notes:
[1] Average daily dose is averaged over the lifetime consistent with the derivation of the toxicity value for cadmium as discussed in the toxicity assessment.

Figure 8 shows the HQs related to cadmium exposure through consumption of each of the produce types from unremediated soils. These hazard quotients are all less than 1.

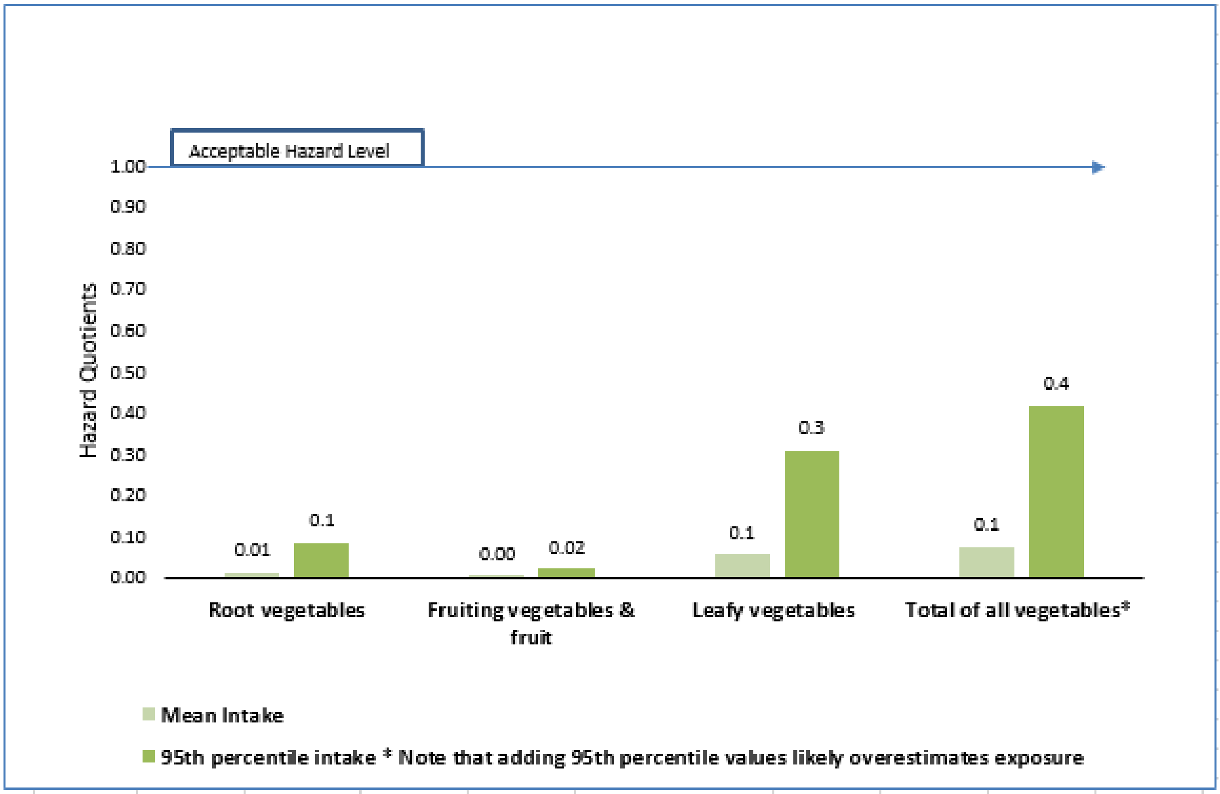

Figure 8. Cadmium Hazard Quotients for Mean and 95th Percentile Consumption of Homegrown Produce

Assessing the risk of adverse effects requires that all exposure pathways be considered. Based on the Phase 4 HHRA, the highest HQ for soil and dust exposures was a value of 0.012 in Tadanac. Thus, combined HQs for cadmium in produce and in soil and dust are much less than 1, and no adverse health effects would be expected.

5.2 Uncertainty Assessment – Thallium Risk Characterization

The findings from risk characterization are used by risk managers to make decisions regarding the need, if any, for actions to reduce risks. For this reason, the uncertainty assessment is conducted to evaluate major assumptions, scientific judgments, and estimates of uncertainties described in the assessment. Risk assessment methods are designed to be conservative to address the uncertainties associated with each step in the risk assessment process. Thus, “true” site risks are likely to be less than risks estimated using standard risk assessment methods. General sources of uncertainty include the site characterization (adequacy of the sampling plan and quality of the analytical data), the exposure assumptions, and estimation of chemical toxicity. A key uncertainty in this assessment is the lack of an approved toxicity reference value for thallium. As described above, the thallium TRV used in the Phase 4 HHRA has been withdrawn, and no reliable TRV is currently available. In order to provide information for risk managers, risk estimates for thallium using the TRV used in the Phase 4 HHRA (the withdrawn USEPA RfD of 7×10^{-5} mg/kg-day) are provided and discussed in the uncertainty assessment.

Table 9 shows HQs for thallium related to homegrown produce from gardens (both remediated and unremediated) near the smelter. As described above, produce data from gardens were grouped because concentrations did not vary markedly and too few data are available to derive estimates for unremediated gardens alone.

Table 9. Thallium Hazard Quotients for Homegrown Produce Consumption

Produce Type	Conc. Mg/kg UCLM	Intake rate (g/day)		Chronic Daily Intake (mg/kg-d)		Hazard Quotients	
Hazard Quotients at mean intake rates							
Produce Type	**Conc. Mg/kg UCLM**	**Adult**	**Toddler**	**Adult**	**Toddler**	**Adult**	**Toddler**
Root vegetables	0.03	30	10.5	1.3.E-06	2.2.E-06	0.02	0.03
Fruiting vegetables & fruit	0.0095	49	18.3	6.0.E-07	1.1.E-06	0.01	0.02
Leafy vegetables	0.96	25	3.3	3.1.E-05	2.1.E-05	0.4	0.30
Total at mean intake				3.3.E-05	2.4.E-05	0.47	0.34
Hazard Quotients at 95th percentile intake rates							
Produce Type	**Conc. Mg/kg UCLM**	**Adult**	**Toddler**	**Adult**	**Toddler**	**Adult**	**Toddler**
Root vegetables	0.03	189	70	7.9.E-06	1.4.E-05	0.11	0.21
Fruiting vegetables & fruit	0.0095	244	127	3.0.E-06	7.8.E-06	0.04	0.11
Leafy Vegetables excluding only 1 outlier							
Leafy vegetables[a]	0.96	131	21	1.6.E-04	1.3.E-04	**2.3**	**1.8**
Total at 95th percentile intake				1.8.E-04	1.5.E-04	2.50	2.16
Leafy Vegetables excluding 4 additional samples							
Leafy vegetables[b]	0.14	131	21	2.4.E-05	1.9.E-05	**0.34**	**0.27**
Total at 95th percentile intake						0.50	0.59

Notes:
[a]Excludes outlier leafy sample with 78 mg/kg thallium
[b] Excludes outlier leafy sample with 78 mg/kg thallium and also 4 other leafy samples greater than 1 mg/kg.

HQs exceed 1 for thallium for both adult and child scenarios for consumption of leafy vegetables. As described above, three kale samples and one turnip top sample had concentrations much higher than the other 47 samples. We also calculated HQs with those four samples excluded to demonstrate their influence on the risk estimates.

Produce samples analyzed during the different sampling events were harvested opportunistically, and the compiled data do not necessarily provide a valid representation of the mix of produce consumed by most Trail gardeners. As shown in Table 10, the counts of leafy vegetable types sampled are very different for unremediated and remediated properties. As such, there is uncertainty in drawing conclusions based on the available data.

Table 10. Leafy Vegetables Sampled	
Unremediated	Count
Beet top	3
Lettuce	10
Swiss chard	2
Remediated	Count
Basil	1
Beet top	9
Broccoli	1
Celery	1
Kale	4
Lettuce	5
Mint	2
Nasturtium	2
Sorrel	2
Swiss chard	9
Turnip top	1

IPCS (1996) reviews studies of thallium uptake by plants. Many studies were conducted in highly contaminated environments, but consistently show greater thallium uptake into brassicas such as kale and some cabbages. Even among brassicas, the degree of thallium uptake varied by specific plant type. Generally thallium uptake is highest in chlorophyll producing plant parts, and in some cases concentrations higher than those in soil have been observed. Uptake is also a function of environmental factors, e.g., higher uptake occurs in acid soils, while uptake is reduced with high potassium concentrations. Factors of this sort could explain high variability among samples collected from different gardens in Trail.

6 Conclusions

This assessment was conducted to update exposure and risk estimates for cadmium and thallium exposure from homegrown produce in the Phase 4 HHRA. Recently collected produce data were incorporated to make for a more robust assessment. Assumptions for consumption of various produce types and of the relative contribution of produce to overall intake of cadmium and thallium were updated. Produce concentrations were found to vary by plant part, with leafy produce having the highest concentrations for both metals. For cadmium produce concentrations were not statistically different based on the year of collection over the period from 2007 through 2013, whereas for thallium the relative produce concentrations were variable based on produce category.

Health protective assumptions were applied to estimate exposures through consumption of homegrown produce using data from produce samples collected from Trail neighborhoods. Risk calculations showed that consumption of Trail garden produce would not cause cadmium intakes to exceed recommended levels. Even when 95th percentile consumption rate estimates are applied in evaluating produce from unremediated soils, the resulting HQ for consumption of produce is less than 1 indicating that no adverse effects would be expected. Concentrations of cadmium in root vegetables and fruiting vegetables (e.g., tomatoes and corn) were low enough that there is no concern about eating any quantity of those kinds of produce from Trail gardens.

For leafy vegetables, there is also no concern about typical consumption rates. Very high consumption rates of leafy vegetables (e.g., 60 meals of 80 grams each per year) also do not pose a health risk for the general population of nonsmokers; however, smoking cigarettes may cause total cadmium intakes to exceed recommended levels.

Currently the Trail Health and Environment Program remediates soil in gardens that are found to contain greater than 1000 mg/kg lead, which is statistically associated with an average concentration of 16.4 mg/kg cadmium. Any garden where a concentration of 30 mg/kg cadmium (i.e., the BC Ministry of Environment "Upper Cap Concentration") or greater is found is also remediated regardless of the lead concentration. This program will contribute to a continued decline in cadmium concentrations in garden soil.

Several uncertainties limited the ability to reliably assess potential risk from exposures to thallium in produce from Trail gardens. A very small number of leafy green samples had markedly elevated thallium concentrations, making it difficult to assess typical exposures. Additionally, the thallium TRV used in the Phase 4 HHRA has been withdrawn, and no reliable TRV is currently available. Risk calculations using the withdrawn TRV showed that at average consumption rates Trail garden produce would not cause thallium intakes to exceed recommended levels. At high consumption rates there is also no concern about consumption of root vegetables or fruiting vegetables. For leafy vegetables, high consumption rates may result in intakes in excess of the TRV when the small number of samples with high concentrations is included.

Risk estimates for thallium need to be considered in the context of the low reliability of the thallium TRV used in this analysis. The TRV is 1/3,000 times a dose at which hair loss was observed in rats. WHO considers that urinary concentrations below 5 µg/L are unlikely to cause adverse health effects (IPCS 1996). This urinary level was not exceeded in the biomonitoring study conducted in 50 Trail residents in 2001. The urinary concentration of 5 µg/L was assumed to be associated with a daily intake of 10 µg thallium, an intake that is approximately twice the TRV used for these risk estimates. Based on these considerations, health risks in Trail consumers of homegrown produce are expected to be low; however, continued monitoring of thallium concentrations in produce may be warranted.

Specification of data quality objectives for ongoing produce monitoring may result in a revised vegetable sampling study design. Teck notes that sampling of garden soil in Trail has not found thallium concentrations in soil to exceed the BC Ministry of Environment "upper cap concentration" of 650 mg/kg. The maximum concentration was 3.66 mg/kg.

Trail Operations has also initiated a fugitive dust reduction project, aimed to reduce lead emissions into the community. This program will result in reductions in arsenic, cadmium and thallium emissions due to the association of these elements with the lead bearing minerals. As such, it is expected that concentrations of these metals in the community, including garden soil and produce, will be reduced over time.

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