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Revision 0

Native American Risk Assessment for the 100-BC-5 Groundwater Operable Unit

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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D. L. Morgans
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ch2m
P.O. Box 1600
Richland, Washington 99352

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Contents

1 Purpose **1**

2 Background **1**

2.1 Carcinogenic Effects 1

2.2 Noncarcinogenic Effects 2

2.3 Exposure Routes 3

2.4 References 3

3 Methodology **4**

3.1 Drinking Water Exposure Pathways 4

3.1.1 Intake and Risk Equations for Water Ingestion 4

3.1.2 Intake and Risk Equations for Drinking Water Inhalation (Volatiles Only) 12

3.1.3 Intake and Risk Equations for Drinking Water Dermal Absorption 13

3.2 Sweat Lodge Exposure Pathways 15

3.2.1 Intake and Risk Equations for Sweat Lodge Inhalation of Volatiles and Semi-Volatiles 22

3.2.2 Intake and Risk Equations for Sweat Lodge Inhalation of Nonvolatiles 23

3.2.3 Intake and Risk Equations for Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles 24

3.2.4 Intake and Risk Equations for Sweat Lodge Dermal Exposure to Nonvolatiles 25

3.3 Cumulative Risk—Cancer 27

3.4 Hazard Index—Noncancer 27

4 Assumptions and Inputs **28**

4.1 Exposure Inputs and Assumptions 28

4.2 Groundwater Analytes and Exposure Point Concentrations 33

4.3 Toxicity Values 35

4.3.1 Toxicity Values for Nonradionuclides 35

4.3.2 Toxicity Values for Radionuclides 36

4.3.3 Toxicity Values for Sweat Lodge Equations 36

5 Software Applications **41**

6 Calculation **41**

6.1 Drinking Water Exposure Worksheets 41

6.2 Sweat Lodge Exposure Worksheets 42

6.3 Hand Calculations 42

7 Results/Conclusions **43**

7.1 Summary of the CTUIR Risk Assessment 43

7.1.1 Use of Groundwater as a Potential Drinking Water Source 43

7.1.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use 44
7.2 Summary of the Yakama Nation Risk Assessment 46
7.2.1 Use of Groundwater as a Potential Drinking Water Source 46
7.2.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use 47
8 References 50

Figures

Figure 6-1. Hand Calculations 53

Tables

Table 3-1. Summary of Exposure Assumptions for the Drinking Water Exposure Pathways for the CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit 5
Table 3-2. Summary of Exposure Assumptions Used for the Drinking Water Exposure Pathways for the Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit 8
Table 3-3. Calculated Values and Reference Bases Used for the Drinking Water Ingestion Exposure Route 11
Table 3-4. Calculated Values and Reference Bases Used for the Drinking Water Inhalation of Volatiles Exposure Route 12
Table 3-5. Calculated Values and Reference Bases Used for the Drinking Water Dermal Exposure Route 13
Table 3-6. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit 16
Table 3-7. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit 19
Table 3-8. Calculated Values and Reference Bases Used for the Sweat Lodge Inhalation of Volatiles and Semi-Volatiles Exposure Route 22
Table 3-9. Calculated Values and Reference Bases Used for the Sweat Lodge Inhalation of Nonvolatiles Exposure Route 23
Table 3-10. Calculated Values and Reference Bases Used for the Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles Exposure Route 24
Table 3-11. Calculated Values and Reference Bases Used for the Sweat Lodge Dermal Exposure to Nonvolatiles Exposure Route 25
Table 4-1. Summary of Key Exposure Assumptions Used for the Sweat Lodge Exposure Pathway for the CTUIR Exposure Scenario 29
Table 4-2. Summary of Key Exposure Assumptions Used for the Sweat Lodge Exposure Pathway for the Yakama Nation Exposure Scenario 31
Table 4-3. 100-BC-5 Groundwater Operable Unit Grouped Well Exposure Point Concentration Summary 34
Table 4-4. Toxicity Criteria for 100-BC-5 Groundwater Analytes 37
Table 6-1. Excel Worksheets for the CTUIR Drinking Water Exposure Calculations 41
Table 6-2. Excel Worksheets for the Yakama Nation Drinking Water Exposure Calculations 41

Table 6-3. Excel Worksheets for the CTUIR Sweat Lodge Exposure Calculations 42
Table 6-4. Excel Worksheets for the Yakama Nation Sweat Lodge Exposure Calculations 42
Table 7-1. CTUIR Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source 43
Table 7-2. CTUIR Exposure Scenario—Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge 44
Table 7-3. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source 46
Table 7-4. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge 48

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Terms

ATSDR	Agency for Toxic Substances and Disease Registry
CalEPA	California Environmental Protection Agency
CDI	chronic daily intake
COPC	contaminant of potential concern
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DA_{event}	Dermally absorbed dose per event
DOE	U.S. Department of Energy
ECF	Environmental Calculation File
ELCR	excess lifetime cancer risk
EPA	Environmental Protection Agency
EPC	exposure point concentration
ERMA	Environmental Risk Management Archive
ET	event time
GIABS	gastrointestinal absorption factor
HEAST	Health Effects Assessment Summary Tables
HEIS	Hanford Environmental Information System
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
MRL	Minimal Risk Levels
NCEA	National Center for Environmental Assessment
NJDEP	New Jersey Department of Environmental Protection
OEHHA	Office of Environmental Health Hazard Assessment (CalEPA)
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response (EPA)
OU	Operable Unit
pCi	picocurie

PPRTV	Provisional Peer Reviewed Toxicity Values
RAGS	Risk Assessment Guidance for Superfund
RAIS	Risk Assessment Information System
RfC	reference concentration
RfD	reference dose
RME	reasonable maximum exposure
SF	slope factor
STSC	superfund health risk technical support center
VF	volatilization factor

1 Purpose

The purpose of this environmental calculation is to document the assumptions, equations, and methods used to calculate the potential human health risks and hazards associated with exposure to contaminants in the 100-BC-5 Groundwater Operable Unit (OU) for two Native American exposure scenarios. Exposure is evaluated assuming a hypothetical failure of current administrative controls, such that tribal use of 100-BC-5 OU groundwater becomes possible. Cancer risks and non-cancer hazards are calculated based on current groundwater conditions for both radiological and nonradiological analytes. For purposes of this calculation, any analyte detected at least once in groundwater at the 100-BC-5 OU is included in the exposure and risk calculations. Cancer risks and noncancer hazards are calculated for ingestion, inhalation, and dermal contact exposure routes from use of groundwater as a domestic drinking water source and from use of groundwater as a source of steam in a sweat lodge. The results of all exposure routes are summed to calculate total excess lifetime cancer risk (ELCR) and hazard index (HI). Risks and hazards are calculated and presented using a composite dataset of 37 wells located in the 100-BC-5 groundwater OU. This risk assessment supports DOE/RL-2010-96, *Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units.*

2 Background

Several local and regional tribes have ancestral ties to the Hanford Reach of the Columbia River, and the U.S. Department of Energy (DOE) has requested that each tribe provide an exposure scenario that reflects their traditional activities. The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Yakama Nation have provided scenarios.

For purposes of this environmental calculation, adult and child members of the CTUIR and the Yakama Nation are assumed to use groundwater from the 100-BC-5 OU as a drinking water source (i.e., domestic supply) and to make steam in a sweat lodge (adult tribal members only) as a part of their traditional lifeways.

Use of groundwater to irrigate crops and water livestock is not evaluated, because those exposure pathways, although potentially complete, are considered insignificant and secondary to the drinking water and sweat lodge exposure pathways. Such food-chain and leaching exposure pathways are evaluated separately in the PRG calculations provided in DOE/RL-2010-96, because the RESRAD model (ANL, 2014, *RESRAD*, Version 7.0) used to estimate exposures considers these pathways. Contact with contaminated drill cuttings is not addressed; only the drinking water and sweat lodge exposure pathways are relevant to the Native American exposure scenarios.

2.1 Carcinogenic Effects

The potential for carcinogenic effects is evaluated by estimating the incremental increase in the probability of developing cancer over a lifetime (excess lifetime cancer risk [ELCR]), above the background probability of developing cancer (that is, if no exposure to site contaminants occurs). Cancer slope factors developed by the Environmental Protection Agency (EPA) are considered to be plausible upper bound estimates of the cancer potencies of contaminants. Using these cancer slope factors in calculating risks results in plausible, upper-bound estimates of risk; there is reasonable confidence that the actual cancer risks will not exceed the estimated risks and may actually be lower (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final)*. The following equations are used to estimate cancer risk for non-radionuclides and radionuclides:

For nonradionuclides:

$$Risk = CDI \times SF \tag{1}$$

where:

Risk = Excess lifetime cancer risk (unitless probability)
CDI = Chronic daily intake averaged over a lifetime (mg/kg-day)
SF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$

For radionuclides:

$$Risk = Intake \times SF \tag{2}$$

where:

Risk = Excess lifetime cancer risk (unitless probability)
Intake = Activity (pCi)
SF = Cancer slope factor $(pCi)^{-1}$

For cases with high ELCR values, defined as an ELCR greater than 0.01, the following "one-hit" cancer risk equation from EPA Risk Assessment Guidance for Superfund (RAGS) Part A guidance (EPA/540/1-89/002) is used.

$$Risk = 1 - \exp(-CDI \times SF) \tag{3}$$

where:

Risk = Excess lifetime cancer risk (unitless probability)
CDI = Chronic daily intake, averaged over a lifetime (mg/kg-day) or (pCi)
SF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$ or $(pCi)^{-1}$

Although synergistic or antagonistic interactions might occur between cancer-causing contaminants and other contaminants, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, in this assessment, cancer risks are treated as independent, and additive within an exposure route. This is consistent with the EPA guidelines on chemical mixtures presented in EPA/630/P-03/001F, *Guidelines for Carcinogen Risk Assessment*.

2.2 Noncarcinogenic Effects

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular contaminant with the highest level of exposure that is considered protective (that is, its reference dose [RfD]). The ratio of the chronic daily intake (CDI) divided by the RfD is termed the hazard quotient (HQ):

$$HQ = \frac{Chemical\ Intake\ (\frac{mg}{kg-day})}{RfD\ (\frac{mg}{kg-day})} \tag{4}$$

When the HQ for a contaminant exceeds 1 (that is, exposure exceeds the RfD), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple contaminants, a hazard index (HI) approach is used, in accordance with EPA guidance (EPA/540/1-89/002). This approach assumes that the noncancer hazards associated with exposure to

multiple contaminants are simply additive; synergistic or antagonistic interactions between contaminants, which are largely unknown, are not accounted for.

2.3 Exposure Routes

Potentially complete exposure routes for adult and child tribal members associated with using groundwater as a domestic drinking water supply are:

- Ingestion of water,
- Inhalation of volatiles when showering or bathing and using drinking water for other domestic purposes, and
- Dermal contact with water while showering or bathing and using drinking water for other domestic purposes (e.g., washing dishes).

Potentially complete exposure routes for adult tribal members associated with using groundwater in a sweat lodge are:

- Inhalation of volatiles, semi-volatiles, and aerosolized non-volatiles, while spending time in a sweat lodge, and
- Dermal contact with vapors and condensed liquid, while spending time in a sweat lodge.

2.4 References

For the drinking water exposure pathway, contaminant intake is quantified using standard EPA equations and procedures as specified in the following references:

- EPA/540/1-89/002, *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual, Part A, Interim Final*;
- EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim*;
- EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Final*;
- EPA-540-R-070-002, *Risk Assessment Guidance for Superfund: Volume 1: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment), Final.*
- ORNL, 2016, The Risk Assessment Information System (RAIS) (http://rais.ornl.gov/)
  - RAIS Risk Exposure Models for Chemicals User's Guide (http://rais.ornl.gov/tools/rais_chemical_risk_guide.html)
  - RAIS Risk Exposure Models for Radionuclides User's Guide (http://rais.ornl.gov/tools/rais_rad_risk_guide.html)

For the sweat lodge exposure pathway, contaminant intake is quantified based on standard EPA methods, coupled with the sweat lodge steam model provided in:

- Harris and Harper, 2004, Exposure Scenario for CTUIR Traditional Subsistence Lifeways.

The CTUIR and Yakama Nation provided many of the exposure factors necessary to quantify contaminant intake in the following references. Those values are used preferentially, rather than EPA residential default values. Where tribal-specific factors are not provided, EPA defaults are used (EPA/540/R-92/003).

- Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways;*
- Harris, 2008, *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments; and*
- Ridolfi, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment.*

3 Methodology

This section provides the equations (and their bases) used to calculate the cancer risks and noncancer hazards associated with exposure to analytes detected in the 100-BC-5 groundwater OU via the exposure routes associated with the drinking water and sweat lodge exposure pathways.

3.1 Drinking Water Exposure Pathways

Definitions of the variables and input values for the drinking water exposure pathway equations are provided in Table 3-1 for the CTUIR exposure scenario and in Table 3-2 for the Yakama Nation exposure scenario.

3.1.1 Intake and Risk Equations for Water Ingestion

The bases for the equations used to calculate intake, risk, and hazard associated with the water ingestion exposure route are summarized in Table 3-3. Equations are provided in the following subsections.

3.1.1.1 Drinking Water Ingestion—Carcinogenic Effects

For ingestion of carcinogens, the chronic daily intake (CDI) is calculated using the following equations:

$$CDI = \frac{C_w \times IRW_{adj} \times EF}{AT_{can} \times CFI} \tag{5}$$

where:

$$IRW_{adj} = \frac{ED_c \times IRW_c}{BW_c} + \frac{(ED_r - ED_c) \times IRW_a}{BW_a} \tag{6}$$

Cancer risk is calculated using the following equation:

$$Risk = CDI \times CSF_o \tag{7}$$

Table 3-1. Summary of Exposure Assumptions for the Drinking Water Exposure Pathways for the CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens	AT_{can}	70	years	Harris, 2008
Averaging Time – noncarcinogens	AT_{nc}	6	years	Harris, 2008
Partitioning Constant Derived by Bunge Model	B	analyte-specific	unitless	See Table 4-4
Body Weight - adult	BW_a	70	kg	Harris and Harper, 2004
Body Weight - child	BW_c	15	kg	Harris and Harper, 2004
Conversion Factor	CF1	365	days/year	1 year = 365 days
Conversion Factor	CF2	1/24	days/ hour	1 day = 24 hours
Conversion Factor	CF3	0.001	L/cm^3	1 L = 1,000 cm^3
Cancer Slope Factor - oral	CSF_o	analyte-specific	$(mg/kg\text{-}day)^{-1}$	See Table 4-4
Chronic Daily Intake – carcinogenic ingestion	CDI	Calculated value	mg/kg-day	Equation 5
Chronic Daily Intake – noncarcinogenic ingestion	CDI	Calculated value	mg/kg-day	Equation 8
Chronic Daily Intake – radiological ingestion	CDI	Calculated value	pCi	Equation 10
Chronic Daily Intake – carcinogen inhalation	CDI	Calculated value	$\mu g/m^3$	Equation 13
Chronic Daily Intake – noncarcinogenic inhalation	CDI	Calculated value	mg/m^3	Equation 15
Chronic Daily Intake – radiological inhalation	CDI	Calculated value	pCi	Equation 17
Chronic Daily Intake – carcinogenic dermal	CDI	Calculated value	mg/kg-day	Equation 20
Chronic Daily Intake – noncarcinogenic dermal	CDI	Calculated value	mg/kg-day	Equation 23
Contaminant concentration in groundwater	C_w	analyte-specific	mg/L or pCi/L	ECF-100BC5-11-0016
Absorbed dose per event	DA_{event}	Calculated value	mg/cm^2-event	Equation 26, 27,and 28
Exposure Duration - CTUIR resident	ED_r	70	years	Harris and Harper, 2004

Table 3-1. Summary of Exposure Assumptions for the Drinking Water Exposure Pathways for the CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Exposure Duration - child	ED_c	6	years	Harris, 2008
Exposure Frequency	EF	365	days/year	Harris and Harper, 2004
Exposure Time – adult dermal	ET_a	0.71	hours/event	EPA/600/R-090/052F
Exposure Time – child dermal	ET_c	0.54	hours/event	EPA/600/R-090/052F
Age-Adjusted Exposure Time – dermal	ET_{adj}	0.695	hours/event	Equation 25
Exposure Time	ET	24	hours/day	OSWER Directive 9200.1-120
Event Frequency	EV	1	event/day	EPA/540/R/99/005
Fraction of absorbed water	FA	analyte-specific	unitless	See Table 4- 4
Gastrointestinal Absorption Factor	GIABS	analyte-specific	unitless	See Table 4- 4
Inhalation Rate - adult	INH_a	25	m^3/day	Harris, 2008
Inhalation Rate - child	INH_c	15	m^3/day	Harris, 2008
Age-Adjusted Inhalation Rate - radiological	INH_RAD_{adj}	1,690	m^3-year/day	Equation 18
Water Ingestion Rate - adult	IRW_a	4	L/day	Harris, 2008
Water Ingestion Rate - child	IRW_c	1	L/day	Harris and Harper, 2004
Age-adjusted Water Ingestion Rate – nonradiological	IRW_{adj}	4.057	L-year/kg-day	Equation 6
Age-adjusted Water Ingestion Rate – radiological	IRW_RAD_{adj}	262	L-year/day	Equation 11
Inhalation Unit Risk	IUR	analyte-specific	$(\mu g/m^3)^{-1}$	See Table 4- 4
Dermal permeability coefficient	K_p	analyte-specific	cm/hour	See Table 4- 4
The constant pi	π	3.14159	unitless	--

Table 3-1. Summary of Exposure Assumptions for the Drinking Water Exposure Pathways for the CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Reference Concentration	RfC	analyte-specific	mg/m^3	See Table 4-4
Reference Dose - oral	RfD_o	analyte-specific	mg/kg-day	See Table 4-4
Skin Surface Area - adult	SA_a	19,652	cm^2	EPA/600/R-090/052F
Skin Surface Area - child	SA_c	6,365	cm^2	EPA/600/R-090/052F
Age-adjusted skin surface area	SA_{adj}	20,514	cm^2-year-event/kg-day	Equation 21
Slope Factor - inhalation	SF_i	analyte-specific	Risk/pCi	See Table 4-4
Slope Factor - oral	SF_o	analyte-specific	Risk/pCi	See Table 4-4
Time to reach steady state conditions	t*	analyte-specific	hours	See Table 4-4
Lag time	τ	analyte-specific	hours/event	See Table 4-4
Volatilization Factor	VF	0.5	L/m^3	EPA/540/R-92/003

Notes:

ECF-100BC5-11-0016, *Calculation of Exposure Point Concentrations for the 100-BC-5 Groundwater Operable Unit.*

EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim.*

EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment).*

EPA/600/R-090/052F, *Exposure Factors Handbook: 2011 Edition.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

Harris, 2008, *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments.*

OSWER Directive 9200.1-120, *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors.*

Table 3-2. Summary of Exposure Assumptions Used for the Drinking Water Exposure Pathways for the Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens	AT_c	70	year	Ridolfi, 2007
Averaging Time – noncarcinogens	AT_{nc}	6	years	Ridolfi, 2007
Partitioning constant Derived by Bunge Model	B	analyte-specific	unitless	See Table 4-4
Body Weight - adult	BW_a	70	kg	Ridolfi, 2007
Body Weight - child	BW_c	16	kg	Ridolfi, 2007
Conversion Factor	CF1	365	days/year	1 year = 365 days
Conversion Factor	CF2	1/24	days/hour	1 day = 24 hours
Conversion Factor	CF3	0.001	L/cm^3	1 L = 1,000 cm^3
Cancer Slope Factor - oral	CSF_o	analyte-specific	$(mg/kg\text{-}day)^{-1}$	See Table 4-4
Chronic Daily Intake – carcinogenic ingestion	CDI	Calculated value	mg/kg-day	Equation 5
Chronic Daily Intake – noncarcinogenic ingestion	CDI	Calculated value	mg/kg-day	Equation 8
Chronic Daily Intake – radiological ingestion	CDI	Calculated value	pCi	Equation 10
Chronic Daily Intake – carcinogenic inhalation	CDI	Calculated value	$\mu g/m^3$	Equation 13
Chronic Daily Intake – noncarcinogenic inhalation	CDI	Calculated value	mg/m^3	Equation 15
Chronic Daily Intake – radiological inhalation	CDI	Calculated value	pCi	Equation 17
Chronic Daily Intake – carcinogenic dermal	CDI	Calculated value	mg/kg-day	Equation 20
Chronic Daily Intake – noncarcinogenic dermal	CDI	Calculated value	mg/kg-day	Equation 23
Contaminant concentration in groundwater	C_w	analyte-specific	mg/L or pCi/L	ECF-100BC5-11-0016
Absorbed Dose per Event	DA_{event}	Calculated value	mg/cm^2-event	Equations 26, 27, and 28
Exposure Duration - Yakima Nation resident	ED_r	70	year	Ridolfi, 2007

Table 3-2. Summary of Exposure Assumptions Used for the Drinking Water Exposure Pathways for the Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Exposure Duration - child	ED_c	6	year	Ridolfi, 2007
Exposure Frequency	EF	365	days/year	Ridolfi, 2007
Exposure Time – adult dermal	ET_a	0.71	hours/event	EPA/600/R-090/052F
Exposure Time – child dermal	ET_c	0.54	hours/event	EPA/600/R-090/052F
Age-Adjusted Exposure Time – dermal	ET_{adj}	0.695	hours/event	Equation 25
Exposure Time	ET	24	hours/day	OSWER Directive 9200.1-120
Event Frequency	EV	1	event/day	EPA/540/R/99/005
Fraction of absorbed water	FA	analyte-specific	unitless	See Table 4-4
Gastrointestinal Absorption Factor	GIABS	analyte-specific	unitless	See Table 4-4
Inhalation Rate - adult	INH_a	26	m^3/day	Ridolfi, 2007
Inhalation Rate - child	INH_c	16	m^3/day	Ridolfi, 2007
Age-Adjusted Inhalation Rate - radiological	INH_RAD_{adj}	1,760	m^3-year/day	Equation 18
Water Ingestion Rate - adult	IRW_a	4	L/day	Ridolfi, 2007
Water Ingestion Rate - child	IRW_c	2	L/day	Ridolfi, 2007
Age-adjusted Water Ingestion Rate – nonradiological	IRW_{adj}	4.407	L-year/kg-day	Equation 6
Age-adjusted Water Ingestion Rate – radiological	IRW_RAD_{adj}	268	L-year/day	Equation 11
Inhalation Unit Risk	IUR	analyte-specific	$(\mu g/m^3)^{-1}$	See Table 4-4
Dermal permeability coefficient	K_p	analyte-specific	cm/hour	See Table 4-4
The constant pi	π	3.14159	unitless	--

Table 3-2. Summary of Exposure Assumptions Used for the Drinking Water Exposure Pathways for the Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Reference Concentration	RfC	analyte-specific	mg/m^3	See Table 4-4
Reference Dose - oral	RfD_o	analyte-specific	mg/kg-day	See Table 4-4
Skin Surface Area - adult	SA_a	19,652	cm^2	EPA/600/R-090/052F
Skin Surface Area - child	SA_c	6,365	cm^2	EPA/600/R-090/052F
Age-adjusted skin surface area	SA_{adj}	20,354	cm^2-year-event/kg-day	Equation 21
Slope Factor - inhalation	SF_i	analyte-specific	Risk/pCi	See Table 4-4
Slope Factor - oral	SF_o	analyte-specific	Risk/pCi	See Table 4-4
Time to reach steady state conditions	t*	analyte-specific	hours	See Table 4-4
Lag time	τ	analyte-specific	hours/event	See Table 4-4
Volatilization Factor	VF	0.5	L/m^3	EPA/540/R-92/003

Notes:

ECF-100BC5-11-0016, *Calculation of Exposure Point Concentrations for the 100-BC-5 Groundwater Operable Unit.*

EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim.*

EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment).*

EPA/600/R-090/052F, *Exposure Factors Handbook: 2011 Edition.*

OSWER Directive 9200.1-120, *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors.*

Ridolfi, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment.*

Table 3-3. Calculated Values and Reference Bases Used for the Drinking Water Ingestion Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic	CDI IRWadj	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2016)
	Risk	EPA/540/R-92/003
Noncarcinogenic	CDI	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2016)
	HQ	EPA/540/R-92/003
Radionuclide	CDI IRW_RADadj	RAIS Risk Exposure Models for Radionuclides User's Guide (ORNL, 2016)
	Risk	EPA/540/R-92/003

Notes:

CDI= chronic daily intake

HQ= hazard quotient

IRWadj = age-adjusted water ingestion rate.

IRW_RADadj = age-adjusted water ingestion rate for radionuclides.

EPA/540/R-92/003, Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim.

ORNL, 2016, The Risk Assessment Information System (RAIS).

3.1.1.2 Drinking Water Ingestion—Noncarcinogenic Effects

For ingestion of noncarcinogens, the CDI is calculated using the following equation:

$$CDI = \frac{C_w \times IRW_c \times EF \times ED_c}{BW_c \times AT_{nc} \times CF1} \tag{8}$$

Noncancer hazard is calculated using the following equation:

$$HQ = \frac{CDI}{RfD_o} \tag{9}$$

3.1.1.3 Drinking Water Ingestion—Radionuclides

For ingestion of radionuclides, the CDI is calculated using the following equations:

$$CDI = C_w \times IRW_RAD_{adj} \times EF \tag{10}$$

where:

$$IRW_RAD_{adj} = (ED_c \times IRW_c) + ([ED_r - ED_c] \times IRW_a) \tag{11}$$

Radiological cancer risk is calculated using the following equation:

$$Risk = CDI \times SF_o \tag{12}$$

3.1.2 Intake and Risk Equations for Drinking Water Inhalation (Volatiles Only)

The bases for the equations used to calculate intake, risk, and hazard associated with inhalation of volatiles in drinking water are summarized in Table 3-4. Equations are provided in the following subsections.

Table 3-4. Calculated Values and Reference Bases Used for the Drinking Water Inhalation of Volatiles Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic	CDI	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2016)
	Risk	EPA-540-R-070-002
Noncarcinogenic	CDI	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2016)
	HQ	EPA-540-R-070-002
Radionuclide	CDI INH_RAD_{adj}	RAIS Risk Exposure Models for Radionuclides User's Guide (ORNL, 2016)
	Risk	EPA/540/R-92/003

Notes:
CDI= chronic daily intake.
HQ = hazard quotient.
INH_RAD_{adj} = age-adjusted radionuclide inhalation rate.
EPA-540-R-070-002, *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment).*
EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim.*
ORNL, 2016, The Risk Assessment Information System (RAIS).

3.1.2.1 Drinking Water Inhalation of Volatiles—Carcinogenic Effects

For inhalation of carcinogens, the CDI is calculated using the following equation:

$$CDI = \frac{C_w \times ED_r \times EF \times ET \times CF2 \times VF \times \left(1000 \frac{\mu g}{mg}\right)}{AT_{can} \times CF1} \tag{13}$$

Cancer risk is calculated using the following equation:

$$Risk = CDI \times IUR \tag{14}$$

3.1.2.2 Drinking Water Inhalation of Volatiles—Noncarcinogenic Effects

For inhalation of noncarcinogens, the CDI is calculated using the following equation:

$$CDI = \frac{C_w \times ED_c \times EF \times ET \times CF2 \times VF}{AT_{nc} \times CF1} \tag{15}$$

Noncancer hazard is calculated using the following equation:

$$HQ = \frac{CDI}{RfC} \tag{16}$$

3.1.2.3 Drinking Water Inhalation of Volatiles—Radionuclides

For inhalation of radionuclides, the CDI is calculated using the following equations:

$$CDI = C_w \times INH_RAD_{adj} \times VF \times EF \times ET \times CF2 \tag{17}$$

where:

$$INH_RAD_{adj} = (ED_c \times INH_c) + ([ED_r - ED_c] \times INH_a) \tag{18}$$

Radiological cancer risk is calculated using the following equation:

$$Risk = CDI \times SF_i \tag{19}$$

3.1.3 Intake and Risk Equations for Drinking Water Dermal Absorption

The bases for the equations used to calculate intake, risk, and hazard associated with the drinking water dermal absorption exposure route are provided in Table 3-5. The equations are presented in the following subsections.

Table 3-5. Calculated Values and Reference Bases Used for the Drinking Water Dermal Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic	CDI	EPA/540/R/99/005
	SA_{adj}	EPA/540/R/99/005
	ET_{adj}	EPA/540/R/99/005
	DA_{event}	EPA/540/R/99/005
	Risk	EPA/540/R/99/005
Noncarcinogenic	CDI	EPA/540/R/99/005
	DA_{event}	EPA/540/R/99/005
	HQ	EPA/540/R/99/005
Radionuclide	Not applicable	

Notes:
CDI= chronic daily intake.
DA_{event} = absorbed dose per event.
ET_{adj} = age-adjusted exposure time.
HQ = hazard quotient.
SA_{adj} = age-adjusted skin surface area.
EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Part E, Supplemental Guidance for Dermal Risk Assessment): Final.*

3.1.3.1 Drinking Water Dermal Absorption— Carcinogenic Effects

For dermal exposure to carcinogens, the CDI is calculated using the following equations:

$$CDI = \frac{DA_{event} \times SA_{adj} \times EF}{AT_{can} \times CF1} \tag{20}$$

where:

$$SA_{adj} = \frac{ED_c \times SA_c \times EV}{BW_c} + \frac{(ED_r - ED_c) \times SA_a \times EV}{BW_a} \tag{21}$$

Cancer risk is calculated using the following equation:

$$Risk = CDI \times \frac{CSF_o}{GIABS} \tag{22}$$

3.1.3.2 Drinking Water Dermal Absorption— Noncarcinogenic Effects

For dermal exposure to noncarcinogens, the CDI is calculated using the following equation:

$$CDI = \frac{DA_{event} \times SA_c \times EF \times ED_c \times EV}{BW_c \times AT_{nc} \times CF1} \tag{23}$$

Noncancer hazard is calculated using the following equation:

$$HQ = \frac{CDI}{RfD_o \times GIABS} \tag{24}$$

3.1.3.3 Drinking Water Dermal Absorption— Event Time (Carcinogenic Effects and Noncarcinogenic Effects)

The event time used in the risk calculations is health effect-dependent. For noncarcinogens, the event time is not age-adjusted ($ET = ET_c$). For carcinogens, an age-adjusted event time is calculated using the following equation:

$$ET = \frac{(ED_c \times ET_c) + ([ED_r - ED_c] \times ET_a)}{ED_r} \tag{25}$$

3.1.3.4 Drinking Water Dermal Absorption— Dermally Absorbed Dose (Carcinogenic Effects and Noncarcinogenic Effects)

For organics, the following equations are used to calculate the dermally absorbed dose per event (DA_{event}), using the child exposure time for noncarcinogenic effects and the age-adjusted exposure time (as calculated above) for carcinogenic effects and:

If $ET \leq t^*$, then the following nonsteady-state equation is used:

$$DA_{event} = 2 \times FA \times K_p \times C_w \times CF3 \times \sqrt{\frac{6 \times \tau \times ET}{\pi}} \tag{26}$$

If ET > t*, then the following pseudosteady-state equation is used:

$$DA_{event} = FA \times K_p \times C_w \times CF3 \times \left[\frac{ET}{1+B} + 2 \times \tau \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right] \quad (27)$$

Where $ET = ET_c$ *or* ET_{adj}, for noncarcinogenic and carcinogenic effects, respectively.

For inorganics, the following steady-state equation is used to estimate DA_{event}:

$$DA_{event} = K_p \times C_w \times ET \times CF3 \quad (28)$$

Where $ET = ET_c$ *or* ET_{adj}, for noncarcinogenic and carcinogenic effects, respectively.

3.1.3.5 Drinking Water Dermal Exposure— Radionuclides

Dermal exposure to radionuclides in drinking water is not evaluated. Although EPA publishes equations and cancer slope factors to estimate exposure from immersion in water, this exposure route is not evaluated in the Native American risk assessment because it is not described or defined in either of the Native American exposure scenarios provided.

3.2 Sweat Lodge Exposure Pathways

Exposure factors used to quantify contaminant intake from the sweat lodge exposure pathways are provided in Table 3-6 for the CTUIR exposure scenario and in Table 3-7 for the Yakama Nation exposure scenario. Sweat lodge exposure is evaluated (for adults only) based on an exposure frequency of 365 days/yr over a 68-year exposure duration (first 2 years of life excluded)[1] for the CTUIR scenario and a 70-year exposure duration for the Yakama Nation scenario (although the provided exposure scenarios indicate that childhood sweats occur, exposure assumptions are made for adults only).

[1] Child exposure assumptions were not provided for the purpose of evaluating exposure through sweat lodge use; therefore, an adult exposure duration was assumed to be 68 years for the CTUIR scenario and 70 years for the Yakama Nation scenario.

Table 3-6. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens[a]	AT	70	year	Harris and Harper, 2004
Averaging Time –noncarcinogens[a]	AT	68	year	Harris and Harper, 2004
Average Body Weight – adult	BW	70	kg	Harris and Harper, 2004
Conversion Factor	CF1	365	days/year	1 year = 365 days
Conversion Factor	CF2	0.01	m/cm	1 meter = 100 cm
Conversion Factor	CF3	10	L/m^2-cm	1 L = 0.01 m^2 x 10 cm
Groundwater Concentration[b]	C_{dw}	analyte-specific	mg/L or pCi/L	ECF-100BC5-11-0016
Cancer Slope Factor - oral	CSF_o	analyte-specific	$(mg/kg\text{-}day)^{-1}$	See Table 4-4
Cancer Slope Factor - inhalation	CSF_i	analyte-specific	$(mg/kg\text{-}day)^{-1}$	Equation 49
Exposure Duration or Number of Years a Person Sweats in a Lifetime - adult	ED	68	year	Harris and Harper, 2004
Exposure Frequency or Number of Sweats per Year	EF	365	events/year	Harris and Harper, 2004
Length of Sweat Event – adult[c]	ET	1/24	days/event	Harris and Harper, 2004
Gastrointestinal Absorption Factor	GIABS	analyte-specific	unitless	See Table 4-4
Inhalation Intake of Analytes in Sweat Lodge— volatile and semi-volatile nonradionuclides	I_{inh}	Calculated value	mg/kg-day	Equation 29
Inhalation Intake of Analytes in Sweat Lodge— volatile and semi-volatile radionuclides	I_{inh}	Calculated value	pCi	Equation 32
Inhalation Intake of Analytes in Sweat Lodge— nonvolatile nonradionuclides	I_{inh}	Calculated value	mg/kg-day	Equation 34
Inhalation Intake of Analytes in Sweat Lodge— nonvolatile radionuclides	I_{inh}	Calculated value	pCi	Equation 37

Table 3-6. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Dermal Intake of Analytes in Sweat Lodge— volatile and semi-volatile vapor	$I_{d,v} = I_{d,total}$	Calculated value	mg/kg-day	Equation 39
Dermal Intake of Analytes in Sweat Lodge— nonvolatile condensed liquid	$I_{d,l}$	Calculated value	mg/kg-day	Equation 42
Dermal Intake of Analytes in Sweat Lodge— nonvolatile vapor	$I_{d,v}$	Calculated value	mg/kg-day	Equation 43
Inhalation Rate - adult	IR	25	m^3/day	Harris, 2008
Inhalation Unit Risk	IUR	analyte-specific	$(\mu g/m^3)^{-1}$	See Table 4-4
Analyte-Specific Permeability Coefficient	K_p	analyte-specific	cm/hour	See Table 4-4
Molecular Weight of Water	MW_w	18	g/gmole	Harris and Harper, 2004
Density of Liquid Water	ρ_w	1,000	g/L	Harris and Harper, 2004
The Constant pi	π	3.14159	unitless	--
Radius of Sweat Lodge	r	1	m	Harris and Harper, 2004
Ideal Gas Law Constant	R	0.06237	mmHg-m^3/mole-K	Harris and Harper, 2004
Ideal Gas Law Constant[d]	R	62.37	mmHg-L/mole-K	Harris and Harper, 2004
Reference Concentration	RfC	analyte-specific	mg/m^3	See Table 4-4
Reference Dose - inhalation	RfD_i	analyte-specific	mg/kg-day	Equation 50
Reference Dose - oral	RfD_o	analyte-specific	mg/kg-day	See Table 4-4
Skin Surface Area - adult	SA	18,000	cm^2	Harris and Harper, 2004
Slope Factor - inhalation	SF_i	analyte-specific	Risk/pCi	See Table 4-4
Temperature of the Sweat Lodge[e]	T	338.7	K	Harris and Harper, 2004

Table 3-6. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for CTUIR Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Cumulative Volume of Water Used in Sweat	$V_{w,total}$	4	Liters	Harris and Harper, 2004

Notes:

a. Averaging time of 1 year provided in Harris and Harper, 2004 was replaced with 70 years for carcinogens and 68 years for noncarcinogens to account for lifetime intake rather than annual intake.

b. Harris and Harper (2004, Appendix 4) indicates water concentration (C_{dw}) is "dissolved surface water concentration of the COPC (mg/L); calculated according to EPA 1998a, Appendix B." However, for this assessment analyte exposure point concentrations reflect total concentrations in groundwater.

c. For sweat lodge inhalation exposure, exposure time of 1 hour provided in Harris and Harper, 2004 was replaced with 1/24 days/event so that intake values have appropriate units (mg/kg-day or pCi) when calculated using the inhalation equations provided in Harris and Harper (2004, Equations 7 and 15).

d. For sweat lodge dermal exposure, the ideal gas law constant of 0.06237 mmHg-m3/gmole-K provided in Harris and Harper, 2004 was replaced with 62.37 mmHg-L/gmole-K so that intake values have appropriate units (mg/kg-day) when calculated using the equations provided in Harris and Harper, (2004, Equations 15 and 20).

e. Temperature of 389 K provided in Harris and Harper, 2004 was replaced with 338.7 K (150 °F) for consistency with stated assumption in Harris and Harper, 2004 that sweat lodge internal temperature is maintained at 150 °F.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation

ECF-100BC5-11-0016, *Calculation of Exposure Point Concentrations for the 100-BC-5 Groundwater Operable Unit.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

Harris, 2008, *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments.*

Table 3-7. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens[a]	AT	70	year	Harris and Harper, 2004
Averaging Time –noncarcinogens[a]	AT	70	year	Harris and Harper, 2004
Average Body Weight - adult	BW	70	kg	Ridolfi, 2007
Conversion Factor	CF1	365	days/year	1 year = 365 days/year
Conversion Factor	CF2	0.01	m/cm	1 meter = 100 cm
Conversion Factor	CF3	10	L/m^2-cm	1 L = 0.01 m^2 x 10 cm
Groundwater Concentration[b]	C_{dw}	analyte-specific	mg/L or pCi/L	ECF-100BC5-11-0016
Cancer Slope Factor - oral	CSF_o	analyte-specific	$(mg/kg\text{-}day)^{-1}$	See Table 4-4
Cancer Slope Factor - inhalation	CSF_i	analyte-specific	$(mg/kg\text{-}day)^{-1}$	Equation 49
Exposure Duration or Number of Years a Person Sweats in a Lifetime - adult	ED	70	year	Ridolfi, 2007
Exposure Frequency or Number of Sweats per Year	EF	365	events/year	Ridolfi, 2007
Length of Sweat Event – adult[c]	ET	7/24	days/event	Ridolfi, 2007
Gastrointestinal Absorption Factor	GIABS	analyte-specific	unitless	See Table 4-4
Inhalation Intake of Analytes in Sweat Lodge— volatile and semi-volatile nonradionuclides	I_{inh}	Calculated value	mg/kg-day	Equation 29
Inhalation Intake of Analytes in Sweat Lodge— volatile and semi-volatile radionuclides	I_{inh}	Calculated value	pCi	Equation 32
Inhalation Intake of Analytes in Sweat Lodge— nonvolatile nonradionuclides	I_{inh}	Calculated value	mg/kg-day	Equation 34
Inhalation Intake of Analytes in Sweat Lodge— nonvolatile radionuclides	I_{inh}	Calculated value	pCi	Equation 37

Table 3-7. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Dermal Intake of Analytes in Sweat Lodge— volatile and semi-volatile vapor	$I_{d,total} = I_{d,v}$	Calculated value	mg/kg-day	Equation 39
Dermal Intake of Analytes in Sweat Lodge— nonvolatile condensed liquid	$I_{d,l}$	Calculated value	mg/kg-day	Equation 42
Dermal Intake of Analytes in Sweat Lodge— nonvolatile vapor	$I_{d,v}$	Calculated value	mg/kg-day	Equation 43
Inhalation Rate - adult	IR	26	m^3/day	Ridolfi, 2007
Inhalation Unit Risk	IUR	analyte-specific	$(\mu g/m^3)^{-1}$	See Table 4-4
Analyte-Specific Permeability Coefficient	K_p	analyte-specific	cm/hour	See Table 4-4
Molecular Weight of Water	MW_w	18	g/gmole	Harris and Harper, 2004
Density of Liquid Water	ρ_w	1,000	g/L	Harris and Harper, 2004
The Constant pi	π	3.14159	unitless	--
Radius of Sweat Lodge	r	1	m	Harris and Harper, 2004
Ideal Gas Law Constant	R	0.06237	mmHg-m^3/mole-K	Harris and Harper, 2004
Ideal Gas Law Constant[d]	R	62.37	mmHg-L/mole-K	Harris and Harper, 2004
Reference Concentration	RfC	analyte-specific	mg/m^3	See Table 4-4
Reference Dose - inhalation	RfD_i	analyte-specific	mg/kg-day	Equation 50
Reference Dose - oral	RfD_o	analyte-specific	mg/kg-day	See Table 4-4
Skin Surface Area - adult	SA	18,000	cm^2	Harris and Harper, 2004
Slope Factor - inhalation	SF_i	analyte-specific	Risk/pCi	See Table 4-4

Table 3-7. Summary of Exposure Assumptions Used for the Sweat Lodge Exposure Pathways for Yakama Nation Exposure Scenario in the 100-BC-5 Groundwater Operable Unit

Exposure Factor	Symbol	Value	Units	Source
Temperature Inside the Sweat Lodge[e]	T	338.7	K	Harris and Harper, 2004
Cumulative Volume of Water Used in Sweat	$V_{w,total}$	4	Liters	Harris and Harper, 2004

Notes:

a. Averaging time of 1 year provided in Harris and Harper, 2004 was replaced with 70 years for both carcinogens and noncarcinogens to account for lifetime intake rather than annual intake.

b. Harris and Harper (2004, Appendix 4) indicates water concentration (Cdw) is "dissolved surface water concentration of the COPC (mg/L); calculated according to EPA 1998a. Appendix B." However, for this assessment analyte exposure point concentrations reflect total concentrations in groundwater.

c. For sweat lodge inhalation exposure, exposure time of 7 hr provided in Ridolfi, 2007 was replaced with 7/24 days/event so that the intake values have appropriate units.(mg/kg-day or pCi) when calculated using the inhalation equations provided in Harris and Harper (2004, Equations 7 and 15).

d. For sweat lodge dermal exposure, the ideal gas law constant of 0.06237 mmHg-m3/gmole-K provided in Harris and Harper, 2004 was replaced with 62.37 mmHg-L/gmole-K so that intake values have appropriate units (mg/kg-day) when calculated using the equations provided in Harris and Harper, (2004, Equations 15 and 20).

e. Temperature of 389 K provided in Harris and Harper, 2004 was replaced with 338.7 K (150 °F) for consistency with stated assumption in Harris and Harper, 2004 that sweat lodge internal temperature is maintained at 150 °F.

ECF-100BC5-11-0016, Calculation of Exposure Point Concentrations for the 100-BC-5 Groundwater Operable Unit.

Harris and Harper, 2004, Exposure Scenario for CTUIR Traditional Subsistence Lifeways.

Ridolfi, 2007, Yakama Nation Exposure Scenario for Hanford Site Risk Assessment.

3.2.1 Intake and Risk Equations for Sweat Lodge Inhalation of Volatiles and Semi-Volatiles

The bases for the equations used to calculate intake, risk, and hazard associated with the inhalation of volatiles and semi-volatiles during sweat lodge use are summarized in Table 3-8. Equations are provided in the following subsections.

Table 3-8. Calculated Values and Reference Bases Used for the Sweat Lodge Inhalation of Volatiles and Semi-Volatiles Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic and Noncarcinogenic	I_{inh}	Harris and Harper, 2004
Carcinogenic	Risk	EPA-540-R-070-002
Noncarcinogenic	HQ	EPA-540-R-070-002
Radionuclide	I_{inh}	Harris and Harper, 2004
	Risk	EPA/540/R-92/003

Notes:
I_{inh} = Inhalation intake of analytes in sweat lodge.
HQ = hazard quotient.
EPA-540-R-070-002, *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment).*
EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim.*
Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

3.2.1.1 Sweat Lodge Inhalation of Volatiles and Semi-Volatiles—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

Inhalation intake of volatiles and semi-volatiles in sweat lodge vapor is calculated using the following equation (Harris and Harper 2004, Appendix 4, Equation 7):

$$I_{inh} = \frac{C_{dw} \times \left(\frac{V_{w,total}}{2}\right) \times \left(\frac{1}{2/3 \times \pi \times r^3}\right) \times IR \times ET \times EF \times ED}{BW \times AT \times CF1} \quad (29)$$

3.2.1.2 Sweat Lodge Inhalation of Volatiles and Semi-Volatiles—Carcinogenic Effects

For carcinogens, the cancer risk is calculated using the following equation:

$$Risk = CSF_i \times I_{inh} \quad (30)$$

3.2.1.3 Sweat Lodge Inhalation of Volatiles and Semi-Volatiles—Noncarcinogenic Effects

For noncarcinogens, the noncancer hazard is calculated using the following equation:

$$HQ = \frac{1}{RfD_i} \times I_{inh} \quad (31)$$

3.2.1.4 Sweat Lodge Inhalation of Volatiles and Semi-Volatiles—Radionuclides

Inhalation intake of volatile and semi-volatile radionuclides in sweat lodge vapor is calculated using the following equation (modified for pCi/L groundwater concentration units and inhalation slope factors from Harris and Harper, 2004, Appendix 4, Equation 7):

$$I_{inh} = C_{dw} \times \left(\frac{V_{w,total}}{2}\right) \times \left(\frac{1}{{}^{2}/_{3} \times \pi \times r^{3}}\right) \times IR \times ET \times EF \times ED \qquad (32)$$

Radiological cancer risk is calculated using the following equation:

$$Risk_{rad} = SF_i \times I_{inh} \qquad (33)$$

3.2.2 Intake and Risk Equations for Sweat Lodge Inhalation of Nonvolatiles

The bases for the equations used to calculate intake, risk, and hazard associated with the inhalation of nonvolatiles exposure route during sweat lodge use are summarized in Table 3-9. Equations are provided in the following subsections.

Table 3-9. Calculated Values and Reference Bases Used for the Sweat Lodge Inhalation of Nonvolatiles Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic and Noncarcinogenic	I_{inh}	Harris and Harper, 2004
Carcinogenic	Risk	EPA-540-R-070-002
Noncarcinogenic	HQ	EPA-540-R-070-002
Radionuclide	I_{inh}	Harris and Harper, 2004
	Risk	EPA/540/R-92/003

Notes:
I_{inh} = Inhalation intake of analytes in sweat lodge.
HQ = hazard quotient.

EPA-540-R-070-002, *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment).*

EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals): Interim.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

3.2.2.1 Sweat Lodge Inhalation of Nonvolatiles—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

Inhalation intake of aerosolized nonvolatile contaminants in a sweat lodge is calculated using the following equation (Harris and Harper 2004, Appendix 4, Equation 15):

$$I_{inh} = \left(\frac{IR \times ET \times EF \times ED}{BW \times AT \times CF1}\right) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times EXP\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \qquad (34)$$

3.2.2.2 Sweat Lodge Inhalation of Nonvolatiles—Carcinogenic Effects

For carcinogens, the cancer risk is calculated using the following equation:

$$RISK = CSF_i \times I_{inh} \tag{35}$$

3.2.2.3 Sweat Lodge Inhalation of Nonvolatiles—Noncarcinogenic Effects

For noncarcinogens, the noncancer hazard is calculated using the following equation:

$$HQ = \frac{1}{RfD_i} \times I_{inh} \tag{36}$$

3.2.2.4 Sweat Lodge Inhalation of Nonvolatiles—Radionuclides

Inhalation intake of aerosolized nonvolatile radionuclides in a sweat lodge is calculated with the following equation (modified for pCi/L groundwater concentration units and inhalation slope factors from Harris and Harper, 2004, Appendix 4, Equation 15):

$$I_{inh} = (IR \times ET \times EF \times ED) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times EXP\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \tag{37}$$

Radiological cancer risk is calculated using the following equation:

$$Risk_{rad} = SF_i \times I_{inh} \tag{38}$$

3.2.3 Intake and Risk Equations for Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles

The bases for the equations used to calculate intake, risk, and hazard associated with the dermal exposure route for volatiles and semi-volatiles during sweat lodge use are summarized in Table 3-10. Equations are provided in the following subsections.

Table 3-10. Calculated Values and Reference Bases Used for the Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic and Noncarcinogenic	$I_{d,v} = I_{d,total}$	Harris and Harper, 2004
Carcinogenic	Risk	EPA/540/R/99/005
Noncarcinogenic	HQ	EPA/540/R/99/005

Notes:

$I_{d,v}$ = Dermal intake of volatile and semi-volatile analytes in vapor in sweat lodge.

$I_{d,total}$ = Total dermal intake of volatile and semi-volatile analytes in sweat lodge.

HQ = hazard quotient.

EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Part E, Supplemental Guidance for Dermal Risk Assessment): Final.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

3.2.3.1 Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

For volatile and semi-volatile compounds, the Harris and Harper model assumes 100% volatilization within the sweat lodge. Vapor exposure is the primary exposure pathway, and exposure from condensed water is considered incomplete. Therefore, $I_{d,total}$ is equal to $I_{d,v}$.

Exposure from dermal contact with volatile and semi-volatile contaminants in sweat lodge vapor is calculated using the following equation (Harris and Harper 2004, Appendix 4, Equation 18):

$$I_{d,total} = I_{d,v} = \frac{C_{dw} \times \left(\frac{V_{w,total}}{2}\right) \times \left(\frac{1}{2/_3 \times \pi \times r^3}\right) \times SA \times K_p \times ET \times EF \times ED \times CF2}{BW \times AT \times CF1} \quad (39)$$

3.2.3.2 Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles—Carcinogenic Effects

For carcinogens, the cancer risk is calculated using the following equation:

$$Risk = \frac{CFS_o}{GIABS} \times I_{d,total} \quad (40)$$

3.2.3.3 Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles—Noncarcinogenic Effects

For noncarcinogens, the noncancer hazard is calculated using the following equation:

$$HQ = \frac{1}{RfD_o \times GIABS} \times I_{d,total} \quad (41)$$

3.2.3.4 Sweat Lodge Dermal Exposure to Volatiles and Semi-Volatiles—Radionuclides

Dermal exposure to volatile and semi-volatile radionuclides in a sweat lodge is not evaluated. Although EPA publishes equations and cancer slope factors to estimate exposure from immersion in water, the exposure route is not evaluated in the Native American risk assessment because it is not described or defined in either of the Native American exposure scenarios provided.

3.2.4 Intake and Risk Equations for Sweat Lodge Dermal Exposure to Nonvolatiles

The bases for the equations used to calculate intake, risk, and hazard associated with the dermal exposure route for nonvolatiles during sweat lodge use are summarized in Table 3-11. Equations are provided in the following subsections.

Table 3-11. Calculated Values and Reference Bases Used for the Sweat Lodge Dermal Exposure to Nonvolatiles Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic and Noncarcinogenic	$I_{d,l}$	Harris and Harper, 2004
Carcinogenic and Noncarcinogenic	$I_{d,v}$	Harris and Harper, 2004
Carcinogenic and Noncarcinogenic	$I_{d,total}$	Harris and Harper, 2004
Carcinogenic	Risk	EPA/540/R/99/005
Noncarcinogenic	HQ	EPA/540/R/99/005

Table 3-11. Calculated Values and Reference Bases Used for the Sweat Lodge Dermal Exposure to Nonvolatiles Exposure Route

Effect	Symbol for Calculated Value	Reference

Notes:

$I_{d,l}$ = Dermal intake of nonvolatiles analytes in condensed liquid in sweat lodge.

$I_{d,v}$ = Dermal intake of nonvolatile analytes in vapor in sweat lodge.

$I_{d,total}$ = Total dermal intake of nonvolatile analytes in sweat lodge.

HQ = hazard quotient.

EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

3.2.4.1 Sweat Lodge Dermal Exposure to Nonvolatiles in Condensed Liquid—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

In the Harris and Harper model, total dermal intake of nonvolatile contaminants is calculated as the sum of intakes from dermal exposure to vapors and to aqueous condensate. For condensed liquid, the model assumes nonvolatile contaminant concentrations in the condensed water are equal to that of the water added to the heated rocks. Intake from dermal contact with nonvolatile compounds in sweat lodge condensed liquid is calculated using the following equation (Harris and Harper 2004, Appendix 4, Equation 19):

$$I_{d,l} = \frac{C_{dw} \times SA \times K_p \times ET \times EF \times ED \times CF3}{BW \times AT \times CF1} \tag{42}$$

3.2.4.2 Sweat Lodge Dermal Exposure to Nonvolatiles in Vapor—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

Intake from dermal contact with nonvolatile compounds in sweat lodge vapor is calculated using the following equation (Harris and Harper 2004, Appendix 4, Equation 20):

$$I_{d,v} = \left(\frac{SA \times K_p \times ET \times EF \times ED \times CF3}{BW \times AT \times CF1}\right) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times EXP\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \tag{43}$$

3.2.4.3 Sweat Lodge Dermal Exposure to Nonvolatiles in Vapor—Total Intake (Carcinogenic Effects and Noncarcinogenic Effects)

The total dermal exposure for nonvolatile compounds in a sweat lodge is calculated using the following equation (Harris and Harper 2004, Appendix 4, Equation 21):

$$I_{d,total} = I_{d,v} + I_{d,l} \tag{44}$$

3.2.4.4 Sweat Lodge Dermal Exposure to Nonvolatiles—Carcinogenic Effects

For carcinogens, the cancer risk is calculated using the following equation:

$$Risk = \frac{CSF_o}{GIABS} \times I_{d,total} \tag{45}$$

3.2.4.5 Sweat Lodge Dermal Exposure to Nonvolatiles—Noncarcinogenic Effects

For noncarcinogens, the noncancer hazard is calculated using the following equation:

$$HQ = \frac{1}{RfD_o \times GIABS} \times I_{d,total} \tag{46}$$

3.2.4.6 Sweat Lodge Dermal Exposure to Nonvolatiles—Radionuclides

Dermal exposure to radionuclides in a sweat lodge is not evaluated. Although EPA publishes equations and cancer slope factors to estimate exposure from immersion in water, the exposure route is not evaluated in the Native American risk assessment because it is not described or defined in either of the Native American exposure scenarios provided.

3.3 Cumulative Risk—Cancer

For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used. The basis for the equation is provided in EPA/540/1-89/002.

$$Risk_T = \sum_1^N Risk_i \tag{47}$$

where:

$Risk_T$	=	Total cancer risk from route of exposure
$Risk_i$	=	Cancer risk for the ith chemical
N	=	Number of chemicals

3.4 Hazard Index—Noncancer

The HI is calculated using the following equation. The basis for the equation is provided in EPA/540/1-89/002.

$$HI = \sum_1^N \frac{CDI_i}{RfD_i} \tag{48}$$

where:

HI	=	hazard index
CDI_i	=	chronic daily intake of the ith chemical (mg/kg-day)
RfD_i	=	reference dose of the ith chemical (mg/kg-day)
N	=	number of chemicals

4 Assumptions and Inputs

Assumptions and inputs associated with the exposure scenarios and human health toxicity values, along with the groundwater analytes and associated exposure point concentrations (EPCs) used in the CTUIR and Yakama Nation human health risk calculations, are described below.

4.1 Exposure Inputs and Assumptions

- Exposure inputs used to quantify intake from the drinking water exposure pathways are provided in Tables 3-1 and 3-2 for the CTUIR and Yakama Nation exposure scenarios, respectively. Exposure inputs used to quantify intake from the sweat lodge exposure pathway are provided in Tables 3-6 and 3-7 for the CTUIR and Yakama Nation exposure scenarios, respectively.
- Exposure routes evaluated for the drinking water exposure pathways for the CTUIR and Yakama Nation exposure scenarios are ingestion, inhalation, and dermal absorption. Dermal exposure is evaluated for nonradionuclides only.
- Exposure routes evaluated for the sweat lodge exposure pathways for the CTUIR and Yakama Nation exposure scenarios are inhalation and dermal absorption. Dermal exposure is evaluated for nonradionuclides only.
- For domestic use of groundwater as a drinking water supply, EPA considers the inhalation pathway potentially complete only for volatile contaminants, because there is no mechanism for release of nonvolatile chemicals into the air in significant concentrations (EPA/540/R-92/003). For the drinking water exposure pathway, inhalation intake is quantified for volatile contaminants as defined by EPA, 2015b, *Regional Screening Levels for Chemical Contaminants at Superfund Sites*.
- Exposure times for dermal exposure to drinking water are assumed to be 0.71 hours for an adult and 0.54 hours for a child based on the EPA recommended values for showering/bathing under a reasonable maximum exposure (RME) residential scenario (EPA/600/R-090/052F). Exposure times for inhalation of volatiles in water is assumed to be 24 hours per day.
- The Yakama Nation exposure scenario (Ridolfi, 2007) did not provide intake equations for exposures related to sweat lodge use; therefore, equations provided by Harris and Harper were used.
- The CTUIR exposure scenario (Harris and Harper 2004) provides a full set of factors needed to quantify contaminant intake from sweat lodge use. The Yakama Nation exposure scenario (Ridolfi 2007) provides a partial set of the needed factors. The tribal-specific factors are used preferentially in the sweat lodge calculations. Where tribal-specific factors are not provided, values consistent with those used in the River Corridor Baseline Risk Assessment (RCBRA) (DOE/RL-2007-21, River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment) are generally used. Summaries of the key exposure assumptions used to quantify contaminant intake from sweat lodge use for the CTUIR and Yakama Nation scenarios are provided in Table 4-1 and Table 4-2, respectively.
- Harris and Harper, 2004, Appendix 4, indicates that the water concentration (C_{dw}) is "dissolved surface water concentration of the contaminant of potential concern (COPC) (mg/L); calculated according to EPA 1998a, Appendix B." However, for this assessment, the groundwater EPCs were used for C_{dw}; the EPCs are calculated based on total concentrations (not dissolved concentrations) in groundwater. Total concentrations are typically higher than dissolved concentrations.

Table 4-1. Summary of Key Exposure Assumptions Used for the Sweat Lodge Exposure Pathway for the CTUIR Exposure Scenario

Exposure Factor	Symbol	Units	RI/FS Value	RCBRA Value	RCBRA Reference	CTUIR Value	CTUIR Reference
Averaging Time – carcinogens	AT	year	70[a]	75	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	1	Harris and Harper, 2004, Appendix 4
Averaging Time – noncarcinogens	AT	year	68[a]	69 (ED)	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	1	Harris and Harper, 2004, Appendix 4
Average Body Weight – adult	BW	kg	70	70	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	70	Harris and Harper, 2004, Appendix 4
Exposure Duration or Number of Years a Person Sweats in a Lifetime – adult	ED	year	68	69	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	68	Harris and Harper, 2004, Appendix 4
Exposure Frequency or Number of Sweats per Year	EF	events/year	365	365	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	365	Harris and Harper, 2004, Appendix 4
Length of Sweat Event – adult	ET	hours/event	1[b]	1	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	1	Harris and Harper, 2004, Appendix 4
Inhalation Intake of Analytes in Sweat Lodge—nonvolatile nonradionuclides	I_{inh}	mg/kg-day	Calculated value	Calculated value	RCBRA Rev. 0, Volume II, Part 1, p. 3-72 and p. 6-2	Calculated value	Harris and Harper, 2004, Appendix 4
Inhalation Intake of Analytes in Sweat Lodge—nonvolatile radionuclides	I_{inh}	pCi	Calculated value	Calculated value	RCBRA Rev. 0, Volume II, Part 1, p. 3-72 and p. 6-2	Calculated value	Harris and Harper, 2004, Appendix 4

Table 4-1. Summary of Key Exposure Assumptions Used for the Sweat Lodge Exposure Pathway for the CTUIR Exposure Scenario

Exposure Factor	Symbol	Units	RI/FS Value	RCBRA Value	RCBRA Reference	CTUIR Value	CTUIR Reference
Inhalation Rate—adult	IR	m^3/day	25	30[c]	RCBRA Rev. 0, Volume II, Part 2, p. 3-27, Table 3-19	25	Harris, 2008
Radius of Sweat Lodge	r	m	1	1	RCBRA Rev. 0, Volume II, Part 1, p. 3-71	1	Harris and Harper, 2004, Appendix 4
Skin Surface Area – adult	SA	cm^2	18,000	18,000	RCBRA Rev. 0, Volume II, Part 2, p. 3-27, Table 3-19	18,000	Harris and Harper, 2004, Appendix 4
Cumulative Volume of Water Used in Sweat	$V_{w,total}$	Liters	4	4	RCBRA Rev. 0, Volume II, Part 1, p. 3-71	4	Harris and Harper, 2004, Appendix 4

Notes:

a. Averaging time of 1 year provided in Harris and Harper, 2004 was replaced with 70 years for carcinogens and 68 years for noncarcinogens to account for lifetime intake rather than annual intake.

b. Inhalation intake calculated using 1/24 days/event for unit consistency with equations provided in Harris and Harper, 2004.

c. RCBRA references 1.25 m^3/hr, which is equivalent to 30 m^3/day (1.25 m^3/hr × 24 hrs/day).

RCBRA = River Corridor Baseline Risk Assessment (DOE/RL-2007-21)

DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

Harris, 2008, *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments.*

Table 4-2. Summary of Key Exposure Assumptions Used for the Sweat Lodge Exposure Pathway for the Yakama Nation Exposure Scenario

Exposure Factor	Symbol	Units	RI/FS Value	RCBRA Value	RCBRA Reference	Yakama Nation Value	Yakama Nation Reference
Averaging Time – carcinogens	AT	year	70[a]	70	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	Not specified	NA
Averaging Time – noncarcinogens	AT	year	70[a]	64 (ED)	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	Not specified	NA
Average Body Weight – adult	BW	kg	70	70	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	70	Ridolfi, 2007, Table 7
Exposure Duration or Number of Years a Person Sweats in a Lifetime – adult	ED	year	70	64	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	70	Ridolfi, 2007, Table 7
Exposure Frequency or Number of Sweats per Year	EF	events/year	365	365	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	365	Ridolfi, 2007, Table 7
Length of Sweat Event – adult	ET	hours/event	7[b]	7	RCBRA Rev. 0, Volume II, Part 2, p. 3-28, Table 3-19	7	Ridolfi, 2007, Table 7
Inhalation Intake of Analytes in Sweat Lodge— nonvolatile nonradionuclides	I_{inh}	mg/kg-day	Calculated both with and without	Not calculated	RCBRA Rev. 0, Volume II, Part 1, p. 3-72 and p. 6-2	Not specified	NA
Inhalation Intake of Analytes in Sweat Lodge— nonvolatile radionuclides	I_{inh}	pCi	Calculated both with and without	Not calculated	RCBRA Rev. 0, Volume II, Part 1, p. 3-72 and p. 6-2	Not specified	NA
Inhalation Rate – adult	IR	m^3/day	26	26[c]	RCBRA Rev. 0, Volume II, Part 2, p. 3-27, Table 3-19	26	Ridolfi, 2007, Table 7
Radius of Sweat Lodge	r	m	1	1	RCBRA Rev. 0, Volume II, Part 1, p. 3-71	Not specified	NA

Table 4-2. Summary of Key Exposure Assumptions Used for the Sweat Lodge Exposure Pathway for the Yakama Nation Exposure Scenario

Exposure Factor	Symbol	Units	RI/FS Value	RCBRA Value	RCBRA Reference	Yakama Nation Value	Yakama Nation Reference
Skin Surface Area – adult	SA	cm^2	18,000	18,000	RCBRA Rev. 0, Volume II, Part 2, p. 3-27, Table 3-19	Not specified	NA
Cumulative Volume of Water Used in Sweat	$V_{w,total}$	Liters	4	4	RCBRA Rev. 0, Volume II, Part 1, p. 3-71	Not specified	NA

Notes:

a. Averaging time of 1 year provided in Harris and Harper, 2004 was replaced with 70 years for both carcinogens and noncarcinogens to account for lifetime intake rather than annual intake.

b. Inhalation intake calculated using 7/24 days/event for unit consistency with equations provided in Harris and Harper, 2004.

c. RCBRA references 1.08 m^3/hr, which is equivalent to 26 m^3/day (1.08 m^3/hr × 24 hrs/day).

RCBRA = River Corridor Baseline Risk Assessment (DOE/RL-2007-21)

DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment.*

Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways.*

Ridolfi, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment.*

- For the sweat lodge scenario, an exposure time of 1 hour/event is used for the CTUIR based on Harris and Harper, 2004. For the Yakama Nation, an exposure time of 7 hours/event is used based on Ridolfi, 2007. Seven hours/day is the recommended sweat lodge exposure time based on the maximum value reported in a tribal survey (Ridolfi, 2007).
- The sweat lodge scenario assumes 4 liters of groundwater are poured over hot rocks to make steam in a hemispherical sweat lodge with a radius of 1 m (Harris and Harper, 2004). The internal temperature of the sweat lodge is assumed to be maintained at a constant 150 degrees Fahrenheit (Harris and Harper, 2004). This scenario creates a unique environment where volatile, semi-volatile, and nonvolatile analytes could potentially be present in the air and available for inhalation and dermal exposure. Harris and Harper, 2004 describes a method for calculating a vaporization factor for the sweat lodge scenario. The vaporization factor is applied to the groundwater concentration to estimate analyte concentrations in sweat lodge steam. Ridolfi (2007) does not specify a method for estimating analyte concentrations in sweat lodge steam; therefore, the Harris and Harper steam model is used for both the CTUIR and Yakama Nation intake calculations.
- Harris and Harper recommend different methods for calculating vaporization factors for volatile and semi-volatile analytes, versus nonvolatile analytes. For volatile and semi-volatile analytes, the model assumes 100 percent volatilization throughout the sweat; hence, dermal exposure to volatiles and nonvolatiles in condensed water is considered an incomplete pathway. Therefore, volatile and semi-volatile analytes (including tritium) are evaluated for intake via inhalation and dermal absorption only from the vapor phase.
- For nonvolatile analytes, the model assumes that the analytes become airborne as an aerosol and that, once airborne, the analytes can deposit onto the skin surface as aqueous condensate. Nonvolatile analyte intake is assumed to occur via inhalation from the vapor phase and dermal absorption from both the vapor and liquid phases. The Harris and Harper model assumes the concentration of nonvolatiles in condensed water is equal to the concentration in the water used to create the steam.

4.2 Groundwater Analytes and Exposure Point Concentrations

The analytes assessed in this environmental calculation were identified from the analytical data set for the 100-BC-5 Groundwater OU in the Hanford Environmental Information System (HEIS) database. The data set was first processed and reduced as described in ECF-100BC5-0016, *Calculation of Exposure Point Concentrations for the 100-BC-5 Groundwater Operable Unit.*

Following the data processing and reduction steps, any analyte in the (processed) data set with at least one reported detection and available toxicity values was assessed in the Native American risk calculations for the 100-BC-5 Groundwater OU.

The EPCs used for the Native American risk calculations are the analyte–specific 95UCL or ProUCL values calculated from a combined analytical data set of 37 wells located in the 100-BC-5 Groundwater OU, as described in ECF-100BC5-0016. The identified analytes and their EPCs are presented in Table 4-3.

Table 4-3. 100-BC-5 Groundwater Operable Unit Grouped Well Exposure Point Concentration Summary

Analyte Name	CAS No.	Units	100-BC-5 Groundwater OU
Acetone	67-64-1	µg/L	1.0
Aluminum	7429-90-5	µg/L	28
Antimony	7440-36-0	µg/L	2.9
Arsenic	7440-38-2	µg/L	2.6
Barium	7440-39-3	µg/L	31
Beryllium	7440-41-7	µg/L	0.13
Boron	7440-42-8	µg/L	14
Bromomethane	74-83-9	µg/L	0.27
Cadmium	7440-43-9	µg/L	0.12
Chloroform	67-66-3	µg/L	1.0
Chloromethane	74-87-3	µg/L	0.20
Chromium	7440-47-3	µg/L	30
Cobalt	7440-48-4	µg/L	0.15
Copper	7440-50-8	µg/L	4.1
Fluoride	16984-48-8	µg/L	192
Hexavalent Chromium	18540-29-9	µg/L	27
Iron	7439-89-6	µg/L	59
Lithium	7439-93-2	µg/L	6.1
Manganese	7439-96-5	µg/L	4.7
Methylene chloride	75-09-2	µg/L	2.6
Molybdenum	7439-98-7	µg/L	4.2
Nickel	7440-02-0	µg/L	1.7
Nitrate	14797-55-8	µg/L	11,137
Nitrite	14797-65-0	µg/L	136
Selenium	7782-49-2	µg/L	1.3
Silver	7440-22-4	µg/L	0.14
Strontium	7440-24-6	µg/L	190
Tin	7440-31-5	µg/L	0.89
Trichloroethene	79-01-6	µg/L	1.3
Uranium	7440-61-1	µg/L	2.0
Vanadium	7440-62-2	µg/L	11
Zinc	7440-66-6	µg/L	7.5
Americium-241	14596-10-2	pCi/L	0.090
Cesium-137	10045-97-3	pCi/L	2.0
Strontium-90	10098-97-2	pCi/L	13
Technetium-99	14133-76-7	pCi/L	17
Tritium	10028-17-8	pCi/L	7,230

4.3 Toxicity Values

The toxicity criteria used for the Native American human health risk calculations are provided in Table 4-4. The sources for these criteria are discussed below.

4.3.1 Toxicity Values for Nonradionuclides

For nonradionuclides, the analyte-specific toxicity values shown in Table 4-4 are determined using the recommended reference hierarchy as described in Cook, 2003, "Human Health Toxicity Values in Superfund Risk Assessments." The hierarchy is summarized below.

- Tier 1 – The EPA Integrated Risk Information System (IRIS)
- Tier 2 – The EPA Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3 – Other Toxicity Values

Tier 1 – IRIS

The preferred source of toxicity data is the EPA IRIS database (http://www.epa.gov/iris/index.html). Expert toxicologists at the EPA have derived the values in this database and most values have undergone a thorough review and validation both within and outside the EPA. If a toxicity value is available in IRIS, that value is used in preference to any other value.

Tier 2 – PPRTVs

If a toxicity value is not available in IRIS, the next source is the EPA PPRTVs. This source includes toxicity values that have been developed by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC). This database is not available to the general public, but is accessible to EPA risk assessors via the EPA intranet. These values are also published at the EPA Regional Screening Levels website (EPA, 2015b).

Tier 3 – Other Toxicity Values

Tier 3 includes additional EPA and non-EPA sources of toxicity information, including:

- The California EPA (CalEPA)'s Toxicity Criteria Database contains toxicity values that are peer reviewed and address both cancer and non-cancer effects.
- The Agency for Toxic Substances and Disease Registry (ATSDR)'s Minimal Risk Levels (MRLs) for Hazard Substances are peer-reviewed estimates of the daily human exposure to hazardous substances that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure.
- Toxicity values in EPA/540-R-97-036, *Health Effects Assessment Summary Tables (HEAST)*.

When Tier 1, Tier 2, and Tier 3 toxicity values are not available for an analyte, the toxicity values from the National Center for Environmental Assessment (NCEA) are used. NCEA values can be found in RAIS (ORNL, 2016).

For this environmental calculation, two toxicity values required conversion to a different concentration basis: nitrate and nitrite.

- **Nitrate**. A derived RfD for nitrate (NO_3^-) was calculated from the RfD reported in IRIS, which is given as 1.6 mg/kg-day for *nitrate as nitrogen* (NO_3^- as N). Conversion from *nitrate as nitrogen* to *nitrate* was made using the mass fraction of nitrogen in nitrate. The mass fraction of nitrogen in nitrate = mol wt N/mol wt NO_3^- = (14 g/mol)/(62 g/mol) = 0.226. The derived RfD for *nitrate* = (1.6 mg NO_3^- as N/kg-day) x (1 mg NO_3^-/0.226 mg NO_3^- as N) = 7.1 mg NO_3^-/kg-day.

- **Nitrite**. A derived RfD for nitrate (NO_2^-) was calculated from the RfD reported in IRIS, which is given as 0.1 mg/kg-day for *nitrite as nitrogen* (NO_2^- as N). Conversion from *nitrite as nitrogen* to *nitrite* was made using the mass fraction of nitrogen in nitrite. The mass fraction of nitrogen in nitrite = mol wt N/mol wt NO_2^- = (14 g/mol)/(46 g/mol) = 0.304. The derived RfD for *nitrite* = (0.1 mg NO_2^- as N/kg-day) × (1 mg NO_2^-/0.304 mg NO_2^- as N) = 0.3 mg NO_2^-/kg-day.

For the following nonradionuclide analytes, the toxicity value used was obtained from a different source than recommended by the EPA Superfund hierarchy (Cook 2003). The differences in toxicity values are summarized below.

- For hexavalent chromium, this assessment considers cancer effects only for inhalation exposures. An oral cancer slope factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral cancer slope factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$ as presented in NJDEP, 2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for Cr+6 Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*. Assessing only inhalation cancer effects from hexavalent chromium has the potential to under-estimate cancer risk.

4.3.2 Toxicity Values for Radionuclides

The cancer slope factors for radionuclides in Table 4-4 were obtained from thePRG Download Area "Resident Tapwater", dated November, 2014, available online from EPA, 2015a, "Preliminary Remediation Goals for Radionuclides (PRG)", http://epa-prgs.ornl.gov/radionuclides. For each radionuclide listed, slope factors correspond to the risks per unit intake or exposure for that radionuclide only, except when marked with a "+D" to indicate that the risks from associated short-lived radioactive daughter products (i.e., those daughter products with radioactive half-lives less than or equal to 6 months) are also included. The intention of this designation is to make realistic risk estimates by including the contributions from their short-lived daughter products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment."

4.3.3 Toxicity Values for Sweat Lodge Equations

EPA has published guidance to address chemical inhalation exposures in EPA-540-R-070-002. A methodology is provided to use the toxicity values that are currently provided in IRIS as concentrations (reference concentrations [RfC] for non-cancer effects and inhalation unit risk values [IUR] for cancer endpoints). These values now supersede the intake-based approach specified in EPA/540/1-89/002.

The method described in Harris and Harper, 2004 for inhalation of nonradionuclide analytes in sweat lodge vapor follows the former EPA/540/1-89/002 approach of quantifying intake. Therefore, in the sweat lodge exposure pathway calculations, the IUR and RfC values from the EPA toxicity tables (EPA, 2015b) were converted to CSF_i and RfD_i values, following the protocol given in EPA/540/1-89/002. The following equations were used, based on an assumed breathing rate of 20 m^3/day and an assumed body weight of 70 kg.

$$CSF_i\ (kg\text{-}day/mg) = IUR\ (m^3/\mu g) \times 1/20\ (m^3/day) \times 70\ (kg) \times 1000\ (\mu g/mg) \quad (49)$$

$$RfD_i\ (mg/kg\text{-}day) = RfC\ (mg/m^3) \times 20\ (m^3/day) \times 1/70\ (kg) \quad (50)$$

The CSF_i and RfD_i values are used to calculate inhalation cancer risks and inhalation non-cancer hazards, respectively. For inhalation of radionuclides in sweat lodge vapor, no toxicity factor conversions are necessary. Sweat lodge radiological risk is calculated by quantifying inhalation intake (pCi) and then multiplying by the EPA inhalation slope factor (risk/pCi).

Table 4-4. Toxicity Criteria for 100-BC-5 Groundwater Analytes

Analyte Name[a]	Oral Reference Dose (RfD_o)[b] (mg/kg-day)	Key	Oral Cancer Slope Factor (CSF_o)[b] $(mg/kg\text{-}day)^{-1}$ or Oral Slope Factor (SF_o)[c] (Risk/pCi)	Key	Inhalation Reference Concentration (RfC)[b] (mg/m^3)	Key	Inhalation Unit Risk (IUR)[b] $(\mu g/m^3)^{-1}$	Key	Inhalation Cancer Slope Factor (SF_i)[c] (Risk/pCi)	Key	Volatile Nonradionuclides[b] Radionuclides[c]	GIABS Nonradionuclides[b] (unitless)	K_p[d] (cm/hr)	B[d] (unitless)	τ[d] (hours/event)	t*[d] (hours)	FA[d] (unitless)
Acetone	9.00E-01	I	--	--	3.10E+01	A	--	--	--	--	V	1.00E+00	5.12E-04[e]	--	--	--	--
Aluminum	1.00E+00	P	--	--	5.00E-03	P	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Americium-241	--	--	1.04E-10	--	--	--	--	--	3.8E-08	--	--			--	--	--	--
Antimony	4.00E-04	I	--	--	--	--	--	--	--	--	--	1.50E-01	1.00E-03	--	--	--	--
Arsenic	3.00E-04	I	1.50E+00	I	1.50E-05	C	4.30E-03	I	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Barium	2.00E-01	I	--	--	5.00E-04	H	--	--	--	--	--	7.00E-02	1.00E-03	--	--	--	--
Beryllium	2.00E-03	I	--	--	2.00E-05	I	2.40E-03	I	--	--	--	7.00E-03	1.00E-03	--	--	--	--
Boron	2.00E-01	I	--	--	2.00E-02	H	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Bromomethane	1.40E-03	I	--	--	5.00E-03	I	--	--	--	--	V	1.00E+00	2.80E-03	0	0.36	0.87	1
Cadmium	5.00E-04	I	--	--	1.00E-05	A	1.80E-03	I	--	--	--	5.00E-02	1.00E-03	--	--	--	--
Cesium-137+D	--	--	3.05E-11	--	--	--	--	--	1.1E-10	--	--	--	--	--	--	--	--
Chloroform	1.00E-02	I	3.10E-02	C	9.80E-02	A	2.30E-05	I	--	--	V	1.00E+00	6.80E-03	0	0.5	1.19	1
Chloromethane	--	--	--	--	9.00E-02	I	--	--	--	--	V	1.00E+00	3.30E-03	0	0.2	0.49	1
Chromium	1.50E+00	I	--	--	--	--	--	--	--	--	--	1.30E-02	1.00E-03	--	--	--	--
Cobalt	3.00E-04	P	--	--	6.00E-06	P	9.00E-03	P	--	--	--	1.00E+00	4.00E-04	--	--	--	--
Copper	4.00E-02	H	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Fluoride	6.00E-02	I	--	--	1.30E-02	C	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Hexavalent Chromium	3.00E-03	I	--	--	1.00E-04	I′	8.40E-02	S	--	--	--	2.50E-02	2.00E-03	--	--	--	--
Iron	7.00E-01	P	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Lithium	2.00E-03	P	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Manganese	2.40E-02	S	--	--	5.00E-05	I	--	--	--	--	--	4.00E-02	1.00E-03	--	--	--	--
Methylene chloride	6.00E-03	I	2.00E-03	I	6.00E-01	I	1.00E-08	I	--	--	V	1.00E+00	3.50E-03	0	0.32	0.76	1

Table 4-4. Toxicity Criteria for 100-BC-5 Groundwater Analytes

Analyte Name[a]	Oral Reference Dose (RfD_o)[b] (mg/kg-day)	Key	Oral Cancer Slope Factor (CSF_o)[b] $(mg/kg\text{-}day)^{-1}$ or Oral Slope Factor (SF_o)[c] (Risk/pCi)	Key	Inhalation Reference Concentration (RfC)[b] (mg/m^3)	Key	Inhalation Unit Risk (IUR)[b] $(\mu g/m^3)^{-1}$	Key	Inhalation Cancer Slope Factor (SF_i)[c] (Risk/pCi)	Key	Volatile Nonradionuclides[b] Radionuclides[c]	GIABS Nonradionuclides[b] (unitless)	K_p[d] (cm/hr)	B[d] (unitless)	τ[d] (hours/event)	t*[d] (hours)	FA[d] (unitless)
Molybdenum	5.00E-03	I	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Nickel	2.00E-02	I	--	--	9.00E-05	A	2.60E-04	C	--	--	--	4.00E-02	2.00E-04	--	--	--	--
Nitrate	7.1E+00	I	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Nitrite	3.00E-01	I	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Selenium	5.00E-03	I	--	--	2.00E-02	C	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Silver	5.00E-03	I	--	--	--	--	--	--	--	--	--	4.00E-02	6.00E-04	--	--	--	--
Strontium	6.00E-01	I	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Strontium-90+D	--	--	7.40E-11	--	--	--	--	--	4.3E-10	--	--	--	--	--	--	--	--
Technetium-99	--	--	2.75E-12	--	--	--	--	--	3.8E-11	--	--	--	--	--	--	--	--
Tin	6.00E-01	H	--	--	--	--	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Trichloroethene	5.00E-04	I	4.60E-02	I	2.00E-03	I	4.10E-06	I	--	--	V	1.00E+00	1.20E-02	0.1	0.58	1.39	1
Tritium	--	--	5.07E-14	--	--	--	--	--	8.5E-13	--	V	--	--	--	--	--	--
Uranium	3.00E-03	I	--	--	4.00E-05	A	--	--	--	--	--	1.00E+00	1.00E-03	--	--	--	--
Vanadium	5.00E-03	S	--	--	1.00E-04	A	--	--	--	--	--	2.60E-02	1.00E-03	--	--	--	--
Zinc	3.00E-01	I	--	--	--	--	--	--	--	--	--	1.00E+00	6.00E-04	--	--	--	--

Notes:

a. Source = ECF-100BC5-11-0016.

b. Source = EPA, 2015b.

c. Source = EPA, 2015a.

d. Source = EPA/540/R/99/005, Exhibits 3-1 (inorganic analytes) and B-3 (organic analytes).

e. Source = ORNL, 2016.

-- = indicates toxicity value not available for this contaminant and exposure route.

+D = Indicates radionuclide whose slope factors include contributions from ingrowth of short-lived radioactive decay products.

A = ATSDR

B = partitioning constant.

C = Cal EPA

FA = fraction absorbed.

Table 4-4. Toxicity Criteria for 100-BC-5 Groundwater Analytes

Analyte Name[a]	Oral Reference Dose (RfD_o)[b] (mg/kg-day)	Key	Oral Cancer Slope Factor (CSF_o)[b] $(mg/kg\text{-}day)^{-1}$ or Oral Slope Factor (SF_o)[c] (Risk/pCi)	Key	Inhalation Reference Concentration (RfC)[b] (mg/m^3)	Key	Inhalation Unit Risk (IUR)[b] $(\mu g/m^3)^{-1}$	Key	Inhalation Cancer Slope Factor (SF_i)[c] (Risk/pCi)	Key	Volatile Nonradionuclides[b] Radionuclides[c]	GIABS Nonradionuclides[b] (unitless)	K_p[d] (cm/hr)	B[d] (unitless)	τ[d] (hours/event)	t*[d] (hours)	FA[d] (unitless)

GIABS = gastrointestinal absorption factor.

H = HEAST

I = IRIS

K_p = dermal permeability constant.

P = PPRTV

S = Vanadium uses the toxicity values for "Vanadium and Compounds"

t* = time to reach steady-state.

τ = lag time

V = volatile

ECF-100BC5-11-0016 *Calculation of Exposure Point Concentrations for the 100-BC-5 Groundwater Operable Unit.*

EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final.*

EPA, 2015a, "Resident Tapwater Table", dated November, 2014, available online at "Preliminary Remediation Goals for Radionuclides (PRG)", http://epa-prgs.ornl.gov/radionuclides.

EPA, 2015b, "Summary Table", dated November, 2015, available online at "Regional Screening Levels for Chemical Contaminants at Superfund Sites.", http://www.epa.gov/risk/regional-screening-table.

ORNL, 2016, "Chemical Parameters", available online at "The Risk Assessment Information System (RAIS)", http://rais.ornl.gov/.

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5 Software Applications

All calculations for this Environmental Calculation were performed on electronic spreadsheets using Microsoft Excel®. The organization of the workbooks containing the spreadsheets is presented in Section 6.

6 Calculation

Potential human health risks to members of the CTUIR and the Yakama Nation are calculated using the methodology, analytes, EPCs, and toxicity factors documented in Sections 3 and 4 of this environmental calculation. The calculation spreadsheets were validated by comparison with the hand calculations presented in Figure 6-1.

6.1 Drinking Water Exposure Worksheets

The drinking water exposure calculations for the CTUIR exposure scenario are provided in an Excel workbook, organized by worksheet as listed in Table 6-1. The drinking water exposure calculations for the Yakama Nation exposure scenario are provided in an Excel workbook, organized by worksheet as listed in Table 6-2. The Excel workbook files have been archived under this ECF number in the Environmental Risk Management Archive (ERMA).

Table 6-1. Excel Worksheets for the CTUIR Drinking Water Exposure Calculations

A-1: Results Summary – CTUIR
A-2: Ingestion of Nonradiological Analytes in Drinking Water – CTUIR
A-3: Dermal Absorption of Nonradiological Analytes in Drinking Water – CTUIR
A-4: Inhalation of Volatile Nonradiological Analytes in Drinking Water – CTUIR
A-5: Ingestion of Radiological Analytes in Drinking Water – CTUIR
A-6: Inhalation of Volatile Radiological Analytes in Drinking Water – CTUIR

Table 6-2. Excel Worksheets for the Yakama Nation Drinking Water Exposure Calculations

B-1: Results Summary – Yakama Nation
B-2: Ingestion of Nonradiological Analytes in Drinking Water – Yakama Nation
B-3: Dermal Absorption of Nonradiological Analytes in Drinking Water – Yakama Nation
B-4: Inhalation of Volatile Nonradiological Analytes in Drinking Water – Yakama Nation
B-5: Ingestion of Radiological Analytes in Drinking Water – Yakama Nation
B-6: Inhalation of Volatile Radiological Analytes in Drinking Water – Yakama Nation

® Microsoft Excel is a registered product of the Microsoft Corporation.

6.2 Sweat Lodge Exposure Worksheets

The sweat lodge exposure calculations for the CTUIR exposure scenario are provided in an Excel workbook, organized by worksheet as listed in Table 6-3. The sweat lodge exposure calculations for the Yakama Nation exposure scenario are provided in an Excel workbook, organized by worksheet as listed in Table 6-4. The Excel workbook files have been archived under this ECF number in the ERMA.

Table 6-3. Excel Worksheets for the CTUIR Sweat Lodge Exposure Calculations

C-1: Results Summary – CTUIR
C-2: Inhalation of Volatile and Semi-Volatile Nonradiological Analytes in Sweat Lodge Vapor – CTUIR
C-3: Inhalation of Nonvolatile Nonradiological Analytes in Sweat Lodge Vapor – CTUIR
C-4: Dermal Exposure to Volatile and Semi-Volatile Nonradiological Analytes in Sweat Lodge Vapor – CTUIR
C-5: Dermal Exposure to Nonvolatile Nonradiological Analytes in Sweat Lodge Condensed Water – CTUIR
C-6: Dermal Exposure to Nonvolatile Nonradiological Analytes in Sweat Lodge Vapor – CTUIR
C-7: Inhalation of Volatile Radiological Analytes in Sweat Lodge Vapor – CTUIR
C-8: Inhalation of Nonvolatile Radiological Analytes in Sweat Lodge Vapor – CTUIR

Table 6-4. Excel Worksheets for the Yakama Nation Sweat Lodge Exposure Calculations

D-1: Results Summary (with Aerosolized NonVolatile Analytes)
D-2: Results Summary (without Aerosolized NonVolatile Analytes)
D-3: Inhalation of Volatile and Semi-Volatile Nonradiological Analytes in Sweat Lodge Vapor – Yakama Nation
D-4: Inhalation of Nonvolatile Nonradiological Analytes in Sweat Lodge Vapor – Yakama Nation
D-5: Dermal Exposure to Volatile and Semi-Volatile Nonradiological Analytes in Sweat Lodge Vapor – Yakama Nation
D-6: Dermal Exposure to Nonvolatile Nonradiological Analytes in Sweat Lodge Condensed Water – Yakama Nation
D-7: Dermal Exposure to Nonvolatile Nonradiological Analytes in Sweat Lodge Vapor – Yakama Nation
D-8: Inhalation of Volatile Radiological Analytes in Sweat Lodge Vapor – Yakama Nation
D-9: Inhalation of Nonvolatile Radiological Analytes in Sweat Lodge Vapor – Yakama Nation

6.3 Hand Calculations

The electronic spreadsheet calculations are validated by comparison with hand calculations. The hand calculations are presented in Figure 6-1. The hand calculations were performed to validate the formulas used in the spreadsheets.

7 Results/Conclusions

Results of the CTUIR and Yakama Nation human health risk calculations are summarized and discussed in the sections below for the 100-BC-5 Groundwater OU.

7.1 Summary of the CTUIR Risk Assessment

This section summarizes the CTUIR risk assessment results for use of 100-BC-5 groundwater as a drinking water source and to make steam in a sweat lodge.

7.1.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to 100-BC-5 groundwater as a drinking water source is evaluated based on the CTUIR exposure scenario. Potential routes of exposure to groundwater include ingestion, dermal contact (nonradionuclides only), and inhalation of volatiles. Table 7-1 provides a summary of the risk estimates by exposure route.

Table 7-1. CTUIR Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Nonradionuclide Analytes				
Ingestion	2.3 × 10-4	Arsenic (ELCR = 2.2 × 10-4, 9.8%) Chloroform (ELCR = 1.3 × 10-5, 0.59%) Trichloroethene (ELCR = 6.6 × 10-6, 0.29%)	2.8	Antimony (HQ = 0.50, 15%) Arsenic (HQ = 0.57, 17%) Bromomethane (HQ = 0.041, 1.2%) Fluoride (HQ = 0.21, 6.3%) Hexavalent Chromium (HQ = 0.75, 22%) Lithium (HQ = 0.20, 6.0%) Molybdenum (HQ = 0.056, 1.6%) Nitrate (HQ = 0.10, 3.1%) Trichloroethene (HQ = 0.52, 15%) Uranium (HQ = 0.044, 1.3 %) Vanadium (HQ = 0.17, 4.9%)
Dermal	1.3 × 10-6		0.23	
Inhalation	1.4 × 10-5		0.36	
Total	2.4 × 10-4		3.4	
Radionuclide Analytes				
Ingestion	1.4 × 10-4	Tritium (ELCR = 1.9 × 10-3, 85%)	--	--
Inhalation	1.9 × 10-3		--	
Total	2.0 × 10-3		--	
Total Cumulative ELCRa	2.3 × 10-3		--	

Notes:

a. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation.

ELCR = excess lifetime cancer risk.

HI = hazard index.

-- = Indicates HI not applicable.

The total cumulative ELCR for the 100-BC-5 Groundwater OU is 2.3×10^{-3}. The total ELCR for nonradiological analytes is 2.4×10^{-4}, which is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.0×10^{-3}, which is greater than the EPA upper target risk threshold of 1×10^{-4}.

Major contributors to total cumulative ELCR are chloroform (ELCR = 1.3×10^{-5}, 0.59% percent contribution), trichloroethene (ELCR = 6.6×10^{-6}, 0.29% percent contribution), and tritium (ELCR = 1.9×10^{-3}, 85% percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 2.2×10^{-4}, 9.8% percent contribution) where the EPC (2.6 µg/L) is within the range of natural background values. The ELCR without contribution from arsenic is 2.0×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI is 3.4, which is greater than the 2007 MTCA ("Unrestricted Land Use Groundwater Cleanup Standards" [WAC 173-340-720]) target HI of 1.0. The primary contributors to the noncancer HI are antimony (HQ = 0.50; 15 percent contribution), arsenic (HQ = 0.57; 17 percent contribution), bromomethane (HQ = 0.041; 1.2 percent contribution), fluoride (HQ = 0.21; 6.3 percent contribution), hexavalent chromium (HQ = 0.75; 22 percent contribution), lithium (HQ = 0.20; 6.0 percent contribution), molybdenum (HQ = 0.056; 1.6 percent contribution), nitrate (HQ = 0.10; 3.1 percent contribution), trichloroethene (HQ = 0.52; 15 percent contribution), uranium (HQ = 0.044; 1.3 percent contribution), and vanadium (HQ = 0.17; 4.9 percent contribution). The HI without contribution from arsenic is 2.8.

7.1.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to 100-BC-5 groundwater as a source of steam in a sweat lodge is evaluated under the CTUIR scenario. Potential routes of exposure to steam generated from groundwater while spending time in a sweat lodge include inhalation of vaporized volatiles and semi-volatiles and aerosolized nonvolatiles; and dermal contact with vaporized volatiles and semi-volatiles, and aerosolized nonvolatiles and condensed liquid. Table 7-2 provides a summary of the risk estimates by exposure route.

Table 7-2. CTUIR Exposure Scenario—Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Nonradionuclide Analytes				
Inhalation in Sweat Lodge				
Volatile and Semi-Volatiles (vapor)	1.4×10^{-6}	Arsenic (ELCR = 9.2×10^{-5}, 0.49%) Beryllium (ELCR = 2.6×10^{-6}, 0.01 %) Cadmium (ELCR = 1.7×10^{-6}, 0.01%)	0.036	Arsenic (HQ = 1.5, 20%) Barium (HQ = 0.53, 7.2%) Cadmium (HQ = 0.10, 1.4%) Cobalt (HQ = 0.21, 2.8 %) Fluoride (HQ = 0.13, 1.7 %) Hexavalent Chromium (HQ = 2.5, 33%) Manganese (HQ = 0.81, 11%) Nickel (HQ = 0.16, 2.2 %)
Nonvolatile (aerosol)	1.8×10^{-2}		7.1	
Total	1.8×10^{-2}		7.2	
Dermal Exposure in Sweat Lodge				
Volatile and Semi-Volatiles (vapor only)	2.3×10^{-10}		<0.01	

Table 7-2. CTUIR Exposure Scenario—Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Nonvolatile (vapor and aqueous condensate)	9.6 × 10-7	Chloroform (ELCR = 1.1×10^{-6}, 0.01%) Cobalt (ELCR = 1.1×10^{-5}, 0.06%) Hexavalent Chromium (ELCR = 1.8×10^{-2}, 98%) Nickel (ELCR = 3.6×10^{-6}, 0.02%)	0.23	Uranium (HQ = 0.42, 5.7%) Vanadium (HQ = 0.97, 13%)
Total	9.6 × 10-7		0.23	
Total Nonradionuclide	1.8 × 10-2		7.4	
Radionuclide Analytes				
Inhalation in Sweat Lodge				
Volatile and Semi-Volatiles (vapor)	1.5×10^{-4}	Tritium (ELCR = 1.5×10^{-4}, 0.81%)	--	--
Nonvolatile (aerosol)	4.3×10^{-5}		--	
Total Radionuclide	1.9×10^{-4}		--	
Total Cumulative ELCR[a]	1.9×10^{-2}		--	

Notes:

a. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

-- = Indicates HI not applicable.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation.

HI = hazard index.

ELCR = excess lifetime cancer risk.

The total cumulative ELCR for the 100-BC-5 Groundwater OU is 1.9×10^{-2}. The total ELCR for nonradiological analytes is 1.8×10^{-2}, which is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.9×10^{-4} for radiological analytes, which is greater than the EPA upper target risk threshold of 1×10^{-4}.

The major contributors to total cumulative ELCR are beryllium (2.6×10^{-6}; 0.01 percent contribution), cadmium (1.7×10^{-6}; 0.01 percent contribution), chloroform (1.1×10^{-6}; 0.01 percent contribution), cobalt (1.1×10^{-5}; 0.06 percent contribution), hexavalent chromium (1.8×10^{-2}; 98 percent contribution), and nickel (3.6×10^{-6}; 0.02 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.2×10^{-5}, 0.49% percent contribution) where the EPC (2.6 µg/L) is within the range of natural

background values. The ELCR for nonradiological analytes without contribution from arsenic is 1.8×10^{-2}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI is 7.4, which is greater than the 2007 MTCA ("Unrestricted Land Use Groundwater Cleanup Standards" [WAC 173-340-720]) target HI of 1.0. The primary contributors to the noncancer HI are arsenic (HQ = 1.5; 20 percent contribution), barium (HQ = 0.53; 7.2 percent contribution), cadmium (HQ = 0.10; 1.4 percent contribution), cobalt (HQ = 0.21; 2.8 percent contribution), fluoride (HQ = 0.13; 1.7 percent contribution), hexavalent chromium (HQ = 2.5; 33 percent contribution), manganese (HQ = 0.81; 11 percent contribution), nickel (HQ = 0.16; 2.2 percent contribution), uranium (HQ = 0.42; 5.7 percent contribution), and vanadium (HQ = 0.97; 13 percent contribution). The HI without contribution from arsenic is 5.9, which is greater than the target HI of 1.

7.2 Summary of the Yakama Nation Risk Assessment

This section summarizes the Yakama Nation risk assessment results for use of 100-BC-5 groundwater as a drinking water source and to make steam in a sweat lodge.

7.2.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to 100-BC-5 groundwater as a drinking water source is evaluated based on the Yakama Nation exposure scenario. Potential routes of exposure to groundwater include ingestion, dermal contact (nonradionuclides only), and inhalation of volatiles. Table 7-3 provides a summary of the risk estimates by exposure route.

Table 7-3. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Nonradionuclide Analytes				
Ingestion	2.5×10^{-4}	Arsenic (ELCR = 2.4×10^{-4}, 10%) Chloroform (ELCR = 1.4×10^{-5}, 0.57%) Trichloroethene (ELCR = 6.8×10^{-6}, 0.29%)	5.3	Antimony (HQ = 0.92, 16%) Arsenic (HQ = 1.1, 18%) Cobalt (HQ = 0.061, 1.0%) Fluoride (HQ = 0.40, 6.9%) Hexavalent Chromium (HQ = 1.3, 22%) Lithium (HQ = 0.38, 6.6%) Molybdenum (HQ = 0.10, 1.8%) Nitrate (HQ = 0.20, 3.4%) Trichloroethene (HQ = 0.67, 12%) Uranium (HQ = 0.082, 1.4%) Vanadium (HQ = 0.30, 5.1%)
Dermal	1.3×10^{-6}		0.21	
Inhalation	1.4×10^{-5}		0.36	
Total	2.6×10^{-4}		5.9	
Radionuclide Analytes				
Ingestion	1.4×10^{-4}	Tritium (ELCR = 2.0×10^{-3}, 84%)	--	--
Inhalation	2.0×10^{-3}		--	
Total	2.1×10^{-3}		--	

Table 7-3. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Total Cumulative ELCR[a]	2.4×10^{-3}		--	

Notes:

a. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

ELCR = excess lifetime cancer risk.

HI = hazard index.

-- = Indicates HI not applicable.

The total cumulative ELCR for the 100-BC-5 Groundwater OU is 2.4×10^{-3}. The total ELCR for nonradiological analytes is 2.6×10^{-4}, which is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.1×10^{-3}, which is greater than the EPA upper target risk threshold of 1×10^{-4}.

Major contributors to the total cumulative ELCR are chloroform (ELCR = 1.4×10^{-5}, 0.57 percent contribution), trichloroethene (ELCR = 6.8×10^{-6}, 0.29 percent contribution), and tritium (ELCR = 2.0×10^{-3}, 84 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 2.4×10^{-4}, 10 percent contribution), where the EPC (2.6 µg/L) is within the range natural background values. The ELCR without contribution from arsenic is 2.1×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI is 5.9, which is greater than the 2007 MTCA ("Unrestricted Land Use Groundwater Cleanup Standards" [WAC 173-340-720]) target HI of 1.0. The primary contributor to the noncancer HI are antimony (HQ = 0.92; 16 percent contribution), arsenic (HQ = 1.1; 18 percent contribution), cobalt (HQ = 0.061; 1.0 percent contribution), fluoride (HQ = 0.40; 6.9 percent contribution), hexavalent chromium (HQ = 1.3; 22 percent contribution), lithium (HQ = 0.38; 6.6 percent contribution), molybdenum (HQ = 0.10; 1.8 percent contribution), nitrate (HQ = 0.20; 3.4 percent contribution), trichloroethene (HQ = 0.67; 12 percent contribution), uranium (HQ = 0.082; 1.4 percent contribution), and vanadium (HQ = 0.30; 5.1 percent contribution). The HI for the 100-BC-5 Groundwater OU without contribution from arsenic is 4.8, which is greater than the target HI of 1.

7.2.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to 100-BC-5 groundwater as a source of steam in a sweat lodge is evaluated under the Yakama Nation scenario. Potential routes of exposure to steam generated from groundwater while spending time in a sweat lodge include inhalation of vaporized volatiles and semi-volatiles and aerosolized nonvolatiles; and dermal contact with vaporized volatiles and semi-volatiles, and (with and without) aerosolized nonvolatiles, and condensed liquid. Table 7-4 provides a summary of the risk estimates by exposure route.

Table 7-4. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Nonradionuclide Analytes (with Aerosolized Nonvolatile Analytes)				
Inhalation in Sweat Lodge				
Volatile and Semi-Volatiles (vapor)	1.0×10^{-5}	Arsenic ($ELCR = 6.9 \times 10^{-4}$, 0.52%) Beryllium ($ELCR = 2.0 \times 10^{-5}$, 0.01%) Cadmium ($ELCR = 1.3 \times 10^{-5}$, 0.01%) Chloroform ($ELCR = 8.4 \times 10^{-6}$, 0.01%) Cobalt ($ELCR = 8.1 \times 10^{-5}$, 0.06%) Hexavalent Chromium ($ELCR = 1.3 \times 10^{-1}$, 98%) Nickel ($ELCR = 2.7 \times 10^{-5}$, 0.02%) Trichloroethene ($ELCR = 1.9 \times 10^{-6}$, <0.01%)	0.26	Arsenic (HQ = 11, 20%) Barium (HQ = 3.9, 7.2%) Cadmium (HQ = 0.73, 1.4%) Cobalt (HQ = 1.5, 2.8%) Fluoride (HQ = 0.92, 1.7%) Hexavalent Chromium (HQ = 18, 33%) Manganese (HQ = 5.9, 11%) Nickel (HQ = 1.2, 2.2%) Uranium (HQ = 3.1, 5.7%) Vanadium (HQ = 7.1, 13%)
Nonvolatile (aerosol)	1.3×10^{-1}		52	
Total	1.3×10^{-1}		52	
Dermal Exposure in Sweat Lodge				
Volatile and Semi-Volatiles (vapor only)	1.6×10^{-9}		<0.01	
Nonvolatile (vapor and aqueous condensate)	6.9×10^{-6}		1.6	
Total	6.9×10^{-6}		1.6	
Total Nonradionuclide	1.3×10^{-1}		54	
Radionuclide Analytes (with Aerosolized Nonvolatile Analytes)				
Inhalation in Sweat Lodge				
Volatile and Semi-Volatiles (vapor)	1.1×10^{-3}	Americium-241 ($ELCR = 1.1 \times 10^{-4}$, 0.08%) Strontium-90 ($ELCR = 1.8 \times 10^{-4}$, 0.14%) Tritium ($ELCR = 1.1 \times 10^{-3}$, 0.86%)	--	--
Nonvolatile (aerosol)	3.2×10^{-4}		--	
Total Radionuclide	1.5×10^{-3}		--	
Total Cumulative ELCR[a]	1.3×10^{-1}		--	
Nonradionuclide Analytes (without Aerosolized Nonvolatile Analytes)				
Inhalation in Sweat Lodge				
Volatile and Semi-Volatiles (vapor)	1.0×10^{-5}	Arsenic ($ELCR = 6.9 \times 10^{-6}$, 0.60%) Chloroform ($ELCR = 8.4 \times 10^{-6}$, 0.72%)	0.26	Antimony (HQ = 0.087, 4.7%) Bromomethane (HQ = 0.020, 1.1%) Hexavalent Chromium (HQ = 1.3, 69%)
Nonvolatile (aerosol)	--[b]		--[b]	

Table 7-4. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge

Exposure Route	ELCR	Primary Contributors to Total Cumulative ELCRa	HI	Primary Contributors to Total HI (>1%)
Total	1.0 × 10-5	Trichloroethene (ELCR = 1.9×10^{-6}, 0.17%)	0.26	Trichloroethane (HQ = 0.24, 13%) Vanadium (HQ = 0.15, 8.3%)
Dermal Exposure in Sweat Lodge				
Volatile and Semi-Volatiles (vapor only)	1.6 × 10-9		<0.01	
Nonvolatile (aqueous condensate)	6.9 × 10-6		1.6	
Total	6.9 × 10-6		1.6	
Total Nonradionuclide	1.7 × 10-5		1.9	
Radionuclide Analytes (without Aerosolized Nonvolatile Analytes)				
Inhalation in Sweat Lodge				
Volatile and Semi-Volatiles (vapor)	1.1×10^{-3}	Tritium (ELCR = 1.1×10^{-3}, 99%)	--	--
Nonvolatile (aerosol)	--[b]		--	
Total Radionuclide	1.1×10^{-3}		--	
Total Cumulative ELCR[a]	1.2×10^{-3}		--	

Notes:

a. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

b. The inhalation and dermal vapor contact exposure pathways are considered incomplete for nonvolatile contaminants.

-- = Indicates HI not applicable.

HI = hazard index.

ELCR = excess lifetime cancer risk.

The total cumulative ELCR *with* contributions from aerosolized nonvolatile analytes for the 100-BC-5 Groundwater OU is 1.3×10^{-1}. The total ELCR for nonradiological analytes *with* contributions from aerosolized nonvolatile analytes is 1.3×10^{-1}, which is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.5×10^{-3} for radiological analytes, which is greater than the EPA upper target risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR *with* contributions from aerosolized nonvolatile analytes are americium-241 (1.1×10^{-4}; 0.08 percent contribution), beryllium (2.0×10^{-5}; 0.01 percent contribution), cadmium (1.3×10^{-5}; 0.01 percent contribution), chloroform (8.4×10^{-6}; 0.01 percent contribution), cobalt (8.1×10^{-5}; 0.06 percent contribution), hexavalent chromium (1.3×10^{-1}; 98 percent contribution), nickel (2.7×10^{-5}; 0.02 percent contribution), strontium-90 (1.8×10^{-4}; 0.14 percent contribution), trichloroethene (1.9×10^{-6}; <0.01 percent contribution), and tritium (1.1×10^{-3}; 0.86 percent

contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.9×10^{-4}, 0.52% percent contribution) where the EPC (2.6 µg/L) is within the range of natural background values. The ELCR for without contribution from arsenic is 1.3×10^{-1}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI *with* contributions from aerosolized nonvolatile analytes is 54, which is greater than the 2007 MTCA ("Unrestricted Land Use Groundwater Cleanup Standards" [WAC 173-340-720]) target HI of 1.0. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of HI) are arsenic (HQ = 11; 20 percent contribution), barium (HQ = 3.9, 7.2 percent contribution), cadmium (HQ = 0.73; 1.4 percent contribution), cobalt (HQ = 1.5, 2.8 percent contribution), fluoride (HQ = 0.92; 1.7 percent contribution), hexavalent chromium (HQ = 18, 33 percent contribution), manganese (HQ =5.9, 11 percent contribution), nickel (HQ = 1.2, 2.2 percent contribution), uranium (HQ = 3.1, 5.7 percent contribution) and vanadium (HQ = 7.1, 13 percent contribution). Contribution to HI is elevated for arsenic (HQ = 11; 20 percent contribution), where measured concentrations (2.6 µg/L) are within natural background values. The HI without contribution from arsenic is 43, which is greater than the target HI of 1.

The total cumulative ELCR *without* contributions from aerosolized nonvolatile analytes for the 100-BC-5 Groundwater OU is 1.2×10^{-3}. The total ELCR for nonradiological analytes *without* contributions from aerosolized nonvolatile analytes is 1.7×10^{-5}, which is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes without contributions from aerosolized nonvolatile analytes is 1.1×10^{-3}, which is greater than the EPA upper target risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR *without* contributions from aerosolized nonvolatile analytes is chloroform (8.4×10^{-6}; 0.72 percent contribution), trichloroethene (1.9×10^{-6}; 0.17 percent contribution), and tritium (1.1×10^{-3}; 99 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.9×10^{-6}, 0.60% percent contribution) where the EPC (2.6 µg/L) is within the range of natural background values. The ELCR for nonradiological analytes without contribution from arsenic is 1.0×10^{-5}, which is equal to the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI *without* contributions from aerosolized nonvolatile analytes is 1.9, which is greater than the 2007 MTCA ("Unrestricted Land Use Groundwater Cleanup Standards" [WAC 173-340-720]) target HI of 1.0. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of HI) are antimony (HQ = 0.087, 4.7 percent contribution), bromomethane (HQ = 0.020, 1.1 percent contribution), hexavalent chromium (HQ = 1.3, 69 percent contribution), trichloroethene (HQ = 0.24, 13 percent contribution), and vanadium (HQ = 0.15, 8.3 percent contribution).

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Figure 6-1. Hand Calculations

(12 Sheets)

Drinking Water Ingestion Carcinogenic Effects

$$CDI = \frac{C_w \times IRW_{adj} \times EF}{AT_{can} \times CF1} \quad (5)$$

$$IRW_{adj} = \frac{ED_c \times IRW_c}{BW_c} + \frac{(ED_r - ED_c) \times IRW_a}{BW_a} \quad (6)$$

$$Risk = CDI \times CSF_o \quad (7)$$

Arsenic CTUIR

$$IRW_{adj} = \frac{6\,yr \times 1\,L/d}{15\,kg} + \frac{(70\,yr - 6\,yr) \times 4\,L/d}{70\,kg}$$

$$= 4.057\ L\text{-}yr/kg\text{-}d \ \checkmark$$

$$CDI = \frac{0.00256\ mg/L \times 4.057\ L\text{-}yr/kg\text{-}d \times 365\ d/yr}{70\,yr \times 365\ d/yr}$$

$$= 1.48 \times 10^{-4}\ mg/kg\text{-}d \ \checkmark$$

$$Risk = 1.48 \times 10^{-4}\ mg/kg\text{-}d \times 1.5\ (mg/kg\text{-}d)^{-1}$$

$$= 2.23 \times 10^{-4} \ \checkmark \text{ (rounding)}$$

Drinking Water Ingestion Noncarcinogenic Effects

$$CDI = \frac{C_w \times IRW_c \times EF \times ED_c}{BW_c \times AT_{nc} \times CF1} \quad (8)$$

$$HQ = CDI / RfD_o \quad (9)$$

Arsenic CTUIR

$$CDI = \frac{0.00256\ mg/L \times 1.0\ L/d \times 365\ d/yr \times 6\ yr}{15\ kg \times 6\ yr \times 365\ d/yr}$$

$$= 1.71 \times 10^{-4}\ mg/kg\text{-}d$$

$$HQ = 1.71 \times 10^{-4}\ mg/kg\text{-}d \,/\, 3.0 \times 10^{-4}\ mg/kg\text{-}d$$

$$= 5.69 \times 10^{-1} \ \checkmark \text{ (rounding)}$$

Drinking Water Ingestion Radionuclides

$$CDI = C_w \times IRW_RAD_{adj} \times EF \quad (10)$$

$$IRW_RAD_{adj} = (ED_c \times IRW_c) + ([ED_r - ED_c] \times IRW_a) \quad (11)$$

$$Risk = CDI \times SF_o \quad (12)$$

Strontium-90+D CTUIR

$$IRW_RAD_{adj} = (6\,yr \times 1\,L/d) + ([70-6] \times 4\,L/d)$$

$$= 262\ L\text{-}yr/d \checkmark$$

$$CDI = 13.424\,pCi/L \times 262\,L\text{-}yr/d \times 365\,d/yr$$

$$= 1.28 \times 10^{6}\,pCi \checkmark$$

$$Risk = 1.28 \times 10^{6}\,pCi \times 7.40 \times 10^{-11}\,risk/pCi$$

$$= 9.50 \times 10^{-5} \checkmark$$

Inhalation of VOCs in Drinking Water Carcinogenic Effects

$$CDI = \frac{C_w \times ED_c \times EF \times ET \times CF2 \times VF \times 1000\,\mu g/mg}{AT_{can} \times CF1} \quad (13)$$

$$Risk = CDI \times IUR \quad (14)$$

Chloroform CTUIR

$$CDI = \frac{0.001004\,mg/L \times 70\,yr \times 365\,d/yr \times 24\,hr/d \times 1/24\,d/hr \times 0.5\,L/m^3 \times 1000\,\mu g/mg}{70\,yr \times 365\,d/yr}$$

$$= 5.02 \times 10^{-1}\,\mu g/m^3 \checkmark$$

$$Risk = 5.02 \times 10^{-1}\,\mu g/m^3 \times 2.30 \times 10^{-5}\,(\mu g/m^3)^{-1}$$

$$= 1.15 \times 10^{-5} \checkmark$$

Inhalation of VOCs in Drinking Water Noncarcinogenic Effects

$$CDI = \frac{C_w \times ED_c \times EF \times ET \times CF2 \times VF}{AT_{nc} \times CF1} \quad (15)$$

$$HQ = CDI/RfC \quad (16)$$

Inhalation of VOCs in Drinking Water Noncarcinogenic Effects (continued)

Choloroform CTUIR

$$CDI = \frac{0.001004\ mg/L \times 6yr \times 365\ d/yr \times 24\ hr/d \times 1/24\ d/hr \times 0.5\ L/m^3}{6yr \times 365\ d/yr}$$

$$= 5.02 \times 10^{-4}\ mg/m^3 \quad \checkmark$$

$$HQ = 5.02 \times 10^{-4}\ mg/m^3 / 0.098\ mg/m^3$$

$$= 5.12 \times 10^{-3} \quad \checkmark$$

Inhalation of Volatile Radionuclides in Drinking Water

$$CDI = C_w \times INH_RAD_{adj} \times VF \times EF \times ET \times CF2 \quad (17)$$

$$INH_RAD_{adj} = (ED_c \times INH_c) + ([ED_r - ED_c] \times INH_a) \quad (18)$$

$$Risk = CDI \times SF \quad (19)$$

Tritium CTUIR

$$INH_RAD_{adj} = (6yr \times 15\ m^3/d) + ([70yr - 6yr] \times 25\ m^3/d)$$

$$= 1690\ m^3\text{-}yr/d$$

$$CDI = 7{,}230\ pCi/L \times 1690\ m^3\text{-}yr/L \times 0.5\ L/m^3 \times 365\ d/yr \times 24\ hr/d \times 1/24\ d/hr$$

$$= 2.23 \times 10^9\ pCi$$

$$Risk = 2.23 \times 10^9\ pCi \times 8.50 \times 10^{-13}\ risk/pCi$$

$$= 1.90 \times 10^{-3} \quad \checkmark$$

Dermal Absorption of Organics ($ET \le t^*$) in Drinking Water Carcinogenic Effects

$$CDI = \frac{DA_{event} \times SA_{adj} \times EF}{AT_{can} \times CF1} \quad (20)$$

$$SA_{adj} = \frac{ED_c \times SA_c \times EV}{BW_c} + \frac{(ED_r - ED_c) \times SA_a \times EV}{BW_a} \quad (21)$$

$$Risk = CDI \times CSF_o / GIABS \quad (22)$$

$$DA_{event}(ET \le t^*) = 2 \times FA \times k_p \times C_w \times CF3 \times \sqrt{(6 \times \tau \times ET_{adj})/\pi} \quad (26)$$

$$ET_{adj} = \frac{(ET_c \times ED_c) + ([ED_r - ED_c] \times ET_a)}{ED_a} \quad (25)$$

Dermal Absorption of Organics ($ET \leq t^*$) in Water Carcinogenic Effects (continued)

Chloroform ($t^* = 1.19$ hr) CTUIR

$$ET_{adj} = \frac{(0.54\ hr/event \times 6\ yr) + ([70\ yr - 6\ yr] \times 0.71\ hr/event)}{70\ yr}$$

$$= 0.6954\ hr/event \checkmark$$

$ET_{adj} \leq t^*$ ($0.6954 < 1.19$) ∴

$$DA_{event} = 2 \times 1 \times 0.0068\ cm/hr \times 0.001004\ mg/L \times 0.001\ L/cm^3 \times \sqrt{\frac{(6 \times 0.5\ hr/event \times 0.6954\ hr/event)}{3.14}}$$

$$= 1.365 \times 10^{-8}\ mg/cm^2\text{-}hr \times 0.815\ hr/event$$

$$= 1.112 \times 10^{-8}\ mg/cm^2\text{-}event \checkmark$$

$$SA_{adj} = \frac{6\ yr \times 6365\ cm^2 \times 1\ event/d}{15\ kg} + \frac{(70\ yr - 6\ yr) \times 19652\ cm^2 \times 1\ event/d}{70\ kg}$$

$$= 2546\ cm^2\text{-}yr\text{-}event/kg\text{-}d + 17967\ cm^2\text{-}yr\text{-}event/kg\text{-}d$$

$$= 20{,}514\ cm^2\text{-}yr\text{-}event/kg\text{-}d \checkmark$$

$$CDI = \frac{1.112 \times 10^{-8}\ mg/cm^2\text{-}event \times 20{,}514\ cm^2\text{-}yr\text{-}event/kg\text{-}d \times 365\ d/yr}{70\ yr \times 365\ d/yr}$$

$$= 3.26 \times 10^{-6}\ mg/kg\text{-}d \checkmark$$

$$Risk = 3.26 \times 10^{-6}\ mg/kg\text{-}d \times (0.031\ (mg/kg\text{-}d)^{-1}/1.0)$$

$$= 1.01 \times 10^{-7} \checkmark$$

Dermal Absorption of Organics ($ET \leq t^*$) in Drinking Water Noncarcinogenic Effects

$$CDI = \frac{DA_{event} \times SA_c \times EF \times ED_c \times EV}{BW_c \times AT_{nc} \times CF1} \quad (23)$$

$$HQ = CDI / (RfD_o \times GIABS) \quad (24)$$

$$DA_{event}\ (ET \leq t^*) = 2 \times FA \times K_p \times C_w \times CF3 \times \sqrt{(6 \times \tau \times ET_c)/\pi} \quad (26)$$

Chloroform ($t^* = 1.19$ hr) CTUIR

$$DA_{event} = 2 \times 1 \times 0.0068\ cm/hr \times 0.001004\ mg/L \times 0.001\ L/cm^3 \times \sqrt{\frac{(6 \times 0.5\ hr/event \times 0.54\ hr/event)}{3.14}}$$

$$= 1.365 \times 10^{-8}\ mg/cm^2\text{-}hr \times 7.181 \times 10^{-1}\ hr/event$$

$$= 9.805 \times 10^{-9}\ mg/cm^2\text{-}event \checkmark$$

Dermal Absorption of Organics ($ET \le t^*$) in Water Noncarcinogenic Effects (continued)

$$CDI = \frac{9.805\times10^{-9}\ mg/cm^2\text{-event} \times 6365 \times 365\ d/yr \times 6\ yr \times 1\ event/d}{15\ kg \times 6\ yr \times 365\ d/yr}$$

$$= 4.16\times10^{-6}\ mg/kg\text{-}d$$

$$HQ = 4.16\times10^{-6}\ mg/kg\text{-}d \ /\ (0.01\ mg/kg\text{-}d \times 1.0)$$

$$= 4.16\times10^{-4}\ \checkmark$$

Dermal Absorption of Organics ($ET > t^*$) in Drinking Water Carcinogenic Effects

$$DA_{event} = FA \times kp \times C_w \times CF3 \times \left[\frac{ET_{adj}}{1+B} + 2\times\tau\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right] \quad (21)$$

Chloromethane ($t^* = 0.49$ hr) CTUIR

$ET_{adj} > t^*$ ($0.6954 > 0.49$) ∴

$$DA_{event} = 1.0 \times 0.0033\ \frac{cm}{hr} \times 0.0001987\ \frac{mg}{L} \times 0.001\ \frac{L}{cm^2} \times \left[\frac{0.6954\ \frac{hr}{event}}{1+0} + 2\times 0.2\ \frac{hr}{event} \times \left(\frac{1+3(0)+3(0)^2}{(1+0)^2}\right)\right]$$

$$= 6.557\times10^{-10}\ mg/cm^2\text{-}hr \times 1.0954\ \frac{hr}{event}$$

$$= 7.18\times10^{-10}\ mg/cm^2\text{-event}\ \checkmark$$

$$CDI = \frac{7.18\times10^{-10}\ mg/cm^2\text{-event} \times 20514\ \frac{cm^2\text{-}yr\text{-event}}{kg\text{-}d} \times 365\ d/yr}{70\ yr \times 365\ d/yr} \quad (20)$$

$$= 2.105\times10^{-7}\ mg/kg\text{-}d\ \checkmark$$

$$Risk = 2.105\times10^{-7}\ mg/kg\text{-}d \times CSF_o/1.0 \quad (22)$$

CSF_o unavailable ∴ Risk = not calculated

Dermal Absorption of Organics ($ET > t^*$) in Drinking Water Noncarcinogenic Effects

$$DA_{event} = FA \times kp \times C_w \times CF3 \times \left[\frac{ET_c}{1+B} + 2\times\tau\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right] \quad (21)$$

Chloromethane ($t^* = 0.49$ hr) CTUIR

$ET_c > t^*$ ($0.54 > 0.49$) ∴

$$DA_{event} = 1.0 \times 0.0033\ \frac{cm}{hr} \times 0.0001987\ \frac{mg}{L} \times 0.001\ \frac{L}{cm^3} \times \left[\frac{0.54\ \frac{hr}{event}}{1+0} + 2\times 0.2\ \frac{hr}{event} \times \left(\frac{1+3(0)+3(0)^2}{(1+0)^2}\right)\right]$$

$$= 6.557\times10^{-10}\ mg/cm^2\text{-}hr \times 0.94\ \frac{hr}{event}$$

$$= 6.164\times10^{-10}\ mg/cm^2\text{-event}\ \checkmark$$

Dermal Absorption of Organics (ET > t*) in Water Noncarcinogenic Effects (continued)

$$CDI = \frac{6.164 \times 10^{-10}\ mg/cm^2\text{-event} \times 6{,}365\ cm^2 \times 365\ d/yr \times 6\ yr \times 1\ event/d}{15\ kg \times 6\ yr \times 365\ d/yr} \quad (23)$$

$$= 2.62 \times 10^{-7}\ mg/kg\text{-}d \checkmark$$

$$HQ = 2.62 \times 10^{-7}\ mg/kg\text{-}d \,/\, RfD_o \times 1.0 \quad (24)$$

RfD_o unavailable ∴ HQ not calculated ✓

Dermal Absorption of Inorganics in Drinking Water Carcinogenic Effects

$$DA_{event} = k_p \times C_w \times ET_{adj} \times CF3 \quad (28)$$

Arsenic CTU1R

$$DA_{event} = 0.001\ cm/hr \times 0.002558\ mg/L \times 0.6954\ hr/event \times 0.001\ L/cm^3$$

$$= 1.78 \times 10^{-9} \checkmark$$

$$CDI = \frac{1.78 \times 10^{-9}\ mg/cm^2\text{-event} \times 20{,}514\ cm^2\text{-yr-event}/kg\text{-}d \times 365\ d/yr}{70\ yr \times 365\ d/yr} \quad (20)$$

$$= 5.213 \times 10^{-7}\ mg/kg\text{-}d \checkmark$$

$$Risk = 5.213 \times 10^{-7}\ mg/kg\text{-}d \times (1.50\ mg/kg\text{-}d)^{-1}/1.0 \quad (22)$$

$$= 7.82 \times 10^{-7} \checkmark$$

Dermal Absorption of Inorganics in Drinking Water Noncarcinogenic Effects

$$DA_{event} = k_p \times C_w \times ET_c \times CF3 \quad (28)$$

Arsenic CTU1R

$$DA_{event} = 0.001\ cm/hr \times 0.002558\ mg/L \times 0.54\ hr/event \times 0.001\ L/cm^3$$

$$= 1.381 \times 10^{-9}\ mg/cm^2\text{-event} \checkmark$$

$$CDI = \frac{1.381 \times 10^{-9}\ mg/cm^2\text{-event} \times 6{,}365\ cm^2 \times 365\ d/yr \times 6\ yr \times 1\ event/d}{15\ kg \times 6\ yr \times 365\ d/yr} \quad (23)$$

$$= 5.861 \times 10^{-7}\ mg/kg\text{-}d \checkmark$$

$$HQ = 5.861 \times 10^{-7}\ mg/kg\text{-}d \,/\, 0.0003\ mg/kg\text{-}d \times 1.0 \quad (24)$$

$$= 1.95 \times 10^{-3} \checkmark$$

Sweat Lodge Inhalation of VOCs in Vapor Carcinogenic Effects

$$I_{inh} = \frac{C_{dw} \times \left(\frac{V_w}{2}\right) \times \left(\frac{1}{2/3 \times \pi \times r^3}\right) \times IR \times ET \times EF \times ED}{BW \times AT_{ca} \times CF1} \quad (29)$$

$$Risk = CSF_i \times I_{inh} \quad (36)$$

$$CSF_i = IUR \times \frac{1}{20\ m^3/d} \times 70(kg) \times 1000\ \mu g/mg \quad (49)$$

Chloroform CTUIR

$$I_{inh} = \frac{0.0010043\ \frac{mg}{L} \times \frac{4.0L}{2} \times \frac{1}{2/3 \times \pi \times (1m)^3} \times 25\ \frac{m^3}{d} \times \frac{1}{24}\ \frac{d}{event} \times 365\ \frac{event}{yr} \times 68\ yr}{70\ kg \times 70\ yr \times 365\ d/yr}$$

$$= 1.386 \times 10^{-5}\ mg/kg\text{-}d \checkmark$$

$$CSF_i = 2.30 \times 10^{-5}\ (\mu g/m^3)^{-1} \times \frac{1}{20\ m^3/d} \times 70\ kg \times 1000\ \mu g/mg$$

$$= 8.05 \times 10^{-2}\ (mg/kg\text{-}d)^{-1} \checkmark$$

$$Risk = 8.05 \times 10^{-2}\ (mg/kg\text{-}d)^{-1} \times 1.386 \times 10^{-5}\ mg/kg\text{-}d$$

$$= 1.12 \times 10^{-6} \checkmark$$

Sweat Lodge Inhalation of VOCs in Vapor Noncarcinogenic Effects

$$I_{inh} = \frac{C_w \times \left(\frac{V_w}{2}\right) \times \left(\frac{1}{2/3 \times \pi \times r^3}\right) \times IR \times ET \times EF \times ED}{BW \times AT_{nc} \times CF1} \quad (29)$$

$$HQ = \frac{1}{RfD_i} \times I_{inh} \quad (31)$$

$$RfD_i = RfC \times 20\ m^3/d \times 1/70\ kg \quad (50)$$

Chloroform CTUIR

$$I_{inh} = \frac{0.0010043\ \frac{mg}{L} \times \frac{4.0L}{2} \times \frac{1}{2/3 \times \pi \times (1m)^3} \times 25\ \frac{m^3}{d} \times \frac{1}{24}\ \frac{d}{event} \times 365\ \frac{event}{yr} \times 68\ yr}{70\ kg \times 68\ yr \times 365\ d/yr}$$

$$= 1.427 \times 10^{-5}\ mg/kg\text{-}d$$

$$RfD_i = 0.098\ mg/m^3 \times 20\ m^3/d \times 1/70\ kg$$

$$= 2.80 \times 10^{-2}\ mg/kg\text{-}d \checkmark$$

$$HQ = 1/2.80 \times 10^{-2}\ mg/kg\text{-}d \times 1.427 \times 10^{-5}\ mg/kg\text{-}d$$

$$= 5.10 \times 10^{-4} \checkmark$$

Sweat Lodge Inhalation of Volatile Radionuclides in Vapor

$$I_{inh} = C_{dw} \times \frac{V_w}{2} \times \frac{1}{2/3 \times \pi \times r^3} \times IR \times ET \times EF \times ED \quad (32)$$

$$Risk = SF_i \times I_{inh} \quad (33)$$

Tritium CTUIR

$$I_{inh} = 7{,}230\ pCi/L \times \frac{4\ L}{2} \times \frac{1}{2/3 \times 3.14 \times (1m)^3} \times 25\ m^3/d \times \frac{1}{24}\ d/event \times 365\ event/yr \times 68\ yr$$

$$= 1.785 \times 10^8\ pCi$$

$$Risk = 8.50 \times 10^{-13}\ risk/pCi \times 1.785 \times 10^8\ pCi$$

$$= 1.52 \times 10^{-4} \checkmark$$

Sweat Lodge Inhalation of Aerosolized Non-VOCs Carcinogenic Effects

$$I_{inh} = \left(\frac{IR \times ET \times EF \times ED}{BW \times AT_{can} \times CF1}\right) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times Exp\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \quad (34)$$

$$Risk = CSF_i \times I_{inh} \quad (35)$$

Arsenic CTUIR

$$I_{inh} = \left(\frac{25\ m^3/d \times \frac{1}{24}\ d/event \times 365\ event/yr \times 68\ yr}{70\ kg \times 70\ yr \times 365\ d/yr}\right) \times 0.002558\ mg/L \times \left(\frac{18\ g/gmole}{0.06237\ \frac{mmHg\text{-}m^3}{gmole\text{-}K} \times 338.7\ K \times 1000\ g/L}\right) \times \cdots$$

$$\cdots Exp\left(18.3036 - \frac{3816.44}{338.7\ K - 46.13}\right)$$

$$= 1.446 \times 10^{-2}\ m^3/kg\text{-}d \times 0.002558\ mg/L \times 8.521 \times 10^{-4}\ L/mmHg\text{-}m^3 \times Exp(5.259\ mmHg)$$

$$= 6.061 \times 10^{-6}\ mg/kg\text{-}d \checkmark$$

$$CSF_i = 4.30 \times 10^{-3} (\mu g/m^3)^{-1} \times \frac{1}{20\ m^3/d} \times 70\ kg \times 1000\ \mu g/mg \quad (49)$$

$$= 15.05\ (mg/kg\text{-}d)^{-1} \checkmark$$

$$Risk = 15.05\ (mg/kg\text{-}d)^{-1} \times 6.061 \times 10^{-6}\ mg/kg\text{-}d$$

$$= 9.12 \times 10^{-5} \checkmark$$

Sweat Lodge Inhalation of Aerosolized Non-VOCs Noncarcinogenic Effects

$$I_{inh} = \left(\frac{IR \times ET \times EF \times ED}{BW \times AT_{nc} \times CF1}\right) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times Exp\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \quad (34)$$

Sweat Lodge Inhalation of Aerosolized Non-VOCs Noncarcinogenic Effects (continued)

$$HQ = \frac{1}{RFDi} \times I_{inh} \quad (36)$$

Arsenic CTUIR

$$I_{inh} = \left(\frac{25\,\frac{m^3}{d} \times \frac{1}{24}\,\frac{d}{event} \times 365\,\frac{event}{yr} \times 68\,yr}{70\,kg \times 68\,yr \times 365\,d/yr}\right) \times 0.002558\,mg/L \times \left(\frac{18\,g/gmole}{0.06237\,\frac{mmHg\text{-}m^3}{gmole\text{-}K} \times 338.7\,K \times 1000\,g/L}\right) \times \ldots$$

$$\ldots \exp\left(18.3036 - \frac{3816.44}{338.7\,K - 46.13}\right)$$

$$= 1.488 \times 10^{-2}\,\frac{m^3}{kg\text{-}d} \times 0.002558\,\frac{mg}{L} \times 8.521 \times 10^{-4}\,\frac{L}{mmHg\text{-}m^3} \times \exp(5.259\,mmHg)$$

$$= 6.237 \times 10^{-6}\,mg/kg\text{-}d \;\checkmark$$

$$RFDi = 1.5 \times 10^{-5}\,mg/m^3 \times 20\,\frac{m^3}{d} \times \frac{1}{70\,kg} \quad (50)$$

$$= 4.29 \times 10^{-6}\,mg/kg\text{-}d \;\checkmark$$

$$HQ = 1/4.29 \times 10^{-6}\,mg/kg\text{-}d \times 6.237 \times 10^{-6}\,mg/kg\text{-}d$$

$$= 1.45 \;\checkmark \text{ (rounding)}$$

Sweat Lodge Inhalation of Aerosolized Non-Volatile Radionuclides

$$I_{inh} = (IR \times ET \times EF \times ED) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times p_w}\right) \times \exp\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \quad (37)$$

$$Risk = SF_i \times I_{inh} \quad (38)$$

Strontium-90+D CTUIR

$$I_{inh} = \left(25\,\frac{m^3}{d} \times \frac{1}{24}\,\frac{d}{event} \times 365\,\frac{event}{yr} \times 68\,yr\right) \times 13.4239\,pCi/L \times \left(\frac{18\,g/gmole}{0.06237\,\frac{mmHg\text{-}m^3}{gmole\text{-}K} \times 338.7\,K \times 1000\,g/L}\right) \times \ldots$$

$$\ldots \exp\left(18.3036 - \frac{3816.44}{338.7\,K - 46.13}\right)$$

$$= 2.585 \times 10^{4}\,m^3 \times 13.4239\,pCi/L \times 8.521 \times 10^{-4}\,\frac{L}{mmHg\text{-}m^3} \times \exp(5.259\,mmHg)$$

$$= 5.686 \times 10^{4}\,pCi \;\checkmark$$

$$Risk = 4.30 \times 10^{-10}\,risk/pCi \times 5.686 \times 10^{4}\,pCi$$

$$= 2.44 \times 10^{-5} \;\checkmark \text{ (rounding)}$$

Sweat lodge Dermal Exposure to VOCs in Vapor Carcinogenic Effects

$$Id_{total} = \frac{C_{dw} \times (V_w/2) \times (1/(2/3 \times \pi \times r^3)) \times SA \times K_p \times ET \times EF \times ED \times CF2}{BW \times AT_{can} \times CF1} \quad (39)$$

$$Risk = (CSF_o / GIABS) \times I_{d\,total} \quad (40)$$

Chloroform CTUIR

$$Id_{total} = \frac{0.0010043 \frac{mg}{L} \times \frac{4L}{2} \times \frac{1}{2/3 \times \pi \times (1m)^3} \times 1.8 m^2 \times 0.0068 \frac{cm}{hr} \times 1 \frac{hr}{event} \times 365 \frac{event}{yr} \times 68 yr \times 0.01 \frac{m}{cm}}{70 kg \times 70 yr \times 365 d/yr}$$

$$= 1.629 \times 10^{-9} \text{ mg/kg-d} \checkmark$$

$$Risk = (0.031 (mg/kg\text{-}d)^{-1} / 1.0) \times 1.629 \times 10^{-9} \text{ mg/kg-d}$$

$$= 5.05 \times 10^{-11} \checkmark$$

Sweat Lodge Dermal Exposure to VOCs in Vapor Noncarcinogenic Effects

$$Id_{total} = \frac{C_{dw} \times (V_w/2) \times (1/(2/3 \times \pi \times r^3)) \times SA \times K_p \times ET \times EF \times ED \times CF2}{BW \times AT_{nc} \times CF1} \quad (39)$$

$$HQ = (1/RfD_o \times GIABS) \times I_{d\,total} \quad (41)$$

Chloroform CTUIR

$$Id_{total} = \frac{0.0010043 \frac{mg}{L} \times \frac{4L}{2} \times \frac{1}{2/3 \times \pi \times (1m)^3} \times 1.8 m^2 \times 0.0068 \frac{cm}{hr} \times 1 \frac{hr}{event} \times 365 \frac{event}{yr} \times 68 yr \times 0.01 \frac{m}{cm}}{70 kg \times 68 yr \times 365 d/yr}$$

$$= 1.677 \times 10^{-9} \text{ mg/kg-d}$$

$$HQ = (1/0.01 \text{ mg/kg-d}) \times 1.677 \times 10^{-9} \text{ mg/kg-d}$$

$$= 1.68 \times 10^{-7} \checkmark$$

Sweat Lodge Dermal Exposure to Non-VOCs in Condensed Water Carcinogenic Effects

$$Id_L = \frac{C_{dw} \times SA \times K_p \times ET \times EF \times ED \times CF3}{BW \times AT_{can} \times CF1} \quad (42)$$

$$Risk = \frac{CSF_o}{GIABS} \times Id_L \quad (45)$$

Arsenic CTUIR

$$Id_L = \frac{0.0025578 \frac{mg}{L} \times 1.8 m^2 \times 0.001 \frac{cm}{hr} \times 1 \frac{hr}{event} \times 365 \frac{event}{yr} \times 68 yr \times 10 L/m^2\text{-}cm}{70 kg \times 70 yr \times 365 d/yr}$$

$$= 6.389 \times 10^{-7} \text{ mg/kg-d} \checkmark$$

Sweat Lodge Dermal Exposure to Non-VOCs in Condensed Water Carcinogenic Effects (cont'd.)

$$Risk = \frac{1.5(mg/kg\text{-}d)^{-1}}{1.0} \times 6.389 \times 10^{-7}\ mg/kg\text{-}d$$

$$= 9.58 \times 10^{-7} \checkmark$$

Sweat Lodge Dermal Exposure to Non-VOCs in Condensed Water Noncarcinogenic Effects

$$IdL = \frac{C_{dw} \times SA \times k_p \times ET \times EF \times ED \times CF3}{BW \times AT_{nc} \times CF1} \quad (42)$$

$$HQ = \frac{1}{RfD_o \times GIABS} \times IdL \quad (46)$$

Arsenic CTUIR

$$IdL = \frac{0.0025578\ mg/L \times 1.8\,m^2 \times 0.001\ cm/hr \times 1\ \frac{hr}{event} \times 365\ \frac{event}{yr} \times 68\,yr \times 10\ L/m^3\text{-}cm}{70\,kg \times 68\,yr \times 365\ d/yr}$$

$$= 6.577 \times 10^{-7}\ mg/kg\text{-}d \checkmark$$

$$HQ = \frac{1}{0.0003\ mg/kg\text{-}d \times 1.0} \times 6.577 \times 10^{-7}\ mg/kg\text{-}d$$

$$= 2.19 \times 10^{-3} \checkmark$$

Sweat Lodge Dermal Exposure to Aerosolized Non-VOCs Carcinogenic Effects

$$Idv = \left(\frac{SA \times k_p \times ET \times EF \times ED \times CF3}{BW \times AT_{can} \times CF1}\right) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times Exp\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \quad (43)$$

$$Risk = \frac{CSF_o}{GIABS} \times Idv \quad (45)$$

Arsenic CTUIR

$$Idv = \left(\frac{1.8\,m^2 \times 0.001\ cm/hr \times 1\ \frac{hr}{event} \times 365\ \frac{event}{yr} \times 68\,yr \times 10\ L/m^3\text{-}cm}{70\,kg \times 70\,yr \times 365\ d/yr}\right) \times 0.0025578\ mg/L \times \cdots$$

$$\cdots \left(\frac{18\ g/gmole}{62.37\ mmHg\ L/gmole\text{-}K \times 338.7\,K \times 1000\ g/L}\right) \times Exp\left(18.3036 - \frac{3816.44}{338.7\,K - 46.13}\right)$$

$$= 2.498 \times 10^{-4}\ L/kg\text{-}d \times 0.0025578\ mg/L \times 8.521 \times 10^{-7}\ (mmHg)^{-1} \times Exp(5.259\ mmHg)$$

$$= 1.047 \times 10^{-10}\ mg/kg\text{-}d \checkmark$$

$$Risk = (1.5\ (mg/kg\text{-}d)^{-1} / 1.0) \times 1.047 \times 10^{-10}\ mg/kg\text{-}d$$

$$= 1.57 \times 10^{-10} \checkmark$$

Sweat Lodge Dermal Exposure to Aerosolized Non-VOCs Noncarcinogenic Effects

$$Id_v = \left(\frac{SA \times Kp \times ET \times EF \times ED \times CF3}{BW \times AT_{nc} \times CF1}\right) \times C_{dw} \times \left(\frac{MW_w}{R \times T \times \rho_w}\right) \times Exp\left(18.3036 - \frac{3816.44}{T - 46.13}\right) \quad (43)$$

$$HQ = \frac{1}{RfD_o \times GIABS} \times Id_v \quad (46)$$

Arsenic CTUIR

$$Id_v = \left(\frac{1.8\,m^2 \times 0.001\,\frac{cm}{hr} \times 1\,\frac{hr}{event} \times 365\,\frac{event}{yr} \times 68\,yr \times 10^{L/m^2\text{-}cm}}{70\,kg \times 68\,yr \times 365\,d/yr}\right) \times 0.0025578\,mg/L \ldots$$

$$\ldots \left(\frac{18\,g/gmole}{62.37\,mmHg\text{-}L/gmole\text{-}K \times 338.7\,K \times 1000\,g/L}\right) \times Exp\left(18.3036 - \frac{3816.44}{338.7\,K - 46.13}\right)$$

$$= 2.571 \times 10^{-4}\,L/kg\text{-}d \times 0.0025578\,mg/L \times 8.521 \times 10^{-7}\,mmHg \times Exp(5.259\,mmHg)$$

$$= 1.077 \times 10^{-10}\,mg/kg\text{-}d \quad \checkmark$$

$$HQ = \frac{1}{0.0003\,mg/kg\text{-}d \times 1.0} \times 1.077 \times 10^{-10}\,mg/kg\text{-}d$$

$$= 3.59 \times 10^{-7} \quad \checkmark$$