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Revision 0

Native American Risk Assessments for the 100-KR-4 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

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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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
Cr(VI)	Hexavalent chromium
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
HEIS	Hanford Environmental Information System
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
MRL	Minimal Risk Levels
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
RESRAD	RESidual RADioactivity computer code
SF	slope factor
TCE	trichloroethene
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 cancer risks and noncancer hazards associated with exposure to contaminants in the 100-KR-4 Groundwater Operable Unit (OU) for two Native American exposure scenarios, which are the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) exposure scenario and the Yakama Nation exposure scenario. Exposure is evaluated assuming a hypothetical failure of current administrative controls, such that tribal use of 100-KR-4 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-KR-4 OU is included in the exposure and risk calculations, and the list of contaminants of potential concerns (COPCs) and the determined exposure point concentrations (EPCs) are documented in ECF-100KR4-17-0081, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit*, Rev. 0. 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 82 wells. This risk assessment supports DOE/RL-2010-97, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 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 CTUIR and the Yakama Nation have provided exposure 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-KR-4 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 DOE/RL-2010-97 because the RESRAD model (ANL, 2014, RESRAD, Version 7.0) used calculate the residential soil PRGs considers these pathways, as documented in ECF-HANFORD-10-0429, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Report*. Contact with contaminated drill cuttings is not addressed in this risk evaluation; 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 (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:

$$Risk = CDI \times SF \quad (1)$$

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:

$$Risk = CDI \times SF \quad (2)$$

where:

Risk	=	Excess lifetime cancer risk (unitless probability)
CDI	=	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.

$$Risk = 1 - \exp(-CDI \times SF) \quad (3)$$

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 only 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):

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

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, semivolatiles, 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)*;
- ORNL, 2017, 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.*
- 13-AMRP-0007, Letter from DOE-RL to Mr. Russell Jim, dated 10/29/2012

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-KR-4 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 1 for calculated values and reference bases used for both the CTUIR and Yakama Nation drinking water exposure scenarios. Table 2 presents exposure assumptions for the CTUIR and Table 3 presents exposure assumptions for the Yakama Nation.

Table 1. Calculated Values and Reference Bases Used for CTUIR and Yakama Nation Drinking Water Exposure Scenarios

Exposure Factor	Symbol	Value	Units	Source
Partitioning constant Derived by Bunge Model	B	Analyte Specific	Unitless	See Table 17
Cancer Slope Factor - oral	CSF_o	Analyte Specific	$(mg/kg\text{-}day)^{-1}$	See Table 17
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	ug/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-100KR4-17-0081
Absorbed dose per event	DA_{event}	Calculated value	mg/cm^2-event	Equation 26, 27, and 28
Exposure Time – dermal, age-adjusted	ET_{adj}	Calculated value	hours/event	Equation 25
Fraction of absorbed water	FA	Analyte Specific	Unitless	See Table 17
Gastrointestinal Absorption Factor	GIABS	Analyte Specific	Unitless	See Table 17
Inhalation Rate – age-adjusted, radiological	INH_{RADadj}	Calculated value	m^3-year/day	Equation 18
Ingestion Rate – water, age-adjusted, nonradiological	IRW_{adj}	Calculated value	L-year/kg-day	Equation 6
Ingestion Rate – water, age-adjusted, radiological	IRW_{RADadj}	Calculated value	L-year/day	Equation 11
Inhalation Unit Risk	IUR	Analyte Specific	$(ug/m^3)^{-1}$	See Table 17
Dermal permeability coefficient	K_p	Analyte Specific	cm/hour	See Table 17
The constant pi	π	3.14159	Unitless	--
Reference Concentration	RfC	Analyte Specific	mg/m^3	See Table 17
Reference Dose - oral	RfD_o	Analyte Specific	mg/kg-day	See Table 17
Skin Surface Area - age-adjusted	SA_{adj}	Calculated value	cm^2-year-event/kg-day	Equation 21

Table 1. Calculated Values and Reference Bases Used for CTUIR and Yakama Nation Drinking Water Exposure Scenarios

Exposure Factor	Symbol	Value	Units	Source
Slope Factor - inhalation	SF_i	Analyte Specific	Risk/pCi	See Table 17
Slope Factor - oral	SF_o	Analyte Specific	Risk/pCi	See Table 17
Time to reach steady state conditions	t*	Analyte Specific	hours	See Table 17
Lag time	τ	Analyte Specific	hours/event	See Table 17
Conversion Factor	CF1	365	days/year	1 year = 365 days
Conversion Factor	CF2	1/24	days/year	1 day = 24 hours
Conversion Factor	CF3	0.001	L/cm^3	1 L = 1,000cm^3

ECF-100KR4-17-0081, Rev. 0, Cal*culation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit*.

Table 2. Summary of Exposure Assumptions for the CTUIR Drinking Water Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens	AT_{can}	70	years	Harris, 2008
Averaging Time – noncarcinogens	AT_{nc}	6	years	Harris, 2008
Body Weight—Adult	BW_a	70	kg	Harris and Harper, 2004
Body Weight—Child	BW_c	15	kg	EPA/600/R-090/052F OSWER Directive 9200.1-120
Exposure Duration – resident, CTUIR	ED_r	70	years	Harris and Harper, 2004
Exposure Duration - child	ED_c	6	years	Harris, 2008
Exposure Frequency	EF	365	days/year	Harris and Harper, 2004
Exposure Time – dermal, adult	ET_a	0.71	hours/event	EPA/600/R-090/052F OSWER Directive 9200.1-120
Exposure Time – dermal, child	ET_c	0.54	hours/event	EPA/600/R-090/052F OSWER Directive 9200.1-120
Exposure Time - inhalation	ET	24	hours/day	OSWER Directive 9200.1-120
Event Frequency	EV	1	event/day	EPA/540/R/99/005
Inhalation Rate - adult	INH_a	25	m^3/day	Harris, 2008
Inhalation Rate - child	INH_c	15	m^3/day	Harris, 2008
Ingestion Rate – water, adult	IRW_a	4	L/day	Harris, 2008
Ingestion Rate – water, child	IRW_c	1	L/day	Harris and Harper, 2004
Skin Surface Area - adult	SA_a	19,652	cm^2	EPA/600/R-090/052F OSWER Directive 9200.1-120
Skin Surface Area - child	SA_c	6,365	cm^2	EPA/600/R-090/052F OSWER Directive 9200.1-120
Volatilization Factor	VF	0.5	L/m^3	EPA/540/R-92/003

Table 2. Summary of Exposure Assumptions for the CTUIR Drinking Water Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source

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/600/R-090/052F, *Exposure Factors Handbook 2011 Edition (Final).*
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. Summary of Exposure Assumptions for the Yakama Nation Drinking Water Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens	AT_{can}	70	years	Ridolfi, 2007
Averaging Time – noncarcinogens	AT_{nc}	6	years	Ridolfi, 2007
Body Weight—Adult	BW_a	70	kg	Ridolfi, 2007
Body Weight—Child	BW_c	16	kg	Ridolfi, 2007
Exposure Duration – resident, Yakima Nation	ED_r	70	years	Ridolfi, 2007
Exposure Duration - child	ED_c	6	years	Ridolfi, 2007
Exposure Frequency	EF	365	days/year	Ridolfi, 2007
Exposure Time –dermal, adult	ET_a	0.71	hours/event	EPA/600/R-090/052F OSWER Directive 9200.1-120
Exposure Time –dermal, child	ET_c	0.54	hours/event	EPA/600/R-090/052F
Exposure Time - inhalation	ET	24	hours/day	OSWER Directive 9200.1-120
Event Frequency	EV	365	event/day	EPA/540/R/99/005
Inhalation Rate - adult	INH_a	26	m^3/day	Ridolfi, 2007
Inhalation Rate - child	INH_c	16	m^3/day	Ridolfi, 2007
Ingestion Rate – water, adult	IRW_a	4	L/day	Ridolfi, 2007
Ingestion Rate – water, child	IRW_c	2	L/day	Ridolfi, 2007
Skin Surface Area - adult	SA_a	19,652	cm^2	EPA/600/R-090/052F OSWER Directive 9200.1-120
Skin Surface Area - child	SA_c	6,365	cm^2	EPA/600/R-090/052F OSWER Directive 9200.1-120
Volatilization Factor	VF	0.5	L/m^3	EPA/540/R-92/003

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/600/R-090/052F, *Exposure Factors Handbook 2011 Edition (Final).*
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*.

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 4. Equations are provided in the following subsections.

Table 4. Calculated Values and Reference Bases Used for the Drinking Water Ingestion Exposure Route

Effect	Symbol for Calculated Value	Reference
Carcinogenic	CDI IRW_{adj}	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2017)
	Risk	EPA/540/R-92/003
Noncarcinogenic	CDI	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2017)
	HQ	EPA/540/R-92/003
Radionuclide	CDI IRW_{RADadj}	RAIS Risk Exposure Models for Radionuclides User's Guide (ORNL, 2017)
	Risk	EPA/540/R-92/003

Notes:

CDI= chronic daily intake
HQ= hazard quotient
IRW_{adj} = 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, 2017, The Risk Assessment Information System (RAIS).

3.1.1.1 Drinking Water Ingestion—Carcinogenic Effects

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

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

where:

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

Cancer risk is calculated using the following equation:

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

3.1.1.2 Drinking Water Ingestion—Noncarcinogenic Effects

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

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

Noncancer hazard is calculated using the following equation:

$$HQ = \frac{CDI}{RfD_o} \quad (9)$$

3.1.1.3 Drinking Water Ingestion—Radionuclides

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

$$CDI = C_w \times IRW_{RADadj} \times EF \quad (10)$$

Where:

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

Radiological cancer risk is calculated using the following equation:

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

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 5. Equations are provided in the following subsections.

Table 5. 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, 2017)
	Risk	EPA/540/R-070/002
Noncarcinogenic	CDI	RAIS Risk Exposure Models for Chemicals User's Guide (ORNL, 2017)
	HQ	EPA/540/R-070/002
Radionuclide	CDI INH_{RADadj}	RAIS Risk Exposure Models for Radionuclides User's Guide (ORNL, 2017)
	Risk	EPA/540/R-92/003

Notes:

CDI= chronic daily intake
HQ= hazard quotient
INH_{RADadj} = age-adjusted radionuclide inhalation rate.
EPA/540/R-070/002, *Risk Assessment Guidance for Superfund: Volume I – 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, 2017, 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:

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

Cancer risk is calculated using the following equation:

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

3.1.2.2 Drinking Water Inhalation of Volatiles—Noncarcinogenic Effects

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

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

Noncancer hazard is calculated using the following equation:

$$HQ = \frac{CDI}{RfC} \quad (16)$$

3.1.2.3 Drinking Water Inhalation of Volatiles—Radionuclides

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

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

where:

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

Radiological cancer risk is calculated using the following equation:

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

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 6. The equations are presented in the following subsections

Table 6. 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.

Table 6. Calculated Values and Reference Bases Used for the Drinking Water Dermal Exposure Route

Effect	Symbol for Calculated Value	Reference

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:

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

where:

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

Cancer risk is calculated using the following equation:

$$Risk = CDI \times \frac{CSF_o}{GIABS} \quad (22)$$

3.1.3.2 Drinking Water Dermal Absorption— Noncarcinogenic Effects

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

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

Noncancer hazard is calculated using the following equation:

$$HQ = \frac{CDI}{RfD_o \times GIABS} \quad (24)$$

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:

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

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:

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

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 provided in Table 7 for calculated values and reference bases used for both the CTUIR and the Yakama Nation sweat lodge exposure scenarios, Table 8 for the CTUIR exposure assumptions, and Table 9 for the Yakama Nation exposure assumptions.

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).

Table 7. Calculated Values and Reference Bases Used for CTUIR and Yakima Nation Sweat Lodge Exposure Scenarios

Exposure Factor	Symbol	Value	Units	Source
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 × 10 cm
Groundwater Concentration[a]	C_{dw}	Analyte Specific	mg/L or pCi/L	ECF-100KR4-17-0081
Cancer Slope Factor - oral	CSF_o	Analyte Specific	$(mg/kg\text{-}day)^{-1}$	See Table 17
Cancer Slope Factor - inhalation	CSF_i	Analyte Specific Calculated value	$(mg/kg\text{-}day)^{-1}$	Equation 49
Gastrointestinal Absorption Factor	GIABS	Analyte Specific	Unitless	See Table 17

[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 7. Calculated Values and Reference Bases Used for CTUIR and Yakima Nation Sweat Lodge Exposure Scenarios

Exposure Factor	Symbol	Value	Units	Source
Inhalation Intake of Analytes in Sweat Lodge— volatile and semivolatile nonradionuclides	I_{inh}	Calculated value	mg/kg-day	Equation 29
Inhalation Intake of Analytes in Sweat Lodge— 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
Dermal Intake of Analytes in Sweat Lodge— volatile and semivolatile 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 Unit Risk	IUR	Analyte Specific	$(\mu g/m^3)^{-1}$	See Table 17
Analyte-Specific Permeability Coefficient	K_p	Analyte Specific	cm/hour	See Table 17
The Constant pi		3.14159	Unitless	--
Reference Concentration	RfC	Analyte Specific	mg/m^3	See Table 17
Reference Dose - inhalation	RfD_i	Analyte Specific Calculated value	mg/kg-day	Equation 50
Reference Dose - oral	RfD_o	Analyte Specific	mg/kg-day	See Table 17
Slope Factor - inhalation	SF_i	Analyte Specific	Risk/pCi	See Table 17

Notes:
a. 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.

ECF-100KR4-17-0081, Rev. 0, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit.*

Table 8. Summary of Exposure Assumptions for the CTUIR Sweat Lodge Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens[a]	AT_c	70	years	Harris and Harper, 2004
Averaging Time – noncarcinogens[a]	AT_{nc}	68	years	Harris and Harper, 2004
Body Weight—Adult	BW_a	70	kg	Harris and Harper, 2004
Exposure Duration or Number of Years a Person Sweats in a Lifetime - adult	ED_a	68	years	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[b]	ET_a	1	hour/event	Harris and Harper, 2004

Table 8. Summary of Exposure Assumptions for the CTUIR Sweat Lodge Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source
Inhalation Rate - adult	IR_a	25	m^3/day	Harris, 2008
Molecular Weight of Water	MW_w	18	g/gmole	Harris and Harper, 2004
Density of Liquid Water	p_w	1000	g/L	Harris and Harper, 2004
Radius of Sweat Lodge	r	1	m	Harris and Harper, 2004
Ideal Gas Law Constant[c]	R	0.06237	mmHg-m^3/gmole-K	Harris and Harper, 2004
Skin Surface Area - adult	SA_a	1.8	m^2	Harris and Harper, 2004
Temperature of the Sweat Lodge[d]	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 carcinogens and 68 years for noncarcinogens to account for lifetime intake rather than annual intake.

b. 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).

c. For sweat lodge dermal exposure, the ideal gas law constant of 0.06237 mmHg-m^3/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).

d. 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

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 9. Summary of Exposure Assumptions for the Yakama Nation Sweat Lodge Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source
Averaging Time – carcinogens[a]	AT_c	70	years	Harris and Harper, 2004
Averaging Time – noncarcinogens[a]	AT_{nc}	70	years	Harris and Harper, 2004
Body Weight—Adult	BW_a	70	kg	Ridolfi, 2007
Exposure Duration or Number of Years a Person Sweats in a Lifetime - adult	ED_a	70	years	Ridolfi, 2007
Exposure Frequency or Number of Sweats per Year	EF	365	events/year	Ridolfi, 2007
Length of Sweat Event – adult[b]	ET_a	7	hour/event	Ridolfi, 2007
Inhalation Rate - adult	IR_a	26	m^3/day	Ridolfi, 2007
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
Radius of Sweat Lodge	r	1	m	Harris and Harper, 2004

Table 9. Summary of Exposure Assumptions for the Yakama Nation Sweat Lodge Exposure Scenario

Exposure Factor	Symbol	Value	Units	Source
Ideal Gas Law Constant[c]	R	0.06237	mmHg-m^3/gmole-K	Harris and Harper, 2004
Skin Surface Area - adult	SA_a	1.8	m^2	Harris and Harper, 2004
Temperature of the Sweat Lodge[d]	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. 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).

c. 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).

d. For sweat lodge dermal exposure, the ideal gas law constant of 0.06237 mmHg-m^3/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).

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 Semivolatiles

The bases for the equations used to calculate intake, risk, and hazard associated with the inhalation of volatiles and semivolatiles during sweat lodge use are summarized in Table 10. Equations are provided in the following subsections.

Table 10. Calculated Values and Reference Bases Used for the Sweat Lodge Inhalation of Volatiles and Semivolatiles 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 Semivolatiles—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

Inhalation intake of volatiles and semivolatiles 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 Semivolatiles—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 Semivolatiles—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—Radionuclides

Inhalation intake of 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):

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

Radiological cancer risk is calculated using the following equation:

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

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 11. Equations are provided in the following subsections.

Table 11. 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.

Table 11. Calculated Values and Reference Bases Used for the Sweat Lodge Inhalation of Nonvolatiles Exposure Route

Effect	Symbol for Calculated Value	Reference
		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 Aerosolized 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):

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

3.2.2.2 Sweat Lodge Inhalation of Aerosolized Nonvolatiles—Carcinogenic Effects

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

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

3.2.2.3 Sweat Lodge Inhalation of Aerosolized Nonvolatiles—Noncarcinogenic Effects

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

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

3.2.2.4 Sweat Lodge Inhalation of Aerosolized 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):

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

Radiological cancer risk is calculated using the following equation:

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

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

The bases for the equations used to calculate intake, risk, and hazard associated with the dermal exposure route for volatiles and semivolatiles during sweat lodge use are summarized in Table 12. Equations are provided in the following subsections.

Table 12. Calculated Values and Reference Bases Used for the Sweat Lodge Dermal Exposure to Volatiles and Semivolatiles 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 semivolatile analytes in vapor in sweat lodge.
$I_{d,total}$ = Total dermal intake of volatile and semivolatile 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 Semivolatiles—Intake (Carcinogenic Effects and Noncarcinogenic Effects)

For volatile and semivolatile 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 semivolatile 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 Semivolatiles—Carcinogenic Effects

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

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

3.2.3.3 Sweat Lodge Dermal Exposure to Volatiles and Semivolatiles—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—Radionuclides

Dermal exposure to 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 13. Equations are provided in the following subsections.

Table 13. 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

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):

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

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):

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

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):

$$I_{d,total} = I_{d,v} + I_{d,l} \quad (44)$$

3.2.4.4 Sweat Lodge Dermal Exposure to Nonvolatiles—Carcinogenic Effects

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

$$Risk = \frac{CSF_o}{GIABS} \times I_{d,total} \quad (45)$$

3.2.4.5 Sweat Lodge Dermal Exposure to Nonvolatiles—Noncarcinogenic Effects

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

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

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.

$$Risk_T = \sum_1^N Risk_i \quad (47)$$

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.

$$HI = \sum_1^N \frac{CDI_i}{RfD_i} \quad (48)$$

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 Table 1 for inputs common to both scenarios, and Table 2 and Table 3 for the CTUIR-specific and Yakama Nation-specific inputs, respectively. Exposure inputs used to quantify intake from the sweat lodge exposure pathway are provided in Table 7 for inputs common to both scenarios, and Table 8 and Table 9 for the CTUIR-specific and Yakama Nation-specific inputs, 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, 2017b, *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 14 and Table 15, 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 14. 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
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:

Table 14. 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

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 15. 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
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).

Table 15. 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

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, semivolatile, 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 semivolatile analytes, versus nonvolatile analytes. For volatile and semivolatile 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 semivolatile 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-KR-4 Groundwater OU in the Hanford Environmental Information System (HEIS) database. The data set was first processed and reduced as described in ECF-100KR4-17-0081, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit,* Rev. 0.

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-KR-4 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 82 wells, as described in ECF-100KR4-17-0081. The identified analytes and their EPCs are presented in Table 16.

Table 16. 100-KR-4 Groundwater Operable Unit Grouped Well Exposure Point Concentration Summary

Analyte Name	CAS No.	Units	100-KR-4 Groundwater OU
1,2,4-Trichlorobenzene	120-82-1	ug/L	0.65
1,2-Dichlorobenzene	95-50-1	ug/L	0.20
2-Butanol	78-92-2	ug/L	30
2-Butanone	78-93-3	ug/L	0.50
2-Propanol	67-63-0	ug/L	102
Acetone	67-64-1	ug/L	0.78
Aldrin	309-00-2	ug/L	0.31
Aluminum	7429-90-5	ug/L	44
Antimony	7440-36-0	ug/L	0.32
Arsenic	7440-38-2	ug/L	3.5
Barium	7440-39-3	ug/L	36

Table 16. 100-KR-4 Groundwater Operable Unit Grouped Well Exposure Point Concentration Summary

Analyte Name	CAS No.	Units	100-KR-4 Groundwater OU
Beryllium	7440-41-7	ug/L	0.10
Bis(2-ethylhexyl) phthalate	117-81-7	ug/L	10
Boron	7440-42-8	ug/L	32
Bromodichloromethane	75-27-4	ug/L	0.094
Bromomethane	74-83-9	ug/L	0.63
Cadmium	7440-43-9	ug/L	0.10
Carbon disulfide	75-15-0	ug/L	0.074
Carbon tetrachloride	56-23-5	ug/L	1.1
Chlorobenzene	108-90-7	ug/L	0.17
Chloroform	67-66-3	ug/L	0.73
Chloromethane	74-87-3	ug/L	0.096
Chromium	7440-47-3	ug/L	61
Cobalt	7440-48-4	ug/L	0.33
Copper	7440-50-8	ug/L	2.7
Cyanide	57-12-5	ug/L	2.3
Diethylphthalate	84-66-2	ug/L	2.2
Ethylbenzene	100-41-4	ug/L	2.5
Fluoride	16984-48-8	ug/L	182
Hexane	110-54-3	ug/L	0.83
Hexavalent chromium (Cr(VI)	18540-29-9	ug/L	54
Iron	7439-89-6	ug/L	176
Lithium	7439-93-2	ug/L	15
Manganese	7439-96-5	ug/L	235
Mercury	7439-97-6	ug/L	0.040
Methylene chloride	75-09-2	ug/L	0.31
Molybdenum	7439-98-7	ug/L	4.0
Nickel	7440-02-0	ug/L	7.6
Nitrate	14797-55-8	ug/L	24560
Nitrite	14797-65-0	ug/L	64
o-Xylene	95-47-6	ug/L	0.52
Selenium	7782-49-2	ug/L	1.3
Silver	7440-22-4	ug/L	0.28
Strontium	7440-24-6	ug/L	266
Styrene	100-42-5	ug/L	0.051
Tetrahydrofuran	109-99-9	ug/L	1.2
Thallium	7440-28-0	ug/L	0.078
Tin	7440-31-5	ug/L	0.47
Toluene	108-88-3	ug/L	0.066
Trichloroethene (TCE)	79-01-6	ug/L	3.0
Uranium	7440-61-1	ug/L	3.4
Vanadium	7440-62-2	ug/L	10
Xylenes (total)	1330-20-7	ug/L	0.13
Zinc	7440-66-6	ug/L	30
Carbon-14	14762-75-5	pCi/L	1770
Cesium-137	10045-97-3	pCi/L	1.9
Cobalt-60	10198-40-0	pCi/L	12
Nickel-63	13981-37-8	pCi/L	3.7
Selenium-79	15758-45-9	pCi/L	25
Strontium-90	10098-97-2	pCi/L	13
Technetium-99	14133-76-7	pCi/L	17
Tritium	10028-17-8	pCi/L	18564
Uranium-233/234	U-233/234	pCi/L	1.2
Uranium-235	15117-96-1	pCi/L	0.15
Uranium-238	U-238	pCi/L	0.77

ECF-100KR4-17-0081, Rev. 0, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit.*

4.3 Toxicity Values

The toxicity criteria used for the Native American human health risk calculations are provided in Table 17. 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 17 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. 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, 2017b).

Tier 3 – Other Toxicity Values

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

- The California EPA (CalEPA) Toxicity Criteria Database contains toxicity values that are peer reviewed and address both carcinogenic and noncarcinogenic effects.
- The Agency for Toxic Substances and Disease Registry (ATSDR) 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 noncarcinogenic health effects over a specified duration of exposure.

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) × (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 is different from the value values are also published at the EPA Regional Screening Levels website (EPA, 2017b). The differences in toxicity values are summarized below.

- The RfD for uranium that is published in IRIS (0.003 mg/kg-day) was used for hazard calculations in this risk assessment. The reference dose value (0.0002 mg/kg-day) published in the memorandum dated December 21, 2016, Considering a Noncancer Oral Reference Dose for Uranium for Superfund Human Health Risk Assessments and referenced in in the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" web site is not published in IRIS and an MCL using this values has not been promulgated. As such, the RfD value of 0.0002 mg/kg-day for uranium was not used in this risk assessment.
- For hexavalent chromium (Cr(VI)), this assessment considers carcinogenic effects only for the inhalation exposure routes. An oral cancer slope factor has 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 Cr(VI) has the potential to under-estimate cancer risk.

4.3.2 Toxicity Values for Radionuclides

The radionuclide-specific cancer slope factors were obtained from "Preliminary Remediation Goals for Radionuclides (PRG)", PRG Download, "Summary Tables", dated November, 2014 (EPA, 2017a). For each radionuclide listed, slope factors correspond to the risks per unit intake or exposure for that radionuclide only, except cesium-137, neptunium-237, radium-228, strontium-90, uranium-235, uranium-238, which have risks from associated short-lived radioactive daughter products that are also included. The intention of this 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, 2017b) 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 m3/day and an assumed body weight of 70 kg.

$$CSFi\ \left(\frac{kg-day}{mg}\right) = IUR\ \left(\frac{m^3}{\mu g}\right) \times \frac{1}{20}\left(\frac{m^3}{day}\right) \times\ 70\ (kg) \times\ 1000\ \left(\frac{\mu g}{mg}\right) \qquad (49)$$

$$RfDi\ \left(\frac{mg}{kg-day}\right) = RfC\ \left(\frac{mg}{m^3}\right) \times\ 20\ \left(\frac{m^3}{day}\right) \times \frac{1}{70}(kg) \qquad (50)$$

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 17. Toxicity Criteria for 100-KR-4 Groundwater Analytes

Analyte Name[a]	CAS	Oral Reference Dose (RfD_o)[b] (mg/kg-day)	RfD_o [b] Key	Oral Cancer Slope Factor (CSF_o)[b] $(mg/kg\text{-}day)^{-1}$ or Oral Slope Factor (SF_o)[c] (Risk/pCi)	CSF_o Key	Inhalation Reference Concentration (RfC)[b] (mg/m^3)	RfC[b] Key	Inhalation Unit Risk (IUR)[b] $(\mu g/m^3)^{-1}$	IUR[b] Key	Immersion Slope Factor (SF_{imm})[c] (risk/yr per pCi/L)	Inhalation Cancer Slope Factor (SF_i)[c] (Risk/pCi)	SF_i 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[b] (unitless)
1,2,4-Trichlorobenzene	120-82-1	0.01	I	0.029	P	0.002	P	--	--	--	--	--	V	1	0.07	0.37	1.1	2.6	1
1,2-Dichlorobenzene	95-50-1	0.09	I	--	--	0.2	H	--	--	--	--	--	V	1	0.045	0.21	0.7	1.7	1
2-Butanol	78-92-2	2	P	--	--	30	P	--	--	--	--	--	V	1	0.0015	0.0051	0.27	0.66	1
2-Butanone	78-93-3	0.6	I	--	--	5	I	--	--	--	--	--	V	1	0.00096	0.0031	0.27	0.64	1
2-Propanol	67-63-0	2	P	--	--	0.2	P	--	--	--	--	--	V	1	0.00078	0.0023	0.23	0.55	1
Acetone	67-64-1	0.9	I	--	--	31	A	--	--	--	--	--	V	1	0.00051	0.0015	0.22	0.53	1
Aldrin	309-00-2	3E-05	I	17	I	--	--	0.0049	I	--	--	--	V	1	0.29	2.2	12	48	1
Aluminum	7429-90-5	1	P	--	--	0.005	P	--	--	--	--	--	--	1	0.001	0.002	0.15	0.36	1
Antimony	7440-36-0	0.0004	I	--	--	--	--	--	--	--	--	--	--	0.15	0.001	0.0042	0.51	1.2	1
Arsenic	7440-38-2	0.0003	I	1.5	I	1.5E-05	C	0.0043	I	--	--	--	--	1	0.001	0.0033	0.28	0.66	1
Barium	7440-39-3	0.2	I	--	--	0.0005	H	--	--	--	--	--	--	0.07	0.001	0.0045	0.62	1.5	1
Beryllium	7440-41-7	0.002	I	--	--	2E-05	I	0.0024	I	--	--	--	--	0.007	0.001	0.0012	0.12	0.28	1
Bis(2-ethylhexyl) phthalate	117-81-7	0.02	I	0.014	I	--	--	2.4E-06	C	--	--	--	--	1	1.1	8.6	16	73	0.8
Boron	7440-42-8	0.2	I	--	--	0.02	H	--	--	--	--	--	--	1	0.001	0.0014	0.13	0.3	1
Bromodichloromethane	75-27-4	0.02	I	0.062	I	--	--	3.7E-05	C	--	--	--	V	1	0.004	0.02	0.87	2.1	1
Bromomethane	74-83-9	0.0014	I	--	--	0.005	I	--	--	--	--	--	V	1	0.0028	0.011	0.36	0.86	1
Cadmium	7440-43-9	0.0005	I	--	--	1E-05	A	0.0018	I	--	--	--	--	0.05	0.001	0.0041	0.45	1.1	1
Carbon disulfide	75-15-0	0.1	I	--	--	0.7	I	--	--	--	--	--	V	1	0.011	0.038	0.28	0.67	1
Carbon tetrachloride	56-23-5	0.004	I	0.07	I	0.1	I	6E-06	I	--	--	--	V	1	0.016	0.078	0.76	1.8	1
Carbon-14	14762-75-5	--	--	1.55E-12	--	--	--	--	--	5.8E-17	1.7E-11	--	V	--	--	--	--	--	--
Cesium-137	10045-97-3	--	--	3.05E-11	--	--	--	--	--	5.16E-12	1.1E-10	--	--	--	--	--	--	--	--
Chlorobenzene	108-90-7	0.02	I	--	--	0.05	P	--	--	--	--	--	V	1	0.028	0.12	0.45	1.1	1
Chloroform	67-66-3	0.01	I	0.031	C	0.098	A	2.3E-05	I	--	--	--	V	1	0.0068	0.029	0.49	1.2	1
Chloromethane	74-87-3	--	--	--	--	0.09	I	--	--	--	--	--	V	1	0.0033	0.009	0.2	0.48	1
Chromium	7440-47-3	1.5	I	--	--	--	--	--	--	--	--	--	--	0.013	0.001	0.0028	0.21	0.49	1
Cobalt	7440-48-4	0.0003	P	--	--	6E-06	P	0.009	P	--	--	--	--	1	0.0004	0.0012	0.22	0.54	1
Cobalt-60	10198-40-0	--	--	1.58E-11	--	--	--	--	--	2.44E-11	1E-10	--	--	--	--	--	--	--	--
Copper	7440-50-8	0.04	H	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0031	0.24	0.57	1
Cyanide	57-12-5	0.0006	I	--	--	0.0008	S	--	--	--	--	--	V	1	0.001	0.002	0.15	0.35	1
Diethylphthalate	84-66-2	0.8	I	--	--	--	--	--	--	--	--	--	--	1	0.0036	0.021	1.8	4.4	1
Ethylbenzene	100-41-4	0.1	I	0.011	C	1	I	2.5E-06	C	--	--	--	V	1	0.049	0.2	0.41	0.99	1
Fluoride	16984-48-8	0.06	I	--	--	0.013	C	--	--	--	--	--	--	1	0.001	0.0024	0.17	0.41	1
Hexane	110-54-3	--	--	--	--	0.7	I	--	--	--	--	--	V	1	0.2	0.72	0.32	1.2	1

Table 17. Toxicity Criteria for 100-KR-4 Groundwater Analytes

Analyte Name[a]	CAS	Oral Reference Dose (RfD_o)[b] (mg/kg-day)	RfD_o [b] Key	Oral Cancer Slope Factor (CSF_o)[b] $(mg/kg\text{-}day)^{-1}$or Oral Slope Factor (SF_o)[c] (Risk/pCi)	CSF_o Key	Inhalation Reference Concentration (RfC)[b] (mg/m^3)	RfC[b] Key	Inhalation Unit Risk (IUR)[b] $(\mu g/m^3)^{-1}$	IUR[b] Key	Immersion Slope Factor (SF_{imm})[c] (risk/yr per pCi/L)	Inhalation Cancer Slope Factor (SF_i)[c] (Risk/pCi)	SF_i 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[b] (unitless)
Cr(VI)	18540-29-9	0.003	I	--	--	0.0001	I	0.084	S	--	--	--	--	0.025	0.002	0.0055	0.21	0.49	1
Iron	7439-89-6	0.7	P	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0029	0.22	0.52	1
Lithium	7439-93-2	0.002	P	--	--	--	--	--	--	--	--	--	--	1	0.001	0.001	0.12	0.28	1
Manganese	7439-96-5	0.024	S	--	--	5E-05	I	--	--	--	--	--	--	0.04	0.001	0.0029	0.21	0.51	1
Mercury	7439-97-6	0.0003	I	--	--	0.0003	S	--	--	--	--	--	--	0.07	0.001	0.0063	3.5	8.4	1
Methylene chloride	75-09-2	0.006	I	0.002	I	0.6	I	1E-08	I	--	--	--	V	1	0.0035	0.013	0.31	0.75	1
Molybdenum	7439-98-7	0.005	I	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0038	0.36	0.87	1
Nickel	7440-02-0	0.02	I	--	--	9E-05	A	0.00026	C	--	--	--	--	0.04	0.0002	0.00059	0.22	0.54	1
Nickel-63	13981-37-8	--	--	6.81E-13	--	--	--	--	--	0	5.9E-12	--	--	--	--	--	--	--	--
Nitrate	14797-55-8	7.1	I	--	--	--	--	--	--	--	--	--	--	1	0.001	0.003	0.23	0.56	1
Nitrite	14797-65-0	0.3	I	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0026	0.19	0.46	1
o-Xylene	95-47-6	0.2	S	--	--	0.1	S	--	--	--	--	--	V	1	0.047	0.19	0.41	0.99	1
Selenium	7782-49-2	0.005	I	--	--	0.02	C	--	--	--	--	--	--	1	0.001	0.0034	0.29	0.7	1
Selenium-79	15758-45-9	--	--	6.92E-12	--	--	--	--	--	6.74E-17	1.9E-11	--	--	--	--	--	--	--	--
Silver	7440-22-4	0.005	I	--	--	--	--	--	--	--	--	--	--	0.04	0.0006	0.0024	0.42	1	1
Strontium	7440-24-6	0.6	I	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0036	0.33	0.78	1
Strontium-90	10098-97-2	--	--	7.4E-11	--	--	--	--	--	3.97E-14	4.3E-10	--	--	--	--	--	--	--	--
Styrene	100-42-5	0.2	I	--	--	1	I	--	--	--	--	--	V	1	0.037	0.15	0.4	0.97	1
Technetium-99	14133-76-7	--	--	2.75E-12	--	--	--	--	--	5.62E-16	3.8E-11	--	--	--	--	--	--	--	--
Tetrahydrofuran	109-99-9	0.9	I	--	--	2	I	--	--	--	--	--	V	1	0.0013	0.0041	0.27	0.64	1
Thallium	7440-28-0	1E-05	X	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0055	1.5	3.5	1
Tin	7440-31-5	0.6	H	--	--	--	--	--	--	--	--	--	--	1	0.001	0.0042	0.49	1.2	1
Toluene	108-88-3	0.08	I	--	--	5	I	--	--	--	--	--	V	1	0.031	0.11	0.35	0.83	1
TCE	79-01-6	0.0005	I	0.046	I	0.002	I	4.1E-06	I	--	--	--	V	1	0.012	0.051	0.57	1.4	1
Tritium	10028-17-8	--	--	5.07E-14	--	--	--	--	--	0	8.5E-13	--	V	--	--	--	--	--	--
Uranium	7440-61-1	0.003	I	--	--	4E-05	A	--	--	--	--	--	--	1	0.001	0.0059	2.3	5.4	1
Uranium-233/234	U-233/234	--	--	7.07E-11	--	--	--	--	--	1.17E-15	2.8E-08	--	--	--	--	--	--	--	--

Table 17. Toxicity Criteria for 100-KR-4 Groundwater Analytes

Analyte Name[a]	CAS	Oral Reference Dose (RfD_o)[b] (mg/kg-day)	RfD_o [b] Key	Oral Cancer Slope Factor (CSF_o)[b] $(mg/kg\text{-}day)^{-1}$or Oral Slope Factor (SF_o)[c] (Risk/pCi)	CSF_o Key	Inhalation Reference Concentration (RfC)[b] (mg/m^3)	RfC[b] Key	Inhalation Unit Risk (IUR)[b] $(\mu g/m^3)^{-1}$	IUR[b] Key	Immersion Slope Factor (SF_{imm})[c] (risk/yr per pCi/L)	Inhalation Cancer Slope Factor (SF_i)[c] (Risk/pCi)	SF_i 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[b] (unitless)
Uranium-235	15117-96-1	--	--	7.18E-11	--	--	--	--	--	1.48E-12	2.5E-08	--	--	--	--	--	--	--	--
Uranium-238	U-238	--	--	8.7E-11	--	--	--	--	--	2.69E-13	2.4E-08	--	--	--	--	--	--	--	--
Vanadium	7440-62-2	0.005	S	--	--	0.0001	A	--	--	--	--	--	--	0.026	0.001	0.0027	0.2	0.49	1
Xylenes (total)	1330-20-7	0.2	I	--	--	0.1	I	--	--	--	--	--	V	1	0.05	0.2	0.41	0.99	1
Zinc	7440-66-6	0.3	I	--	--	--	--	--	--	--	--	--	--	1	0.0006	0.0019	0.24	0.59	1

Notes:
[a] Source = ECF-100KR4-17-0081, Rev. 0, Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit.
[b] Source = EPA, 2017b, "Summary Table", dated June, 2017, available online at "Regional Screening Levels for Chemical Contaminants at Superfund Sites.", http://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017.
[c] Source = EPA, 2017a, "Resident Tapwater Table", dated November, 2014, available online at "Preliminary Remediation Goals for Radionuclides (PRG)", http://epa-prgs.ornl.gov/radionuclides.
[d] Source = EPA, 2017b, "Parameters Table", dated June, 2017 , available online at "Regional Screening Levels for Chemical Contaminants at Superfund Sites.", http://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017.
-- = 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.
GIABS = gastrointestinal absorption factor.
H = HEAST
I = IRIS
K_p = dermal permeability constant.
P = PPRTV
S = See user guide section
X = APPENDIX PPRTV SCREEN
t^* = time to reach steady-state conditions.
τ = lag time
V = volatile

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5 Software Applications

The approved software application POSTAL v3.0 is the primary software program used for calculations reported in this document. The required information about POSTAL v3.0 is provided in this section.

5.1 POSTAL Description

The following presents the description of POSTAL used for this report. See CHPRC-03486, *POSTAL Software Management Plan, Rev. 0* for further details regarding the use of this software.

- Software Title: POSTAL
- Software Version: 3.0
- HISI Identification Number: 4198

Workstation type and description (from which software is run): POSTAL was executed on a Lenovo ThinkPad computer (property tag INTERA-00798) running Windows 10. Computer details are:

- Intel® Core™[2] i7-6600U CPU @ 2.60GHz
- 16 GB RAM
- Windows ®[3] 10 Pro 64-bit Operating System

Additional workstation type and description: POSTAL was executed on a Lenovo ThinkPad computer (property tag INTERA-00707) running Windows 10. Computer details are:

- Intel® Core™ i7-4600U CPU @ 2.10GHz
- 8 GB RAM
- Windows 10 Pro 64-bit Operating System

5.1.1 Software Installation and Checkout

The software installation and checkout forms for POSTAL v3.0 are attached to this document in Appendix A.

5.1.2 Statement of Valid Software Installation

The following presents the statement that POSTAL v3.0 is a valid software application.

- POSTAL was developed by INTERA, Inc., to provide automated execution of ProUCL and automated generation of UCL-, EPC- and risk tables in support of risk assessment activities.
- Acceptance tests were performed that demonstrated POSTAL correctly controlled the execution of ProUCL v5.1 and built UCL-95 and EPC tables from the ProUCL output and established EPC selection rules.
- POSTAL as it has been used in this activity has been implemented within the range of its limitations.

[2] A trademark of Intel Corporation, Santa Clara, California.
[3] A trademark of Microsoft Corporation, Redmond, Washington.

6 Calculation

Calculation of cancer risks and noncancer hazards for the Native American exposure scenarios and the verification of the calculations are discussed below.

6.1 Drinking Water and Sweat Lodge Exposure Scenarios Results

Cancer risks and noncancer hazards were calculated using the methodologies presented in Section 3, and the inputs and assumptions described in Section 4. Results are summarized in the text and tables presented in Section 7. The input files used with and the output files generated by POSTAL are archived in the ERMA under this ECF number.

6.2 Verification of Risk and Hazards Calculations

Verification of the Native American risk assessment calculations were performed by comparing the POSTAL v3.0-generated results against results independently generated by a GoldSIM model of the Native American risk assessment calculations. The comparisons were verified to ensure any discrepancies were within acceptable limits. Additionally, POSTAL results were generated and compared against results generated by Excel®[4] spreadsheets and results generated by hand calculations for a selected subset of wells and analytes. The verification of the calculations is documented in the software quality assurance documentation for POSTAL v3.0.

[4] A trademark of Microsoft Corporation, Redmond, Washington.

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-KR-4 Groundwater OU.

7.1 Summary of the CTUIR Risk Assessment

This section summarizes the CTUIR risk assessment results for use of 100-KR-4 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-KR-4 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 18 provides a summary of the cancer risk and noncancer hazard estimates by exposure route.

Table 18. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]
Nonradionuclides	Ingestion	6.4×10^{-4}	1,2,4-Trichlorobenzene, (ELCR = 2.0×10^{-6}, 0.01%) Aldrin, (ELCR = 4.7×10^{-3}, 23%) Arsenic, (ELCR = 3.1×10^{-4}, 1.5%) Bis(2-ethylhexyl) phthalate, (ELCR = 3.5×10^{-4}, 1.8%) Bromodichloromethane, (ELCR = 2.1×10^{-6}, 0.01%) Carbon tetrachloride, (ELCR = 8.5×10^{-6}, 0.04%) Carbon-14, (ELCR = 9.5×10^{-3}, 48%) Chloroform, (ELCR = 9.7×10^{-6}, 0.05%) Ethylbenzene, (ELCR = 5.3×10^{-6}, 0.03%) TCE, (ELCR = 1.5×10^{-5}, 0.08%) Tritium, (ELCR = 5.0×10^{-3}, 25%)	6.1	1,2,4-Trichlorobenzene, (HQ = 0.17, 0.86%) 2-Propanol, (HQ = 0.26, 1.3%) Aldrin, (HQ = 9.8, 49%) Arsenic, (HQ = 0.79, 4.0%) Bis(2-ethylhexyl) phthalate, (HQ = 1.6, 8.1%) Cyanide, (HQ = 1.7, 8.5%) Fluoride, (HQ = 0.20, 1%) Cr(VI), (HQ = 1.5, 7.7%) Lithium, (HQ = 0.50, 2.5%) Manganese, (HQ = 0.71, 3.5%) Nitrate, (HQ = 0.23, 1.2%) Thallium, (HQ = 0.52, 2.6%) Trichloroethene, (HQ = 1.2, 6.1%) Vanadium, (HQ = 0.16, 0.79%)
	Dermal Contact	4.0×10^{-3}		11	
	Inhalation of Volatiles	7.9×10^{-4}		2.7	
	Total Risk	**5.4×10^{-3}**		Total HI	**20**
	Ingestion	5.0×10^{-4}		--	

Table 18. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]
Radionuclides	Inhalation of Volatiles	1.4×10^{-2}			
	Total Risk	1.5×10^{-2}			
Total Cumulative ELCR[c]		2.0×10^{-2}			

Notes:

a. Percent risk contribution listed for those contributors with an individual ELCR > 1×10^{-4} (radionuclides) or individual ELCR > 1×10^{-6} (chemicals).

b. Percent HI contribution listed for those contributors with an HQ > 0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = not applicable.
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the 100-KR-4 Groundwater OU is 2.0×10^{-2}. The total ELCR for nonradiological analytes is 5.4×10^{-3}, which is greater than the 2013 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^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR are 1,2,4-trichlorobenzene (ELCR = 2.0×10^{-6}, 0.01 percent contribution), aldrin (ELCR = 4.7×10^{-3}, 23 percent contribution), bis(2-ethylhexyl) phthalate (ELCR = 3.5×10^{-4}, 1.8 percent contribution), bromodichloromethane (ELCR = 2.1×10^{-6}, 0.01 percent contribution), carbon tetrachloride (ELCR = 8.5×10^{-6}, 0.04 percent contribution), carbon-14 (ELCR = 9.5×10^{-3}, 48 percent contribution), chloroform (ELCR = 9.7×10^{-6}, 0.05 percent contribution), ethylbenzene (ELCR = 5.3×10^{-6}, 0.03 percent contribution), trichloroethene (TCE) (ELCR = 1.5×10^{-5}, 0.08 percent contribution), and tritium (ELCR = 5.0×10^{-3}, 25 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 3.1×10^{-4}, 1.5 percent contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 5.1×10^{-3}, which is greater than the 2013 MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI is 20, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI are 1,2,4-trichlorobenzene (HQ = 0.17, 0.86 percent contribution), 2-propanol (HQ = 0.26, 1.3 percent contribution), aldrin (HQ = 9.8, 49 percent contribution), arsenic (HQ = 0.79, 4.0 percent contribution), bis(2-ethylhexyl) phthalate (HQ = 1.6, 8.1 percent contribution), cyanide (HQ = 1.7, 8.5 percent contribution), fluoride (HQ = 0.20, 1 percent contribution), Cr(VI) (HQ = 1.5, 7.7 percent contribution), lithium (HQ = 0.50, 2.5 percent contribution), manganese (HQ = 0.71, 3.5 percent contribution), nitrate (HQ = 0.23, 1.2 percent contribution), thallium (HQ = 0.52, 2.6 percent contribution), TCE (HQ = 1.2, 6.1 percent contribution), and vanadium (HQ = 0.16, 0.79 percent contribution). The EPC for thallium is 0.078 µg/L, which is less than the 90th percentile Hanford site background value of 1.67 µg/L. The HI without contribution from arsenic and thallium is 19, which is greater than the target HI of 1.

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

Potential exposure to 100-KR-4 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 semivolatiles and aerosolized nonvolatiles; and dermal contact with vaporized volatiles and semivolatiles, and aerosolized nonvolatiles and condensed liquid. Table 19 provides a summary of the cancer risk and noncancer hazard estimates by exposure route.

Table 19. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]
Nonradionuclide Analytes	Inhalation in Sweat Lodge		Aldrin, (ELCR = 7.5×10^{-5}, 0.19%) Arsenic, (ELCR = 1.3×10^{-4}, 0.33%) Beryllium, (ELCR = 2.0×10^{-6}, 0.01%) Bis(2-ethylhexyl) phthalate, (ELCR = 4.0×10^{-5}, 0.10%) Cadmium, (ELCR = 1.5×10^{-6}, 0.004%) Carbon-14, (ELCR = 7.4×10^{-4}, 1.9%) Cobalt, (ELCR = 2.5×10^{-5}, 0.06%) Cr(VI), (ELCR = 3.7×10^{-2}, 96%) Nickel, (ELCR = 1.6×10^{-5}, 0.04%) Tritium, (ELCR = 3.9×10^{-4}, 1.0%) Uranium-233/234, (ELCR = 1.5×10^{-4}, 0.38%)		Arsenic, (HQ = 2.0, 3.9%) Barium, (HQ = 0.61, 1.2%) Bis(2-ethylhexyl) phthalate, (HQ = 0.15, 0.29%) Cobalt, (HQ = 0.47, 0.92%) Cyanide, (HQ = 0.14, 0.28%) Fluoride, (HQ = 0.12, 0.23%) Cr(VI), (HQ = 5.0, 9.7%) Manganese, (HQ = 40, 78%) Nickel, (HQ = 0.72, 1.4%) Uranium, (HQ = 0.73, 1.4%) Vanadium, (HQ = 0.92, 1.8%)
	Volatile and Semivolatiles (vapor)	7.7×10^{-5}		0.27	
	Nonvolatile (aerosol)	3.7×10^{-2}		51	
	Total (Inh)	3.7×10^{-2}		51	
	Dermal Exposure in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor only)	3.7×10^{-7}		<0.01	
	Nonvolatile (vapor and aqueous condensate)	4.1×10^{-5}		0.62	
	Total (Dermal)	4.2×10^{-5}		0.62	
	Total Risk	**3.7×10^{-2}**		Total HI	**51**
Radionuclide Analytes	Inhalation in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor)	1.1×10^{-3}			
	Nonvolatile (aerosol)	2.8×10^{-4}			
	Total Risk	1.4×10^{-3}			
Total Cumulative ELCR[c]		3.9×10^{-2}			

Table 19. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]

Notes:

a. Percent risk contribution listed for those contributors with an individual ELCR > 1×10^{-4} (radionuclides) or individual ELCR > 1×10^{-6} (chemicals).

b. Percent HI contribution listed for those contributors with an HQ > 0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = not applicable.
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the 100-KR-4 Groundwater OU is 3.9×10^{-2}. The total ELCR for nonradiological analytes is 3.7×10^{-2}, which is greater than the 2013 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 1.4×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR are aldrin (ELCR = 7.5×10^{-5}, 0.19 percent contribution), beryllium (ELCR = 2.0×10^{-6}, 0.01 percent contribution), bis(2-ethylhexyl) phthalate (ELCR = 4.0×10^{-5}, 0.10 percent contribution), cadmium (ELCR = 1.5×10^{-6}, 0.004 percent contribution), carbon-14 (ELCR = 7.4×10^{-4}, 1.9 percent contribution), cobalt (ELCR = 2.5×10^{-5}, 0.06 percent contribution), Cr(VI) (ELCR = 3.7×10^{-2}, 96 percent contribution), nickel (ELCR = 1.6×10^{-5}, 0.04 percent contribution), tritium (ELCR = 3.9×10^{-4}, 1.0 percent contribution), and uranium-233/234 (ELCR = 1.5×10^{-4}, 0.38 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.3×10^{-4}, 0.33 percent contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 3.7×10^{-2}, which is greater than the 2013 MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI is 51, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI are arsenic (HQ = 2.0, 3.9 percent contribution), barium (HQ = 0.61, 1.2 percent contribution), bis(2-ethylhexyl) phthalate (HQ = 0.15, 0.29%), cobalt (HQ = 0.47, 0.92 percent contribution), cyanide (HQ = 0.14, 0.28 percent contribution), fluoride (HQ = 0.12, 0.23 percent contribution), Cr(VI) (HQ = 5.0, 9.7 percent contribution), manganese (HQ = 40, 78 percent contribution), nickel (HQ = 0.72, 1.4 percent contribution), uranium (HQ = 0.73, 1.4 percent contribution), and vanadium (HQ = 0.92, 1.8 percent contribution) . The HI without contribution from arsenic is 49, 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-KR-4 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-KR-4 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 20 provides a summary of the cancer risk and noncancer hazard estimates by exposure route.

Table 20. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]
Nonradionuclides	Ingestion	7.0×10^{-4}	1,2,4-Trichlorobenzene, (ELCR = 2.1×10^{-6}, 0.01%) Aldrin, (ELCR = 4.7×10^{-3}, 23%) Arsenic, (ELCR = 3.4×10^{-4}, 1.6%) Bis(2-ethylhexyl) phthalate, (ELCR = 3.5×10^{-4}, 1.7%) Bromodichloromethane, (ELCR = 2.1×10^{-6}, 0.01%) Carbon tetrachloride, (ELCR = 8.9×10^{-6}, 0.04%) Carbon-14, (ELCR = 9.9×10^{-3}, 48%) Chloroform, (ELCR = 9.8×10^{-6}, 0.05%) Ethylbenzene, (ELCR = 5.4×10^{-6}, 0.03%) TCE, (ELCR = 1.6×10^{-5}, 0.08%) Tritium, (ELCR = 5.2×10^{-3}, 25%)	12	1,2,4-Trichlorobenzene, (HQ = 0.17, 0.71%) 2-Propanol, (HQ = 0.26, 1.1%) Aldrin, (HQ = 9.8, 40%) Antimony, (HQ = 0.10, 0.41%) Arsenic, (HQ = 1.5, 6.0%) Bis(2-ethylhexyl) phthalate, (HQ = 1.5, 6.3%) Bromomethane, (HQ = 0.12, 0.49%) Cobalt, (HQ = 0.14, 0.56%) Cyanide, (HQ = 1.9, 7.8%) Fluoride, (HQ = 0.38, 1.5%) Cr(VI), (HQ = 2.6, 10%) Lithium, (HQ = 0.93, 3.8%) Manganese, (HQ = 1.3, 5.2%) Nitrate, (HQ = 0.43, 1.8%) Thallium, (HQ = 0.98, 4.0%) Trichloroethene, (HQ = 1.6, 6.4%) Uranium, (HQ = 0.14, 0.58%) Vanadium, (HQ = 0.28, 1.1%)
	Dermal Contact	3.9×10^{-3}		10	
	Inhalation of Volatiles	7.9×10^{-4}		2.7	
	Total Risk	**5.4×10^{-3}**		Total HI	**25**
Radionuclides	Ingestion	5.1×10^{-4}		--	
	Inhalation of Volatiles	1.5×10^{-2}			
	Total Risk	1.5×10^{-2}			
Total Cumulative ELCR[c]		2.1×10^{-2}			

Table 20. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]

Notes:

a. Percent risk contribution listed for those contributors with an individual ELCR > 1×10^{-4} (radionuclides) or individual ELCR > 1×10^{-6} (chemicals).

b. Percent HI contribution listed for those contributors with an HQ > 0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = not applicable.
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the 100-KR-4 Groundwater OU is 2.1×10^{-2}. The total ELCR for nonradiological analytes is 5.4×10^{-3}, which is greater than the 2013 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^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR are 1,2,4-trichlorobenzene (ELCR = 2.1×10^{-6}, 0.01 percent contribution), aldrin (ELCR = 4.7×10^{-3}, 23 percent contribution), bis(2-ethylhexyl) phthalate (ELCR = 3.5×10^{-4}, 1.7 percent contribution), bromodichloromethane (ELCR = 2.1×10^{-6}, 0.01 percent contribution), carbon-14 (ELCR = 9.9×10^{-3}, 48 percent contribution), carbon tetrachloride (ELCR = 8.9×10^{-6}, 0.04 percent contribution), chloroform (ELCR = 9.8×10^{-6}, 0.05 percent contribution), ethylbenzene (ELCR = 5.4×10^{-6}, 0.03 percent contribution), TCE (ELCR = 1.6×10^{-5}, 0.08 percent contribution), and tritium (ELCR = 5.2×10^{-3}, 25 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 3.4×10^{-4}, 1.6 percent contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 5.1×10^{-3}, which is greater than the 2013 MTCA (173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI is 25, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI are 1,2,4-trichlorobenzene (HQ = 0.17, 0.71 percent contribution), 2-propanol (HQ = 0.26, 1.1 percent contribution), aldrin (HQ = 9.8, 40 percent contribution), antimony (HQ = 0.10, 0.41 percent contribution), arsenic (HQ = 1.5, 6.0 percent contribution), bis(2-ethylhexyl) phthalate (HQ = 1.5, 6.3 percent contribution), bromomethane (HQ = 0.12, 0.49 percent contribution), cobalt (HQ = 0.14, 0.56 percent contribution), cyanide (HQ = 1.9, 7.8 percent contribution), fluoride (HQ = 0.38, 1.5 percent contribution), Cr(VI) (HQ = 2.6, 10 percent contribution), lithium (HQ = 0.93, 3.8 percent contribution), manganese (HQ = 1.3, 5.2 percent contribution), nitrate (HQ = 0.43, 1.8 percent contribution), thallium (HQ = 0.98, 4.0 percent contribution), TCE (HQ = 1.6, 6.4 percent contribution), uranium (HQ = 0.14, 0.58 percent contribution), and vanadium (HQ = 0.28, 1.1 percent contribution). The EPC for thallium is 0.078 µg/L, which is less than the 90th percentile Hanford site background value of 1.67 µg/L. The HI without contribution from arsenic and thallium is 23, 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-KR-4 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 semivolatiles and aerosolized nonvolatiles;
- dermal contact with vaporized volatiles and semivolatiles, nonvolatiles in condensed liquid and aerosolized nonvolatiles;

or

- inhalation of vaporized volatiles and semivolatiles, *without* aerosolized nonvolatiles;
- dermal contact with vaporized volatiles and semivolatiles and nonvolatiles in condensed liquid, *without* aerosolized nonvolatiles.

Table 21 and Table 22 provide a summary of the cancer risk and noncancer hazard estimates by exposure route *with* and *without* contributions from aerosolized nonvolatiles, respectively.

Table 21. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (*with* Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]
Nonradionuclide Analytes	Inhalation in Sweat Lodge		Aldrin (ELCR = 5.6×10^{-4}, 0.22%) Arsenic (ELCR = 9.6×10^{-4}, 0.37%) Beryllium (ELCR = 1.5×10^{-5}, 0.01%) Bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 0.11%) Bromodichloromethane (ELCR = 1.3×10^{-6}, 0.0005%) Cadmium (ELCR = 1.1×10^{-5}, 0.004%) Carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.0009%) Carbon-14 (ELCR = 5.6×10^{-3}, 2.1%) Chloroform (ELCR = 6.0×10^{-6}, 0.002%) Cobalt (ELCR = 1.9×10^{-4}, 0.07%) Ethylbenzene (ELCR = 2.3×10^{-6}, 0.0008%) Cr(VI) (ELCR = 2.5×10^{-1}, 95%) Nickel (ELCR = 1.2×10^{-4}, 0.05%) Strontium-90 (ELCR = 1.7×10^{-4}, 0.07%) TCE (ELCR = 4.5×10^{-6}, 0.002%) Tritium (ELCR = 2.9×10^{-3}, 1.1%) Uranium-233/234 (ELCR = 1.1×10^{-3}, 0.43%) Uranium-235 (ELCR = 1.2×10^{-4}, 0.05%) Uranium-238 (ELCR = 5.9×10^{-4}, 0.23%)		1,2,4-Trichlorobenzene (HQ = 0.12, 0.03%) 2-Propanol (HQ = 0.18, 0.05%) Aluminum (HQ = 0.55, 0.15%) Arsenic (HQ = 15, 3.9%) Barium (HQ = 4.5, 1.2%) Beryllium (HQ = 0.33, 0.09%) Bis(2-ethylhexyl) phthalate (HQ = 1.0, 0.27%) Boron (HQ = 0.10, 0.03%) Cadmium (HQ = 0.63, 0.17%) Cobalt (HQ = 3.5, 0.92%) Cyanide (HQ = 1.0, 0.28%) Fluoride (HQ = 0.87, 0.23%) Cr(VI) (HQ = 36, 9.7%) Manganese (HQ = 292, 78%) Nickel (HQ = 5.3, 1.4%) TCE (HQ = 0.55, 0.15%) Uranium (HQ = 5.3, 1.4%) Vanadium (HQ = 6.7, 1.8%)
	Volatile and Semivolatiles (vapor)	5.7×10^{-4}		2.0	
	Nonvolatile (aerosol)	2.5×10^{-1}		368	
	Total (Inh)	2.5×10^{-1}		370	
	Dermal Exposure in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor only)	2.7×10^{-6}		0.01	
	Nonvolatile (vapor and aqueous condensate)	3.0×10^{-4}		4.3	
	Total (Dermal)	3.0×10^{-4}		4.3	
	Total Risk	**2.5×10^{-1}**		Total HI	**374**

Table 21. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (*with* Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution[a]	HI	% HI Contribution[b]
Radionuclide Analytes	Inhalation in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor)	8.5×10^{-3}			
	Nonvolatile (aerosol)	2.1×10^{-3}			
	Total Risk	1.1×10^{-2}			
Total Cumulative ELCR[a]		2.6×10^{-1}			

Notes:

a. Percent risk contribution listed for those contributors with an individual ELCR > 1×10^{-4} (radionuclides) or individual ELCR > 1×10^{-6} (chemicals).

b. Percent HI contribution listed for those contributors with an HQ > 0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = not applicable.
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR *with* contributions from aerosolized nonvolatile analytes for the 100-KR-4 Groundwater OU is 2.6×10^{-1}. The total ELCR for nonradiological analytes *with* contributions from aerosolized nonvolatile analytes is 2.5×10^{-1}, which is greater than the 2013 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 1.1×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR are aldrin (ELCR = 5.6×10^{-4}, 0.22%), beryllium (ELCR = 1.5×10^{-5}, 0.01%), bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 0.11%), bromodichloromethane (ELCR = 1.3×10^{-6}, 0.0005%), cadmium (ELCR = 1.1×10^{-5}, 0.004%), carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.0009%), carbon-14 (ELCR = 5.6×10^{-3}, 2.1%), chloroform (ELCR = 6.0×10^{-6}, 0.002%), cobalt (ELCR = 1.9×10^{-4}, 0.07%), ethylbenzene (ELCR = 2.3×10^{-6}, 0.0008%), Cr(VI) (ELCR = 2.5×10^{-1}, 95 percent contribution), nickel (ELCR = 1.2×10^{-4}, 0.05%), strontium-90 (ELCR = 1.7×10^{-4}, 0.07%), TCE (ELCR = 4.5×10^{-6}, 0.002%), tritium (ELCR = 2.9×10^{-3}, 1.1%), uranium-233/234 (ELCR = 1.1×10^{-3}, 0.43%), uranium-235 (ELCR = 1.2×10^{-4}, 0.05%), and uranium-238 (ELCR = 5.9×10^{-4}, 0.23%). Contribution to ELCR is elevated for arsenic (ELCR = 9.6×10^{-4}, 0.37 percent contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 2.5×10^{-1}, which is greater than the 2013 MTCA (173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI *with* contributions from aerosolized nonvolatile analytes is 374, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI are 1,2,4-trichlorobenzene (HQ = 0.12, 0.03%), 2-propanol (HQ = 0.18, 0.05%), aluminum (HQ = 0.55, 0.15%), arsenic (HQ = 15, 3.9 percent contribution), barium (HQ = 4.5, 1.2%), beryllium (HQ = 0.33, 0.09%), bis(2-ethylhexyl) phthalate (HQ = 1.0, 0.27%), boron (HQ = 0.10,

0.03%), cadmium (HQ = 0.63, 0.17%), cobalt (HQ = 3.5, 0.92%), cyanide (HQ = 1.0, 0.28%), fluoride (HQ = 0.87, 0.23%), Cr(VI) (HQ = 36, 9.7 percent contribution), manganese (HQ = 292, 78 percent contribution), nickel (HQ = 5.3, 1.4%), TCE (HQ = 0.55, 0.15%), uranium (HQ = 5.3, 1.4%), and vanadium (HQ = 6.7, 1.8%). The HI without contribution from arsenic is 360, which is greater than the target HI of 1.

Table 22. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (*without* Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclide Analytes	Inhalation in Sweat Lodge		Aldrin (ELCR = 5.6×10^{-4}, 6.0%) Arsenic (ELCR = 9.6×10^{-6}, 0.10%) Bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 3.1%) Bromodichloromethane (ELCR = 1.3×10^{-6}, 0.01%) Carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.03%) Carbon-14 (ELCR = 5.6×10^{-3}, 59%) Chloroform (ELCR = 6.0×10^{-6}, 0.06%) Ethylbenzene (ELCR = 2.3×10^{-6}, 0.02%) TCE (ELCR = 4.5×10^{-6}, 0.05%) Tritium (ELCR = 2.9×10^{-3}, 31%)		1,2,4-Trichlorobenzene (HQ = 0.12, 1.9%) 2-Propanol (HQ = 0.18, 2.9%) Bis(2-ethylhexyl) phthalate (HQ = 1.0, 16%) Cyanide (HQ = 1.0, 17%) Cr(VI) (HQ = 2.6, 41%) Manganese (HQ = 0.44, 7.0%) TCE (HQ = 0.55, 8.7%) Vanadium (HQ = 0.15, 2.3%)
	Volatile and Semivolatiles (vapor)	5.7×10^{-4}		2.0	
	Nonvolatile (aerosol)	--(b)		--(b)	
	Total (Inh)	5.7×10^{-4}		2.0	
	Dermal Exposure in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor only)	2.7×10^{-6}		0.01	
	Nonvolatile (aqueous condensate)	3.0×10^{-4}		4.3	
	Total (Dermal)	3.0×10^{-4}		4.3	
	Total Risk	**8.7×10^{-4}**		Total HI	**6.3**
Radionuclide Analytes	Inhalation in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor)	8.5×10^{-3}			
	Nonvolatile (aerosol)	-- (b)			
	Total Risk	8.5×10^{-3}			
Total Cumulative ELCR[a]		9.3×10^{-3}			

Table 22. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (*without* Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution

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.
-- = Not applicable.
ELCR = excess lifetime cancer risk.
HI = hazard index.
HQ = hazard quotient

The total cumulative ELCR *without* contributions from aerosolized nonvolatile analytes for the 100-KR-4 Groundwater OU is 9.3×10^{-3}. The total ELCR for nonradiological analytes *without* contributions from aerosolized nonvolatile analytes is 8.7×10^{-4}, which is greater than the 2013 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 8.5×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to ELCR *without* contributions from aerosolized nonvolatile analytes are aldrin (ELCR = 5.6×10^{-4}, 6.0 percent contribution), bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 3.1 percent contribution), bromodichloromethane (ELCR = 1.3×10^{-6}, 0.01 percent contribution), carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.03 percent contribution), carbon-14 (ELCR = 5.6×10^{-3}, 59 percent contribution), chloroform (ELCR = 6.0×10^{-6}, 0.06 percent contribution), ethylbenzene (ELCR = 2.3×10^{-6}, 0.02 percent contribution), TCE (ELCR = 4.5×10^{-6}, 0.05 percent contribution), and tritium (ELCR = 2.9×10^{-3}, 31 percent contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.6×10^{-6}, 0.1 percent contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for for nonradiological analytes without contribution from arsenic is 8.7×10^{-4}, which is greater than the 2013 MTCA (173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI *without* contributions from aerosolized nonvolatile analytes is 6.3, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI *without* contributions from aerosolized nonvolatile analytes are 1,2,4-trichlorobenzene, (HQ = 0.12, 1.9 percent contribution), 2-propanol, (HQ = 0.18, 2.9 percent contribution), bis(2-ethylhexyl) phthalate (HQ = 1.0, 16 percent contribution), cyanide (HQ = 1.0, 17 percent contribution), Cr(VI) (HQ = 2.6, 41 percent contribution), manganese (HQ = 0.44, 7.0 percent contribution), TCE (HQ = 0.55, 8.7 percent contribution), and vanadium (HQ = 0.15, 2.3 percent contribution). The HI without contribution from arsenic is 6.3, which is greater than the target HI of 1.

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Appendix A

Software Installation and Checkout Form for POSTAL

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: POSTAL Software Version Nu.: 3.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

   C:\Users\npowers\Desktop\POSTAL3.0\POSTAL.exe

3. Executable Size (bytes): 632,832

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

   Lenovo ThinkPad (property tag INTERA-00707)

5. Operating System (include version number):

   Windows 10 Pro 64-bit

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

   Lenovo ThinkPad (property tag INTERA-00707)

7. Operating System (include version number):

   Windows 10 Pro 64-bit

8. Open Problem Report? (•) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   C:\Users\npowers\Desktop\POSTAL3.0\

10. Procedure(s):

    CHPRC-03486 Rev. 0, POSTAL Software Management Plan (Sections 16 and 13.3.3.9)

11. Libraries:

    N/A

12. Input Files:

    N/A

13. Output Files:

    N/A (to screen)

14. Test Cases:

    POSTAL-ITC-1

15. Test Case Results:

    Passed. Match expected results as presented in CHPRC-03486, POSTAL Software Management Plan Section 13.3.3.9 and Attachment 9: Test Log for POSTAL-ITC-1 template.

16. Test Performed By: Neil Powers

17. Test Results: (•) Satisfactory, Accepted for Use ( ) Unsatisfactory

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: POSTAL Software Version No.: 3.0

18. Disposition (include HISI update):

Installation added to HISI registry. -WE Nichols

Prepared By:

19.	Software Owner (Signature)	William E Nichols (Print)	7 MAR 2018 (Date)

20. Test Personnel:

	Sign	N. Powers (Print)	7 Mar 2018 (Date)
	Sign	Print	Date
	Sign	Print	Date

Approved By:

21.	Software SME (Signature)	N/A (CHRPC-3486) (Print)	Date

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