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BASELINE PARAMETER UPDATE FOR HUMAN HEALTH INPUT AND TRANSFER FACTORS FOR RADIOLOGICAL PERFORMANCE ASSESSMENTS AT THE SAVANNAH RIVER SITE

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYMS

CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CSFII	Continuing Survey of Food Intakes by Individuals
DOE	Department of Energy
EPA	Environmental Protection Agency
EFH	Exposure Factors Handbook
GSA	General Separations Area
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
HLW	High Level Waste
LLW	Low Level Waste
MEI	Maximum Exposed Individual
NCRP	National Council on Radiation Protection and Measurements
NDAA	National Defense Authorization Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NRC	Nuclear Regulatory Commission
PA	Performance Assessment
RESRAD	RESidual RADioactivity
SRS	Savannah River Site
PNNL	Pacific Northwest National Laboratory
ORNL	Oak Ridge National Laboratory
USA	United States of America
USDA	United States Department of Agriculture

ABBREVIATIONS

Bq	becquerel
cm	centimeter
Ci	curie
d	day
ρ	bulk density
hr	hour (s)
kg	kilogram
L	liter
m	meter
mg	milligram
mL	milliliter
p	pico
Sv	sievert
yr	year

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1.0 PURPOSE

The purpose of this report is to update parameters utilized in Human Health Exposure calculations and Bioaccumulation Transfer Factors utilized at the Savannah River Site (SRS) for Performance Assessment modeling. The reason for the update is to utilize more recent information issued, validate information currently used and correct minor inconsistencies between modeling efforts performed in SRS contiguous areas of the heavy industrialized central site usage areas called the General Separations Area (GSA). SRS parameters utilized were compared to a number of other DOE facilities and generic national/global references to establish relevance of the parameters selected and/or verify the regional differences of the southeast USA. The parameters selected were specifically chosen to be expected values along with identifying a range for these values versus the overly conservative specification of parameters for estimating an annual dose to the maximum exposed individual (MEI).

The end uses are to establish a standardized source for these parameters that is up to date with existing data and maintain it via review of any future issued national references to evaluate the need for changes as new information is released. These reviews are to be added to this document by revision.

1.1 Report Structure

Section 2.0 provides background information on the dose estimates for performance assessments at SRS. The remaining sections of this report describe physical human health input parameters (Section 3.0), consumption rates (Section 4.0) and element-specific transfer factors (Section 5.0) for these analyses and discusses differences in updates to these factors.

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2.0 INTRODUCTION

SRS generates Performance Assessments in order to demonstrate compliance with environmental performance objectives including annual radiological doses and groundwater concentrations. Performance Assessment modeling accounts for many aspects of environmental transport modeling including water infiltration through a closure cap and waste form, contaminant releases to the infiltrating water and contaminant transport through the aquifer system(s).

Once groundwater contaminant concentrations are calculated at any location of interest, the contaminant concentrations may need to be converted to an annual radiological dose. There are two categories of doses: dose to a member of the public who is assumed to live or perform activities outside of the controlled buffer zone around a disposal site and dose to an intruder who is assumed to intrude within the disposal site and perform activities. While these are two different types of activities, similar exposure pathways may be used for both categories of dose calculations. The pathways may not require any additional calculations beyond the groundwater contaminant concentrations as in the case of groundwater ingestion. Other pathways will require several layers of calculations as in the case of milk ingestion in which the groundwater contaminant concentrations must be used to calculate fodder contaminant concentrations due to irrigation by contaminated groundwater and transfer of contaminants to the milk from the contaminated fodder ingestion. These calculations use parameters referred to as bioaccumulation and transfer factors to calculate contaminant concentrations via a variety of environmental mechanisms.

Once contaminant concentrations are known in the various environmental media, human consumption of the environmental media can be used to calculate annual radiological doses based on the use of consumption factors. These consumption factors include items such as the amount of groundwater ingested in a day or amount of beef eaten in a year. The assessment of groundwater transport and contaminant concentrations, bioaccumulation factors for environmental media contaminant concentrations and human consumption factors allow the determination of annual radiological doses for comparison to performance objectives.

The values given for the parameters are usually given as ‘expected’ values together with an observed range rather than values for a MEI calculation.

A similar calculation path is performed for airborne releases of contaminants into the air and then their disposition on the soil and plant surfaces. Any significant contribution from this pathway may be added to the groundwater dose calculations.

This report considers parameters and factors used in the air and waterborne pathways associated with the All Pathways and Inadvertent Intruder Analyses for radiological performance assessments at SRS.

2.1 Pathway Modeling

Dose modeling is performed to estimate radiological dose to human receptors in the all-pathways (public release) analysis, the inadvertent intruder analysis and the air pathway analysis.

The all pathways, inadvertent intruder, and air pathway analyses require the use of physical parameters, pathway-specific usage parameters, and bioaccumulation factors. This report provides brief descriptions of these parameters and factors, their current use, and provides recommendations for updates recommending the use of site-specific values when available. If site-specific values are not available then the recommendations use the most recent regional and global values available. Where available, value ranges and distributions are provided for sensitivity and uncertainty analyses. Value ranges are based on those provided in the referenced literature from the hierarchy and the value ranges used at other DOE facilities.

2.1.1 All Pathways Modeling

The all-pathways dose methodology in the application described in Koffman (2006a) is based on the methodology presented in (NRC 1977). This application calculates the impacts from transport of radionuclides from disposed waste in groundwater and facilitates calculation of disposal limits, based on an assumed unit concentration in groundwater as well as calculation of total dose from all radionuclides disposed if a known or projected inventory at closure is available.

Annual dose to a member of the public (all-pathways dose) at SRS is estimated for various exposure pathways. Brief description of exposure scenarios and the associated potential exposure pathways are as follows.

In an all pathways groundwater well dose analysis, a member of the public is assumed to use water from a well for domestic purposes and assumed to be exposed through the following pathways:

- Direct ingestion of well water
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that drink well water
- Ingestion of vegetables grown in garden soil irrigated with well water
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that eat fodder from pasture irrigated with well water.

Secondary and indirect pathways that are expected to contribute relatively minor doses when compared to direct pathways (such as ingestion of milk and meat) include:

- Inhalation of well water used for irrigation
- Ingestion and inhalation of well water while showering
- Inhalation of dust from the soil that was irrigated with well water
- Ingestion of soil that was irrigated with well water
- Direct radiation exposure from radionuclides deposited on the soil that was irrigated with well water.

In an all pathways surface water dose analyses, a member of the public is assumed to use water from the closest surface water for domestic and recreational purposes. Dose due to domestic use of surface water is assumed to occur through the following exposure pathways:

- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that drink surface water
- Ingestion of vegetables grown in garden soil irrigated with surface water
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that eat fodder from pasture irrigated with surface water

Dose from recreational use of contaminated surface water is assumed to occur through the following pathways:

- Direct irradiation during recreational activities (e.g., swimming, fishing) from surface water

- Dermal contact with surface water during recreational activities (e.g., swimming, fishing)
- Incidental ingestion and inhalation of surface water during recreational activities
- Ingestion of fish from the surface water.

Secondary and indirect pathways that are expected to contribute relatively minor doses when compared to direct pathways such as ingestion of milk and meat include:

- Inhalation of surface water used for irrigation
- Inhalation of dust from the soil that was irrigated with surface water
- Inhalation of gaseous radionuclides released from the soil that was irrigated with surface water
- Ingestion of soil that was irrigated with surface water
- Direct radiation exposure from radionuclides deposited on the soil that was irrigated with surface water.

2.1.2 Inadvertent Intruder Modeling

Intruder analysis estimates are performed to determine radionuclide disposal limits that would bound the impacts on hypothetical individuals assumed to inadvertently access the disposal site. Equations used to estimate dose in this application are documented in Koffman (2006b).

Potential exposure scenarios for estimating annual does to an inadvertent intruder include the acute intruder-drilling scenario, acute intruder-construction scenario, acute intruder-discovery scenario, chronic intruder agricultural (post-drilling) scenario, chronic intruder-resident scenario, and the biointrusion scenario. Brief descriptions of exposure scenarios and the associated potential exposure pathways are as follows.

The Acute Intruder-Drilling Scenario assumes the short-term exposure of a hypothetical intruder to drill cuttings from a borehole penetrating the waste disposal site. This scenario involves wastes buried below the depth of typical construction excavations. The acute drilling scenario assumes that an inadvertent intruder drills a well into ancillary equipment, in this case a transfer line and is exposed to contaminated drill cuttings spread over the ground and contaminated airborne dust.

The exposure pathways for this acute drilling scenario include:

- Inhalation of resuspended drill cuttings
- External exposure to the ground source
- Inadvertent soil ingestion.

The Chronic Intruder Agricultural (Post-Drilling) Scenario is an extension of the acute intruder drilling scenario. It is assumed in this scenario that an intruder lives in a building near the well drilled as part of the intruder-drilling scenario and engages in agricultural activities on the contaminated site. The soil is assumed to be contaminated by both drill cuttings and contaminated irrigation water.

The intruder is exposed to:

- Direct ingestion of well water
- Ingestion and inhalation of well water while showering
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that drink well water

- Ingestion of vegetables grown in garden soil irrigated with well water and containing drill cuttings
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that eat fodder from pasture irrigated with well water and containing drill cuttings
- Inhalation of well water used for irrigation
- Inhalation of dust from the soil that was irrigated with well water
- Ingestion of soil that was irrigated with well water
- Direct radiation exposure from radionuclides deposited on the soil that was irrigated with well water.

2.1.3 Air Pathway Modeling

The air pathway analysis model, CAP88, is used to estimate dose to the MEI and therefore requires the use of MEI input parameters. Exposure parameters used in CAP88 V1.0 are described briefly in Lee (2001) and are taken primarily from Hamby (1991 and 1992). Bioaccumulation factors are listed in the model input documented at http://www.epa.gov/rpdweb00/assessment/CAP88/index.html in the CAP88 Mainframe User's Manual.

Members of the public and intruders may be exposed to releases of radionuclides into the air from groundwater wells and surface water (i.e., volatile radionuclides such as H-3, C-14, I-129) are exposed through:

- Direct plume shine
- Inhalation
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that were exposed to airborne radioactivity
- Ingestion of vegetables grown in garden soil exposed to airborne radioactivity
- Ingestion of milk and meat from livestock (e.g., dairy and beef cattle) that eat fodder from pastures that were exposed to airborne radioactivity.

2.2 Literature Review

Numerous studies have been reviewed to update and baseline human health exposure parameters and quantify transfer factors for specific chemical elements as a function of food type. These studies have been compiled in several publications. Most computer codes reference one or more of these compilations as the source of their transfer factors.

2.2.1 Human Health Exposure Parameter

Site-specific information is available for most of the human health exposure parameters required to estimate doses. Hamby (1991) surveyed county agents in South Carolina and Georgia and compiled county-specific statistics on land and water use within a 50-mile radius of SRS. These data were peer reviewed and published in Hamby (1992). Recent efforts are ongoing to update these data including a recent update to the survey to reflect comments received by county agents.

Where Hamby and other site- or regional- specific studies (i.e. CDC Dose Reconstruction Study) do not provide site-specific information for physical parameters and consumption rates, global data are used. Yu et al. (1993 and 2001) provided data for use in RESRAD, a NRC and DOE supported dose model, based on literature review of standard values and publications. The EPA Exposure Factors Handbook (EPA 1997) summarizes and recommends human health exposure parameter data for human exposure to environmental contaminants based on studies published through August 30, 1997. (Kennedy and Strenge 1992) provides generic and site-specific human health data for estimating dose from exposure to residual radioactive contamination. The general hierarchy of the national data use is listed below:

#1. Hamby (1991and 1992) – site-specific

#2. Other site- or regional- specific publications

#3. EPA Exposure Factors Handbook (EPA 1997)

#4. RESRAD Version 6 (Yu et al. 2001)

#5. NUREG/CR-5512 (Kennedy and Strenge 1992)

Isolated situations where other sources of data are used that do not follow the hierarchy listed above are identified in the text.

2.2.2 Bioaccumulation Data

Several frequently referenced compilations of element-specific transfer factors include the International Atomic Energy Agency's Technical Report Series #364, *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments* (IAEA 1994). This document encompasses a wide variety of plant types and is the result of extensive background investigations. It is based on data compiled by the International Union of Radioecologists. A second frequently cited reference is the NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent* (Kennedy and Strenge 1992) because of its large set of data and traceable references. Other references include the National Council on Radiation Protection and Measurements (NCRP) Report #123 (1996), *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground*, and the series of documents by Coughtrey and Thorne (1983), *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems, Vols. 1-6*.

A recent compilation of reviews was determined to contain a hierarchy utilizing the more recent and relevant literature references and the document was reviewed and determined adequate to document a baseline for transfer factors. After extensive review of the above references, SRS has decided to incorporate PNNL-13421 (Staven et al. 2003) into the site hierarchy of transfer value tables for input parameters to SRS performance assessments. PNNL 13421, *A Compendium of Transfer Factors for Agricultural and Animal Products,* was issued June 2003. This document was developed in conjunction with the upgrade to the GENII system of computer codes. The GENII computer code was developed to incorporate the internal dosimetry models recommended by the International Commission on Radiological Protection (ICRP) and the radiological risk estimating procedures of Federal Guidance Report 13 into updated versions of existing environmental pathway analysis models. GENII and the Windows compatible GENII-Version 2 provide state-of-the art, technically peer-reviewed, and documented set of programs for calculating radiation dose and risk from radionuclides released to the environment. Upgrading the codes to GENII-Version 2 provided the opportunity to update and further document the library of transfer factors that support the environmental pathway analyses. Table 2-1 lists the hierarchy of sources of bioaccumulation data used for this report and its source as well as other DOE sites.

In general, site-specific values were used without modification where appropriate. When recent generic compilations were used and the differences were larger than two orders of magnitude, a geometric mean of the generic updated value and the currently used value was selected as a method for averaging the ratios (Wilkipedia 2006).

Table 2-1. Hierarchy of Reference Used for Bioaccumulation Sources

	Literature					SRS			Other DOE Sites PA	
	Staven et al. 2003*	Baes and Sharp 1984†	Kennedy and Strenge 1992‡	NRC 1977§	CDC 2006	Koffman 2006; Lee 2004**	Jannik and Dixon 2006††	This Document‡‡	Hanford 2004§§	Idaho 2003***
	PNNL-13421 9/03	ORNL - 5786 9/04	NUREG/CR-5512, Vol. 1	Reg Guide 1.109	SRS Dose Reconstruction 9/06	SRS Intruder Application	SRS LADTAP Application	SRS Future Baseline	Hanford Tank Waste PA June	Idaho 4/03
#1	IAEA-364 1994	RG 1.109	IUR sixth working group 1989	Site Specific	Site Specific Hamby/ Friday	Hamby 1992 Site specific	RG 1.109 1977	Site Specific Hamby/Friday	PNWD-2023 (1994) Hanford Environmental Dose Reconstruction Project	Site Specific Yucca Mtn Maheras 1997
#2	NUREG/CR-5512 1992	TERRA Code	IAEA 364	UCRL-50163 Prt IV 1968	IAEA-364	ORNL-5786 Baes and Sharp 1984	RESRAD Yu et al. 2001	PNNL-13421 2003	IAEA-364	Baes/Ortin 1979
#3	NRCP 123 1996		Cf- Strenge 1987		GenII Default	RG 1.109 1977	ORNL-5786 Baes and Sharp 1984	ORNL-5786 Baes and Sharp 1984	ORNL-5786 Baes and Sharp 1984	ORNL-5786 Baes and Sharp 1984
#4	GENII Code Napier 1988							NCRP 1996 (#123)	NUREG/CR-5512	
#5	Coughtrey/ Thorne Vol 1-6 1983								NCRP 1996 #123	

* Prepared as part of GENII-Version2 Upgrading
† Review/Analysis Parameters for Transport of Released Radionuclides Through Agriculture
‡ Residual Radioactive Contamination from Decommissioning
§ Regulatory Guidance Calculation of Annual Doses from Routine Reactor Releases
** Automated Application Excel Calculation Intruder Dose
†† Excel Application Environmental Dose Assessment Maximum Exposed Individual
‡‡ PA Input for SRS facilities
§§ Hanford Tank Farm PA
*** Idaho Tank Farm PA

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3.0 PHYSICAL HUMAN HEALTH EXPOSURE PARAMETERS

Physical parameters required for evaluating pathway-specific dose for performance assessments are areal and physical density of soil; atmospheric mass loading of soil particulates while working in garden and residing in home; depth of garden, rate of irrigation for garden; fraction of the year that crops are irrigated; weathering removal rate constant for crops, time periods that soil (buildup time), crops and pasture are exposed to irrigation; pasture grass, agricultural and vegetable crop yields; area of garden; fractional retention of deposition on leaves; and erosion rate. Many of these parameters are generic in nature and are based on industry recommendations.

This report provides updates for continued use of some parameters listed and provides some background for site-specific parameters and those where updates are provided. A summary of current and updated productivity and physical parameters are listed in Table 3-1 and Table 3-2, respectively. These factors for all references considered are listed in APPENDIX A. Where available, probability distributions and associated parameters taken from the literature are provided in the text.

3.1 Exposure Time to Irrigation

Exposure time to irrigation represents the period of time crop, leafy vegetable or pasture grass is exposed during the growing season. NRC (1977) recommends 720 hours (30 days) pasture grass exposure time and 1440 hours (60 days) for crop/vegetation. Simpkins and Hamby (2003) recommend a normal distribution for pasture and crop exposure times with a mean of 70 d and standard deviation of 7 d.

3.2 Crop Yields

Hamby (1991) surveyed 21 county extension agents in Georgia and South Carolina to estimate the average mass, in kilograms, of vegetation harvested in a typical square meter of garden or farmland within a 50-mile radius of SRS. Crop yields in kg/m^2 were estimated for leafy vegetation (cabbage, lettuce and spinach) and other aboveground vegetables (broccoli, cauliflower, green peas, lima beans, and sweet corn). Average agricultural, garden, and pasture grass productivity for farms in the 50-mile region is estimated to be 0.7 kg/m^2, 0.2 kg/m^2 and 1.8 kg/m^2, respectively. Because the garden productivity was estimated to be an order of magnitude lower than the NRC default (NRC 1977), Hamby (1991) assumed the garden productivity is to be equal to agricultural productivity. This report recommends use of the site-specific value of 0.7 kg/m^2 as the expected value for garden productivity, and the 0.2 kg/m^2 should be considered in the uncertainty range. Simpkins and Hamby (2003) recommend lognormal distribution of crop yields with a mean of 0.6 and geometric standard deviation of 1.4.

3.3 Fraction of Foodstuff Intake from Garden

The current assumption of the fractions of vegetables, milk, and meat intake that is from a local garden were based on NRC (1977), professional judgment, and Yu et al. (2001) which considers the 0.5 fraction of vegetable intake to be a maximum value. Table 13-71 of the EPA EFH (EPA 1997) provides regional values for vegetables, milk, and meat intake fractions and scenario-specific values. This report recommends use of the values provided in EPA (1997) for households with gardens who raise animals for an all pathways analysis and those for households who farm for an intruder analysis.

3.4 Area of Garden

The garden size of 100 m^2 for a family of four is assumed in SRS PAs and is based on a site-specific evaluation of consumption needs and annual productivity. It is assumed that a well would not be drilled for a single individual but rather for a household that includes at least two adults. As will be discussed in Section 4.4, Hamby (1991) estimated that a person within a 50 mile radius of SRS consumes 184 kg of vegetables annually. Section 3.1 discusses the average garden vegetable yield of 0.2 kg/m^2 but recommends the use of the agricultural 0.7 kg/m^2 as in Hamby (1991). A garden size of 260 m^2 would be required to support the annual consumption of 184 kg of vegetables for a household with two adults assuming all vegetables consumed by the adults are from their garden. Assuming that only 17% of a person's vegetables are from their home garden (EPA 1997), roughly 100 m^2 would be required to feed a family of four. This report recommends use of the 100 m^2 garden size for vegetables only. However, this area is not large enough to graze livestock. Yu et al. (2001) states that an area of 1 ha (10,000 m^2) is required to graze a single milk cow.

3.5 Soil Exposure Time Period

For soil exposure time period to irrigation (buildup) Jannik and Dixon (2006) recommend 40 yrs to indicate the life time of a facility releasing radionuclides and ½ of a MEI lifetime assuming the MEI is exposed at that location for their lifetime. For the intruder and public scenario, it is assumed that the irrigation and harvesting of vegetables occur during the first year of residence, yielding the 183 d updated value. An updated maximum value of 365 d is recommended here assuming the entire MEI lifetime. However, if the exposure continues throughout the period of residence, a lifetime of exposure of 30 yrs would yield a 5458 d maximum.

3.6 Areal Density of Soil

The areal soil density is estimated by applying the assumed 0.15 m garden depth to the 1600 kg/m^3 soil density yielding a 240 kg/m^2 areal density. Simpkins and Hamby (2003) recommend a normal distribution with a standard deviation of 17 $kg.m^2$.

Table 3-1. Updated Crop Exposure Times and Productivity

Parameter	SRS Current Values	Reference	Update Value*		Reference	Min	Max
Pasture exposure time to irrigation (d)	30-60	NRC 1977	30		NRC 1977	30	90
Vegetable crop exposure times to irrigation(d)†	70	Hamby 1991	N/A			60	90
Soil exposure time period to irrigation (d) (Buildup time in soil)	182-365	Scenario-specific‡	183		Scenario-specific	60	365
Productivity							
Pasture grass (kg/m^2)	1.8-2	Hamby 1991/NRC 1977	1.8		Hamby 1991	0.7	2
Agricultural (vegetable) (kg/m^2)	0.7-2	Hamby 1991/NRC 1977	0.7		Hamby 1991	0.5	4
Vegetable crop yield (kg/m^2)	0.7-2	Hamby 1991/NRC 1977	0.7		Hamby 1991	0.2	4
Fraction of Foodstuff Produced Locally			All Pathway	Intruder			
Vegetables	0.5-1	Yu et al. 2001/NRC 1977	0.173	0.308	EPA 1997§	0	0.5
Meat	1	Yu et al. 2001/NRC 1977	0.306	0.319	EPA 1997§	0	0.5
Milk	1	Yu et al. 2001/NRC 1977	0.207	0.254	EPA 1997§	0	0.5
Dilution Factor for mixing of waste in vegetable garden							
Agricultural scenario	0.2	Napier et al 1984		N/A		0.2	0.2
Post-Drilling Scenario	0.02	McDowell-Boyer et al. 2000**		N/A		0.002	0.02

* N/A - no update recommended
† average growing time for above ground vegetables
‡ Assumes intruder and public assumed to irrigate and grow vegetables during first year of residence allowing a maximum buildup time of 1 yr. The updated value is ½ that.
§ Table 13-71. Assumes member of the public (all pathways) has a garden ('households who garden') and the intruder has a farm ('households who farm').
** Based on professional judgment and conservative relative to value used at Oak Ridge.

Table 3-2. Updated Physical Parameters

Parameter	SRS Current Values	Reference	Update Recommendation			
			Value*	Reference	Min	Max
Areal density of soil (kg/m^2)	240	Hamby 1993b	N/A		180	270
Soil Density (kg/m^3)	1,400†	Baes and Sharp 1983	1,600	Hamby 1993a	1350	1600
Atmospheric mass loading of soil (kg/m^3)						
while working in garden	1.00E-07	McDowell-Boyer et al. 2000‡	N/A		1.0E-08	3.0E-07§
while residing in home**	1.00E-08	McDowell-Boyer et al. 2000‡	N/A		1.0E-09	3.0E-08
Depth of garden (cm)	15	Hamby 1993a	N/A		15	61
Garden irrigation rate (L/d/m^2)	3.4††	Hamby 1993b	3.6††	Hamby 1993b	2.08	5.5
Fraction of the yr that crops are irrigated	0.2	estimated (70/365)	N/A		0.2	0.25
Crop weathering constant (L/d)	0.0495‡‡	NRC 1977	N/A		0.03	0.0495
Fractional retention of deposition on leaves	0.25§§	NRC 1977	N/A		0.2	0.25***
Area of garden for family of four (m^2)	1,000	Based on Section 3.4 estimate†††	100	Based on Section 3.4 estimate	100	1000

* N/A - no update recommended.
† Value in Baes and Sharp (1983) is 1350 and is assumed to be rounded up to 1400.
‡ Based on professional judgment and consistent with literature which recommends a wide range of values.
§ RESRAD value for agricultural generated dust.
** Ranges for home are assumed to be one order of magnitude lower than that for garden.
†† Based on an assumption of 1 in/wk = 0.36 cm/d. For a 1 m^2 area, 0.36 cm/d x 10,000 cm^2/m^2 x 1L/1000 cm^3=3.6 L/d/m^2. Assumed to have been rounded over time. Updated value eliminates rounding errors. Maximum value assumes 0.5 cm/d irrigation.
‡‡ Based on 14 day half life for removal of activity from plants. 0.0021 hr^{-1} reported in NRC (1977): 0.693/14 d = 0.495 d^{-1}*1 d/24 hr=0.0021 hr^{-1}.
§§ NRC (1977) recommends 1 for iodine's and 0.2 for other particulates.
*** Must use 1 as max for iodine. If model not able to handle iodine separately, must use 1 for all.
††† assumes 0.2 kg/m^2 productivity.

4.0 CONSUMPTON RATES

Consumption rates currently used at SRS and updated parameter values required for evaluating dose for the various exposure pathways are listed in Table 4-1. Parameters may vary with exposure scenario and are footnoted where different values are updated by a scenario.

Site-specific human health exposure parameters are available. In some cases, these values were being employed for the all pathways and inadvertent intruder analyses. However, in many cases the values employed are for the MEI. These recommendations are for the use of expected parameter values versus the conservative use of MEI parameters.

Usage parameters evaluated that are updated include water, vegetable, soil, and foodstuff consumption rates. These adjustments are based primarily on the availability of site-specific information and the use of conservative MEI parameters based on model defaults. Recommendations here attempt to advise the use of expected or average rates. These updated rates and suggested ranges for sensitivity and uncertain analyses are listed in Table 4-1. Values evaluated from other sources and used at other DOE facilities are listed in Table A-3. Value ranges are based on those provided in the referenced literature from the hierarchy and the value ranges used at other DOE facilities. Where available, probability distributions and associated parameters taken from the literature are provided in the text.

4.1 Water Ingestion

Ingestion of water is a key usage factor for the all pathway and inadvertent intruder analyses. The rate of contaminated water consumption can vary by exposure scenario based on assumed access to the water supply. For the inadvertent intruder where the contaminated water is expected to come from a well an assumption can be made that water from the well is only used for cooking. Likewise, for the all pathway analyses the assumption could be made that total water intake comes from the community water supply. However, in the absence of site- and/or regional-specific surveys, national estimates are appropriate.

4.1.1 SRS Water Ingestion

The RESRAD (Yu et al. 2001) 511 L/yr (1.4 L/d) average water ingestion rate updated for use in the all pathway analysis is based on EPA surveys published in the early 1990s. The 730 L/yr (2 L/d) water ingestion rates for the inadvertent intruder are taken from Hamby (1992) and are based on NRC (1977) rates for the MEI. The average rate for ingestion of drinking water listed in those sources is 370 L/yr (1 L/d). These publications consider indirect ingestion of water but do not consider whether or not the water is bottled or comes from a community or commercial source.

4.1.2 Water Ingestion Update

EPA (2004) estimates per capita ingestion of water using data from the combined 1994, 1995, 1996, and 1998 Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the United States Department of Agriculture (USDA). This publication considers indirect ingestion of water from food with water added at the final phase of food preparation and reports water consumption from community water, bottled water, water from other sources, missing source, and total water. Summary data found in the Executive Summary (pages vii-viii) provide a 337 L/yr water ingestion rate.

Table 4-1. Updated Individual Exposure Times and Consumption Rates

Parameter	SRS Current Value	Update Recommendation			
		Value	Reference	Min	Max
Breathing rate (m^3/yr)	8000	5,548	EPA 1997	1,267	11,600
Consumption Rate					
Soil (kg/yr)	0.0365	0.0365[*]	EPA 1997	0.0008	0.05
Leafy vegetable (kg/yr)	14-21	21[†]	Hamby 1992	18	43
Other vegetable (kg/yr)	160-163	163[†]	Hamby 1992	90	276
Meat (kg/yr)	63	43	Hamby 1992	26	81
Finfish (kg/yr)	9	9[‡]	Hamby 1992	2.2	19
Seafood (kg/yr)		0[§]	Hamby 1992	0	5
Milk (L/yr)	92	120	Hamby 1992	73.7	230
Water (L/yr)	511-730	337	EPA 2004	184	730
Fodder-Beef cattle (kg/d)	50	36	Hamby 1991	27	50
Fodder-Milk cattle (kg/d)	50	52	Hamby 1991	36	55
Fraction of milk-cow intake from pasture	1	0.56	Hamby 1992	0.5	1
Fraction of beef-cow intake from pasture	1	0.75	Hamby 1992	0.5	1
Water (beef cow) (L/d)	50	28	Hamby 1993b	28	50
Water (milk cow) (L/d)	60	50	Hamby 1993b	50	60
Exposure Time					
Shoreline (hr/yr)	23	23	Hamby 1991	11	35
Swimming (hr/yr)	8.9	8.9	Hamby 1991	8.9	13
Boating (hr/yr)	21	21	Hamby 1991	9.1	31.5
Showering (min/d)		10	EPA 1977	10	30
Fraction of yr working in garden (/yr)	0.01	0.01	Oztunali et al. 1981	0.01	0.08
Fraction of yr residing in home (/yr)	0.5	0.7	EPA 1997	0.3	0.7
Fraction of time cattle on pasture (/yr)	1	1	Hamby 1991	0.75	1
Transport (d)					
Vegetables	14	6	Yu et al. 2001	6	14
Feed-milk-man transport time	3	3	Hamby 1991	1	4
Time from slaughter to consumption	6	6	Hamby 1991	6	20

[*] Converts to 100 mg/d child ingestion rate in EFH recommended for use for the agricultural scenario. Other scenarios should use the 0.019 kg/yr EFH adult intake rate
[†] Intruder leafy and non-leafy vegetables are typically combined (184 kg/yr total) and assume 31% of vegetable intake is from their garden (Table 3-1) yielding a 57 kg/yr input.
[‡] Only valid if it is assumed that a pond is built at the location or and offsite assessment is done well beyond the 100-m.
[§] Value of 2 should be used if the dose is to a person downriver (i.e. Savannah area).

According to EPA (2004), direct water is plain water ingested directly as a beverage and indirect water is water added to foods and beverages during final preparation at home, or by food service establishments such as school cafeterias and restaurants. An example of indirect water is water added to dry cake mix. Community water is tap water from the community water supply; bottled water is purchased plain water; other water is water obtained from a well or rain cistern (household's), spring (household's or public), or other source; and preparation water is water used to prepare foods and includes the water used to prepare foods at home and by local food service establishments (indirect water), as well as, water added by commercial food manufacturers. Missing water source indicates that a survey participant responded "don't know" or "not ascertained" to the survey question regarding the source of water and total water is the sum of direct and indirect water from all sources which includes community water, bottled water, other water and missing sources.

EPA (2004) reports the mean per capita total water ingestion is 1,233 mL/person/d (450 L/yr) when viewed across genders and all age categories with 75% from community water, 13% from bottled water, 10% from other sources (well, spring and cistern, etc.), and 2% from non identified sources. This yields a mean of 924 mL/person/d (337 L/yr) from community water and 12.3 mL/person/d (4.5 L/yr) from other sources (well water).

This report recommends the use of 337 L/yr for all pathway and inadvertent intruder analysis. The recommendation for the inadvertent intruder stems from the agricultural exposure scenario where it is assumed that all of the person's domestic water is from the well. Therefore, it is not reasonable to assume the 4.5 L/yr EPA (2004) value stated above for other sources as it assumes this is only a portion of a person's water.

4.2 Soil Ingestion

Incidental ingestion of contaminated soil is a key usage parameter for the inadvertent intruder analyses. This parameter is expected to vary by exposure scenario based on the frequency of exposure to the contaminated soil.

4.2.1 SRS Soil Ingestion

The 0.037 kg/yr (100 mg/d) ingestion rate used in the inadvertent intruder analysis is the value recommended for a child in EPA (1997). This document recommends 50 mg/d (0.019 kg/yr) for an adult in industrial settings but 100 mg/d for agricultural scenarios. The current all pathways analysis does not consider ingestion of soil irrigated with contaminated water. Suggested values for that pathway if included can be found in Table 4-1.

4.2.2 Soil Ingestion Update

The 0.037 kg/yr (100 mg/d) soil ingestion rate used in the inadvertent intruder analysis is the value recommended for a child in EPA (1997). This document recommends 50 mg/d (0.019 kg/yr) for adults in an industrial setting. The 0.037 kg/yr used for the agricultural scenario is reasonable since a permanent homestead is assumed with an extensive amount of time spent gardening.

Consideration of this pathway for a member of the public in future performance assessments would allow for a reduced soil ingestion rate based on the limited amount of time that the public would spend exposed to the contaminated soil.

4.3 Inhalation Rate

Inhalation of air can vary by exposure scenario based on the expected level of activity. However, for the all pathways and inadvertent intruder analyses they are expected to be similar.

4.3.1 SRS Inhalation Rate

The current inhalation rate used is 8000 m^3/yr which is the breathing rate recommended in NRC (1977) and is derived from data provided in ICRP-23 (ICRP 1974).

4.3.2 Inhalation Rate Update

The inadvertent intruder analysis uses the 8000 m^3/yr breathing rate recommended in NRC (1977) and derived from ICRP (1974). According to EPA (1997), the mean adult female and male breathing rate for long-term exposures are 4113 m^3/yr (11.3 m^3/d) and 5548 m^3/yr (15.2 m^3/d), respectively. This report recommends the 5548 m^3/yr inhalation rate for use in SRS performance assessments for long-term exposure scenarios. For this report, a person is assumed to spend 10% of their time outdoors at the heavy activity level. (2.5 m^3/hr). Of the 90% spent indoors, assuming an activity mix of 20% at a moderate activity level (1.5 m^3/hr), a combined 70% at resting and light activity levels (1.1 m^3/hr), 11,600 m^3/yr is assumed to be the maximum breathing rate. Activity level breathing rates are taken from EPA (1997). Hamby (1993c) recommends a normal distribution with a mean of 8,500 m^3/yr and a 1700 m^3/yr standard deviation.

If acute scenarios are addressed, short-term inhalation rates from EPA (1997) should be employed. According to EPA (1997) an adult performing light or moderate activities for a short period of time would breathe at a rate of 1 m^3/hr (8760 m^3/yr) and 1.6 m^3/hr (14,016 m^3/yr), respectively.

4.4 Foodstuff Consumption

For the inadvertent intruder, vegetable, milk and beef consumption rates are taken from Hamby (1992). These values are based on county specific statistics provided by the counties within the states of South Carolina and Georgia that fall within a 50-mile radius of SRS. This report recommends continued use of Hamby (1991 and 1992) as a reference for these values as they are based on a site-specific evaluation. However, this report recommends use of average values for performance assessment where the MEI values are currently used in some cases.

Simpkins and Hamby (2003) recommend a lognormal distribution for food consumption rates with a 19 kg/yr mean and 2 kg/yr geometric standard deviation for leafy vegetables consumption, 150 kg/yr mean and 2 kg/yr geometric standard deviation for consumption of other vegetables; 90 kg/yr mean and 1.8 kg/yr geometric standard deviation for beef consumption; and 140 kg/yr mean and 2.2 kg/yr geometric standard deviation for consumption of milk.

4.5 Beef and Milk Cow Consumption Rates

Beef and milk cow annual consumption of fodder and water are taken from Hamby (1991 and 1992). Hamby (1993) recommends a standard deviation of 8 kg/d and 11 kg/d for the fodder beef and milk cow consumption, respectively.

4.6 Exposure Times

Recreational usage exposure times are taken from Hamby (1991 and 1992). According to Hamby (1991 and 1992), the NRC recommends increasing average by 50 % to get maximum values. For the external and inhalation exposure pathways, Oztunali et al. (1981) determined that the inadvertent intruder person spends 1% of the year working in a garden (~100 h/yr) and 50% of the year in their (~4000 hr/yr) residence. This report maintains the 0.01 time spent working in garden but adopts 16.4 hr/d. (5,986 hr/yr) time spent inside provided by EPA (1997) that assumes a person spends 70% of the year in their home. A 10 min/d showering exposure time was taken from EPA (1997).

The fraction of the year that cattle spend in pasture is based on a site-specific survey documented in Hamby (1991). Simpkins and Hamby (1993) recommend a uniform distribution for cattle exposure fractions with a range from 75 to 100 percent.

4.7 Food Transport Times

The recommended amount of time that it takes for transport of vegetables from harvest to the consumer is taken from Yu et al. (2001). Simpkins and Hamby (1993) recommends a normal distribution for the vegetable transport time with a mean of 1 d (leafy) and 6 d (other vegetables) and 0.1 d (leafy) and 0.6 d (other vegetables) standard deviations. Milk and beef transport times are taken from Hamby (1991). Simpkins and Hamby (1993) recommends lognormal distribution for milk and beef with 3 d mean and 1.5 d geometric standard deviation for milk and 6 d mean and 1.4 d geometric standard deviation for beef.

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5.0 BIOACCUMULATION FACTORS

For performance assessments at SRS, soil-to-vegetable (also known as soil-to-plant ratios, plant-to-soil ratios), feed-to-milk, feed-to-beef and water-to-fish transfer factors are the bioaccumulation factors considered. Soil-to-vegetable transfer factors determine the fraction of an element that is drawn from the soil into the edible plant. Feed-to-milk transfer factors represent the nuclide fraction transferred from fodder to milk. Feed-to-meat transfer factors represent the nuclide-specific fraction transferred from fodder to beef. Water-to-fish transfer factors are the equilibrium ratios between concentration in aquatic foods and concentration in water.

Current bioaccumulation factors used in SRS performance assessments and their sources are discussed in subsequent sections. This report recommends updating the factors using site-specific values when available but considers Staven et al. (2003) to be the most recent comprehensive evaluation of bioaccumulation factors and recommends this as the secondary source of values. Where bioaccumulation factors are not available in Staven et al. (2003), older sources are referenced in the following order: Kennedy and Strenge (1992), Baes et al. (1984), and NCRP (1996), currently used value (typically NRC [1977]).

Along with discussion on current factors used, updated element-specific bioaccumulation factors for select elements are listed in subsequent sections. For brevity, the text of this report focuses on a select list of radionuclides important to SRS performance assessments. A comprehensive list of recommended bioaccumulation factors are listed in APPENDIX B.

5.1 Soil-to-Vegetable Transfer Factors

Element-specific soil-to-vegetable transfer factors are ratios of the fraction of contaminant concentration in soil (Bq/kg soil) that would be transferred into vegetable roots (Bq/kg vegetable). Soil-to-vegetable transfer factors for the various elements are based primarily on published evaluations and compilations and model defaults which are generic in nature, with some elements based on site-specific information. The use of data from these sources was based on scientific judgment and ensures consistency among the adopted values. For the most part, it is assumed that vegetable consumption in the SRS area are root vegetables with a negligible intake of locally produced leafy vegetables and grains based on a site-specific land and water use evaluation (Hamby 1991 and 1992).

Observed values documented in reports vary widely, mainly the result of different soil and vegetation types and environmental conditions. In addition, management practices such as plowing, liming, fertilization and irrigation greatly affect uptake. Variability can also result if the whole plant is compared to uptake into parts of the plant, such as grain. The approach adopted by IAEA is that for plants consumed by humans, all transfer factors refer to the edible portions, e.g. grains or tubers. Data for animal foodstuffs generally refer to the whole plant.

5.1.1 Summary of Current Value Estimation

With the exception of hydrogen (NRC 1977) and carbon (Sheppard et al. 1991) isotopes, soil-to-plant ratios for the inadvertent intruder analysis are taken from ORNL-5786 (Baes et al. 1984). ORNL-5786 gives concentration ratios for vegetative portions of food crops, which would apply to leafy vegetables, and for non-vegetative (reproductive) portions, which would apply to non-leafy vegetables. The values for non-vegetative portions of food crops were adopted for use because local productivity of non-leafy vegetables is expected to be considerably greater than that of leafy vegetables (Hamby 1991). Tables 5 and 6 in Hamby (1991) provide sector-specific root and leafy vegetable productivity for the sectors within a 50-mile radius of SRS. These data demonstrate that leafy vegetables are only 5% of the total vegetables produced around SRS. Therefore, the non-vegetative (non-leafy) soil-to-plant transfer factors are recommended for use as consistent with Baes et al. (1984).

The reported concentration ratios on a dry-weight basis for non-leafy vegetation were converted to a fresh-weight basis by multiplying by a factor of 0.43, which represents an average conversion factor for all types of non-leafy vegetables. Baes et al. (1984) estimates the dry-to-wet conversion factor of 0.428 dry-to-wet conversion factor assuming 0.126, 0.222, and 0.888 (Baes et al. 1984, Table 2.3) dry-to-wet factors and 20%, 42.2%, and 32% (Baes et al. 1984, Table 2.2) relative importance for exposed produce, protected produce and grains, respectively. Application of this factor to the dry soil-to-plant ratios in Figure 2.2 of Baes et al. (1984) yields the soil-to-vegetable transfer factors in the “Intruder Analysis” column of Table 5-3.

For the all pathways analysis, LADTAP-PA (Jannik and Dixon 2006) employs soil-to-vegetable transfer factors in NRC (1977) where possible and for those not available in the regulatory guide Yu et al. (2001) and Baes et al. (1984) were used. These factors are listed in the “All Pathways” column of Table 5-3 for select radionuclides. For this analysis, hydrogen concentration in vegetables and foodstuff are assumed to equate to the concentration in the irrigation water.

The SRS adopted values of plant uptake factors used in the intruder and all pathway calculations and updated values based on discussions in subsequent sections are listed in Table 5-3 for select radionuclides. A comprehensive list of elements is in APPENDIX B.

5.1.2 Site-specific Considerations

For SRS this conversion factor should be adjusted since Hamby (1991) indicates that exposed and protected root vegetables are dominant for vegetable consumption in South Carolina. Eliminating the consideration for grains, a 0.191 conversion factor could be applied assuming a relative importance similar to the United States indicated in Baes et al. (1984). In addition, this estimate could be refined using a relative importance for South Carolina which was not provided in Baes et al. (1984). Information for Florida and Virginia provided in Table 2.2 of Baes et al. (1984) (see Table 5-1) are averaged since they are also southeastern states.

Table 5-1 Regional Relative Importance of Vegetables from ORNL-5786

	Dry-to-wet weight conversion factors	Relative Importance (% Production)		
		Florida	Virginia	Continental US
Leafy vegetables		4.9	4.7	5.8
Exposed produces	0.126	7.2	31.7	20
Protected produce	0.222	87.4	34.9	42.2
Grains	0.888	0.6	28.6	32

Table 5-2 lists the regional and US conversion factors that are calculated with SRS site-specific consideration of exposed of primarily root vegetables. These values were estimated using the methodology in Baes et al. (1984) described in 5.1.1 where assuming 0.126 and 0.222 (Baes et al. 1984, Table 2.3) dry-to-wet factors and 20% and 42.2% (Baes et al. 1984, Table 2.2) relative importance for exposed produce and protected produce, respectively.

Table 5-2. Site-specific Regional Conversion Factors for Soil-to-Vegetable Transfer Factors based on ORNL-5786

Region	Conversion Factors	
	Root Vegetable Including Grains	Root Vegetable with No Grains
Florida		
Area Harvested	0.239	0.215
Production	0.219	0.215
Virginia		
Area Harvested	0.558	0.192
Production	0.390	0.176
United States		
Area Harvested	0.684	0.202
Production	0.428	0.191
Regional Average Production (Florida and Virginia)	0.305	**0.195**

5.1.3 Updated Soil-to-Vegetable Transfer Factors

Where site-specific soil-to-vegetable factors are not available in the most recent source, Staven et al. (2003), older sources are referenced for recommendation. The hierarchy of the references used beyond Staven et al. (2003) is as discussed in Section 5.0 and listed Table 2-1.

With the exception of NCRP (1996), soil-to-vegetable transfer factors are listed in the references based on dry weight. These factors are converted for fresh vegetable consumption as described in Section 5.1.1 using the site-specific regional conversion factor estimated in Table 5-2 which considers site-specific vegetable consumption (eliminating grains) and assumes southeast relative importance (dry weight transfer factors provided in references are multiplied by 0.195). The resulting updated soil-to-vegetable transfer factors for select elements are listed in Table 5-3. Soil-to-vegetable transfer factors for a comprehensive list of elements are in APPENDIX B, Table B-1. Updated values greater than two orders of magnitude from the currently used values are geometrically averaged to estimate the final updated value. The range of values listed in these tables include those evaluated in the hierarchy, values listed from other DOE sites and sources along with their ranges, and values estimated using non-regional and site-specific dry-to-wet ratios which are not listed in APPENDIX B.

Table 5-3. Updated Soil-to-Vegetable Transfer Factors for Select Elements

		Current SRS Values		Updated Factor				Update/Current Use Ratio	
Z	**Element**	**Intruder Analysis***	**All Pathway Analysis†**	**Updated Value**	**Reference**	**Min**	**Max**	**Intruder**	**All Pathways**
6	C‡	5.60E-01	5.50E+00	1.37E-01	PNNL-13421§	1.37E-01	5.50E+00	0.2	0.02
55	Cs	1.28E-02	1.00E-02	9.00E-01	Friday et al. 1996	2.15E-04	9.00E-01	70.1	90.0
1	H**	4.80E+00	not used	4.80E+00††	Reg. Guide 1.109	0	6.92E+00	1	NA
53	I	2.14E-02	2.00E-02	7.80E-03	PNNL-13421§	6.63E-05	5.00E-02	0.4	0.4
93	Np	4.28E-03	2.50E-03	2.54E-03	PNNL-13421§	1.38E-04	2.73E-02	0.6	1.0
91	Pa	1.07E-04	1.00E-02	4.18E-04‡‡	PNNL-13421§	4.78E-05	1.00E-02	0.6	0.007
94	Pu	1.93E-05	2.50E-04	2.15E-04	PNNL-13421§	7.41E-07	1.09E-02	11.1	0.9
88	Ra	6.42E-03	4.00E-02	4.64E-03§§	PNNL-13421§	3.90E-04	4.00E-02	0.06	0.01
34	Se	1.07E-02	1.30E+00	5.14E-02***	PNNL-13421§	4.78E-03	1.30E+00	0.9	0.008
38	Sr	1.07E-01	1.70E-02	9.75E-02	PNNL-13421§	1.70E-02	1.40E+01	0.9	5.7
43	Tc	6.42E-01	2.50E-01	4.68E-02	PNNL-13421§	4.68E-02	5.46E+00	0.07	0.2
92	U	1.71E-03	2.50E-03	2.34E-03	PNNL-13421§	2.73E-04	2.73E-02	1.4	0.9

*Taken from Fig 2.2 in ORNL-5786 (Baes et al. 1984) with the 0.428 exposed, protected, and grains dry-to-wet conversion factor applied.
†All pathway values taken from NRC (1977), Yu et. al. (2001), Baes et al. (1984).
‡ Intruder value for C is based on Sheppard et al. (1991) x 0.43.
§Dry weight values from reference are multiplied by 0.195 based on Section 5.1.2.
** Intruder H transfer factor is taken from Reg. Guide 1.109 (NRC 1977), Table E-1. All Pathways assumes H-3 concentration in water equates to the plant concentration.
†† 1.0E+01 for all pathways analysis (water pathways).
‡‡Geometric mean of PNNL-13421 site-specific value (6.83E-05) and currently used intruder and all pathways values.
§§Geometric mean of PNNL-13421 site-specific value (3.90E-04) and currently used intruder and all pathways values.
***Geometric mean of PNNL-13421 site-specific value (9.75E-03) and currently used intruder and all pathways values.

5.2 Feed-to-Milk Transfer Factors

Feed-to-milk transfer factors represent the nuclide fraction transferred from fodder to milk. They represent the fraction of daily elemental intake in feed (Bq/d) with is transferred to a liter of milk (Bq/L milk per Bq/d intake). Current values are taken from NRC (1977). Updated values are based on the hierarchy discussed in Section 5.0. Existing and updated feed-to-milk transfer factors are listed in Table 5-4. Feed-to-milk transfer factors for a comprehensive list of elements are in APPENDIX B, Table B-2. Updated values greater than two orders of magnitude from the currently used values are geometrically averaged to estimate the final updated value. Baes et al. (1984) reports feed-to-milk transfer factors in d/kg and states a 1.028 to 1.035 kg/L range for the density of milk. Feed-to-milk values in APPENDIX B are those reported by Baes et al. (1984) multiplied by 1.03 kg/L. The range of values listed in these tables includes those evaluated in the hierarchy and values listed from other DOE sites and sources along with their ranges.

Table 5-4. Updated Feed-to-Milk Transfer Factors (d/L) for Select Elements

Z	Element	Current SRS Values	Updated Factors				Update/Current Use Ratio
			Hierarchy Transfer Factor	Reference	Min	Max	
6	C	1.2E-02	1.20E-02	Reg. Guide 1.109	1.05E-02	1.20E-02	1
55	Cs	1.2E-02	7.90E-03	PNNL-13421	7.00E-03	1.20E-02	0.7
1	H	Not used	1.50E-02	PNNL-13421	0	1.50E-02	NA
53	I	6.0E-03	9.00E-03	PNNL-13421	6.00E-03	1.20E-02	1.5
93	Np	5.0E-06	5.00E-06	PNNL-13421	5.00E-06	1.00E-05	1
91	Pa	5.0E-06	5.00E-06	PNNL-13421	5.00E-06	5.15E-06	1
94	Pu	2.0E-06	1.10E-06	PNNL-13421	1.00E-07	2.00E-06	0.6
88	Ra	1.0E-03	1.30E-03	PNNL-13421	4.50E-04	1.30E-03	1.3
34	Se	4.5E-02	4.00E-03	PNNL-13421	4.00E-03	4.50E-02	0.09
38	Sr	8.0E-04	2.80E-03	PNNL-13421	8.00E-04	2.80E-03	3.5
43	Tc	2.5E-02	1.87E-03*	PNNL-13421	2.30E-05	2.50E-02	0.006†
92	U	5.0E-04	4.00E-04	PNNL-13421	4.00E-04	6.18E-04	0.8

5.3 Feed-to-Meat Transfer Factors

Feed-to-meat transfer factors represent the nuclide-specific fraction transferred from fodder to beef. They represent the fraction of daily elemental intake in feed with is transferred to a kg of meat (Bq/kg meat per Bq/d intake). Currently values are taken from NRC (1977). Updated values are based on the hierarchy discussed in Section 5.0. Existing and updated feed-to-meat transfer factors are listed in Table 5-5. Feed-to-meat transfer factors for a comprehensive list of elements are in APPENDIX B, Table B-3. Updated values greater than two orders of magnitude from the currently used values are geometrically averaged to estimate the final updated value. The range of values listed in these tables includes those evaluated in the hierarchy and values listed from other DOE sites and sources along with their ranges.

* Geometric mean of the PNNL-13241 value (1.4E-04) and currently used value.

† Value greater than two orders of magnitude from the currently used values (update/current ratio > 100 or <0.01) are geometrically averaged.

Table 5-5. Updated Feed-to-Meat Transfer Factors (d/kg) for Select Elements

Z	Element	Current SRS Value	Updated Factor				
			Updated	Reference	Min	Max	Update/Current Use
6	C	3.1E-02	3.10E-02	Reg. Guide 1.109	3.10E-02	4.89E-02	1.0
55	Cs	4.0E-03	5.00E-02	PNNL-13421	4.00E-03	5.00E-02	12.5
1	H	Not Used	1.2E-02	Reg. Guide 1.109	0	1.20E-02	NA
53	I	2.9E-03	4.00E-02	PNNL-13421	2.90E-03	4.00E-02	13.8
93	Np	2.0E-04	1.00E-03	PNNL-13421	5.50E-05	1.00E-03	5.0
91	Pa	5.0E-03	4.47E-04*	PNNL-13421	5.00E-06	5.00E-03	0.008
94	Pu	1.4E-05	1.00E-05	PNNL-13421	5.00E-07	1.00E-04	0.7
88	Ra	1.0E-03	9.00E-04	PNNL-13421	2.50E-04	1.00E-03	0.9
34	Se	1.5E-02	1.50E-02	PNNL-13421	1.50E-02	1.00E-01	1.0
38	Sr	6.0E-04	8.00E-03	PNNL-13421	3.00E-04	1.00E-02	13.3
43	Tc	4.0E-01	6.32E-03†	PNNL-13421	1.00E-04	4.00E-01	0.0003
92	U	3.4E-04	3.00E-04	PNNL-13421	2.00E-04	8.00E-04	0.9

5.4 Water-to-Fish Accumulation

Element-specific water-to-fish bioaccumulation factors are ratios of the fraction of contaminant concentration in water (Bq/L) that would be transferred into fish muscle (Bq/kg). SRS values assume freshwater fish.

With the exception of a site-specific factor of 3,000 L/kg for cesium accumulation in freshwater fish (Jannik 2003), existing aquatic animal bioaccumulation factors, which are the equilibrium ratios between concentration in aquatic foods and concentration in water, can be found in (Jannik and Dixon 2006).

Updated values are based on the hierarchy discussed in Section 5.0. Fish data from Friday (2006) were collected at SRS in ponds having extremely contaminated sediments and employing sampling methods (filtering water before measurement) that would result in very high factors. These values are not recommended for use in this update because of the limitations. However, the data are included in the uncertainty range. Existing and updated water-to-fish transfer factors are listed in Table 5-6. Water-to-fish transfer factors for a comprehensive list of elements are in APPENDIX B, Table B-4. Updated values greater than two orders of magnitude from the currently used values are geometrically averaged to estimate the final updated value. The range of values listed in these tables includes those evaluated in the hierarchy and values listed from other DOE sites and sources along with their ranges which may not be listed in the appendices.

*Geometric mean of PNNL-13421 site-specific value (4.00E-05) and currently used value.

†Geometric mean of PNNL-13421 site-specific value (1.00E-04) and currently used value.

Table 5-6. Updated Water-to-Fish Accumulation Factors (L/kg) for Select Elements

Z	Element	Current SRS Value	Updated Factor				Update/Current Use Ratio
			Updated Value	Reference	Min	Max	
6	C	4.6E+03	5.00E+04	PNNL-13421	4.60E+03	5.00E+04	10.9
55	Cs	3.0E+03	3.00E+03	Jannik 2003	2.00E+03	4.70E+03	1.0
1	H	9.0E-01	1.00E+00	NCRP 123	9.00E-01	1.00E+00	1.1
53	I	1.5E+01	4.00E+01	PNNL-13421	1.50E+01	5.00E+02	2.7
93	Np	1.0E+02	2.10E+01	PNNL-13421	2.10E+01	2.50E+02	0.2
91	Pa	1.1E+01	1.00E+01	PNNL-13421	1.00E+01	1.13E+01	0.9
94	Pu	3.5E+00	3.00E+01	PNNL-13421	3.50E+00	4.70E+03	8.6
88	Ra	5.0E+01	5.00E+01	PNNL-13421	5.00E+01	7.00E+01	1.0
34	Se	1.7E+02	1.70E+02	PNNL-13421	1.70E+02	2.00E+02	1.0
38	Sr	3.0E+01	6.00E+01	PNNL-13421	3.00E+01	4.05E+02	2.0
43	Tc	1.5E+01	2.00E+01	PNNL-13421	1.50E+01	2.00E+01	1.3
92	U	2.0E+00	1.00E+01	PNNL-13421	2.00E+00	5.00E+01	5.0

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6.0 SUMMARY AND CONCLUSIONS

6.1 Summary of Updates

Updated physical human health data (Table 3-1 and Table 3-2) include soil exposure time period to irrigation (buildup); pasture grass, agricultural (veg/produce), vegetable crop yield; fraction of vegetables produced locally; and fraction of leafy vegetables produced locally based on the recommended use of site-specific data primarily taken from Hamby (1991). Consumption rate updates (Table 4-1) are based on the availability of updated information and site-specific data. Element-specific bioaccumulation factor recommended updates (APPENDIX B) are based on availability of recent data based on the hierarchy discussed in Section 5.0 calling for the use of site-specific data when available and secondary sources, primarily Staven et al. (2003). Where large disparities occur (> 2 orders of magnitude), a geometric mean of the site specific and generic value was selected.

6.2 Potential Impact on Performance Assessments

The potential impacts of the recommended updates will be quantified when detailed sensitivity analyses are performed in future performance assessments. Bioaccumulation factors are widely variable across the reviewed sources and are considered significantly different if beyond two orders of magnitude in the summary tables Table 5-3, Table 5-4, Table 5-5, and Table 5-6 and the comprehensive tables, Table B-1, Table B-2, Table B-3, and Table B-4. The use of the geometric mean of the new and old factors reduced the variability in most cases.

A preliminary sensitivity analysis was performed using the Automated Intruder Analysis Application Version 2 (Koffman 2006b) and LADTAP-PA (Jannik and Dixon 2006). A unit source term (i.e. 1 pCi/g) for each of the listed isotopes was utilized for the analyses. These analyses indicate a decline in dose resulting from these updates (Table 6-1 and Table 6-2).

The intruder decrease in dose in Table 6-1 is due primarily to the fraction of homegrown vegetable consumed and inhalation rate listed in Table 3-1 and Table 4-1, respectively. The all pathway decline in dose using updated factors from this report in LADTAP-PA shown in Table 6-2 is primarily due to the fish bioaccumulation factors and fraction of homegrown foodstuff consumed updates listed in Table 5-6 and Table 3-1, respectively.

Because the air pathway analysis employs CAP88, the Environmental Protection Agency (EPA) model required for compliance with 40 CFR 61, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs), adapting this model for consistency with other exposure analyses requires agreement with the EPA. At SRS, efforts are ongoing to upgrade from the currently used version of CAP88 (V1.0) to the more recent EPA approved PC version (V3.0), which may employ some of the parameters and factors discussed in this report.

Preliminary estimates with GOLDSIM for a typical waste tank indicate that the use of the geometric mean averaging methodology would yield a difference of less than 1% for the total dose at the peak concentration time. Evaluations will be performed in the future to assess the need for further sensitivity analysis as modeling efforts are completed.

Table 6-1. Intruder Preliminary Sensitivity Analysis

Radionuclide	Dose from 1 Ci Throughout Slit Trench (mrem/y)				% Change from Baseline
	Baseline*	Consumption Rate and Physical	Transfer Factors	Combined	
C-14	5.01E-02	1.56E-02	3.84E-03	3.84E-03	-92%
Cs-137	4.14E-03	2.21E-03	4.62E-03	4.62E-03	11%
H-3	4.81E-05	1.50E-05	1.50E-05	1.50E-05	-69%
I-129	2.62E-01	8.42E-02	3.34E-02	3.34E-02	-87%
Np-237	9.22E-01	3.39E-01	2.33E-01	2.33E-01	-75%
Pa-231	8.12E-01	5.21E-01	5.16E-01	5.16E-01	-37%
Pu-238	2.77E-02	2.34E-02	2.34E-02	2.34E-02	-16%
Pu-239	6.74E-02	5.68E-02	5.68E-02	5.68E-02	-16%
Ra-226	1.38E+00	5.35E-01	4.32E-01	4.32E-01	-69%
Se-79	4.20E-03	1.39E-03	1.28E-03	1.28E-03	-70%
Sr-90	5.98E-02	1.88E-02	9.93E-03	9.93E-03	-83%
Tc-99	4.08E-02	1.27E-02	9.45E-04	9.45E-04	-98%
U-235	4.11E-01	2.60E-01	2.59E-01	2.59E-01	-37%
U-238	4.02E-02	1.70E-02	1.84E-02	1.84E-02	-54%

Table 6-2. All Pathways Preliminary Sensitivity Analysis

Radionuclide	LADTAP-PA Dose (mrem/yr)				% Change from Baseline
	Baseline†	Consumption Rate and Physical	Transfer Factors	Combined	
C-14	1.57E+00	2.18E-01	3.30E-01	2.91E-01	-81%
H-3	8.82E-05	2.63E-05	6.25E-05	2.64E-05	-70%
I-129	1.65E+00	4.01E-01	1.41E+00	4.14E-01	-75%
Np-237	1.66E+01	5.33E+00	1.55E+01	5.83E+00	-65%
Pa-231	4.71E+01	1.35E+01	3.27E+01	1.25E+01	-73%
Pu-238	1.11E+01	3.60E+00	1.16E+01	5.52E+00	-50%
Pu-239	1.23E+01	3.99E+00	1.28E+01	6.10E+00	-50%
Ra-226	9.54E+00	2.42E+00	4.79E+00	2.07E+00	-78%
Se-79	2.19E+00	2.15E-01	5.40E-02	2.42E-02	-99%
Sr-90	6.82E-01	2.06E-01	8.76E-01	2.49E-01	-64%
Tc-99	1.95E-01	1.89E-02	9.21E-03	2.32E-03	-99%
U-235	9.84E-01	3.15E-01	8.74E-01	3.21E-01	-67%
U-238	9.28E-01	2.89E-01	8.23E-01	2.94E-01	-68%

* Current values in intruder application version 2 (no waterborne pathways).
† Current values in LADTAP-PA.

7.0 REFERENCES

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APPENDIX A. PHYSICAL PARAMETERS AND CONSUMPTION RATES CONSIDERED

Table A-1. Crop Exposure Times and Productivity from the Other Sources

Parameter	EPA 1997		RESRAD (Yu et al. 1993 and 2001)	NUREG/CR-5512 (Kennedy and Strenge 1992)	RG 1.109 (NRC 1977)	Idaho 2003	Hanford 2004	NTS 2000	ORNL 1997
Exposure Time to Irrigation (d)									
Pasture				90	30	90	292		
Crop				90	60	90			
Soil (grass-cow-milk)					5458	60-240			
Soil (crop/veg)					60	60-240			
Productivity									
Pasture grass (kg/m^2)				1	0.7		1.5		
Agricultural (veg/produce) (kg/m^2)				4	2		0.5		
Vegetable crop yield (kg/m^2)				4			2		
Fraction Produced Locally	**All Pathways**	**Intruder**							
Vegetables	0.173	0.308	0.5	0.25	0.76			0.2	
Leafy vegetables	0.173	0.308	0.5		1			0.2	
Beef	0.306	0.319	1					0.4	
Milk	0.207	0.254	1					0.4	
Dilution factor for mixing of waste with soil in vegetable garden									
for agriculture scenario									0.2
for post drilling scenario									0.002

Table A-2. Physical Parameters from the Other Sources

Parameter	RESRAD (Yu et al. 1993 and 2001)	NUREG/CR-5512 (Kennedy and Strenge 1992)	RG 1.109 (NRC 1977)	Idaho 2003	HANFORD 2004	NTS 2000	ORNL 1997
Areal density of soil (kg/m^2)		240					
Soil Density (kg/m^3)				1.60E+03		1.51E+03	1.40E+03
Atmospheric mass loading of soil (kg/m^3)							
while working in garden	2.00E-07			1.0E-07			1.00E-07
while residing in home	2.00E-07					2.10E-08	1.00E-08
Depth of garden (cm)	15	15		61	15		
Garden irrigation rate (L/d/m^2)	5.5	2.08		8.47			
Fraction of the year that crops are irrigated				0.25			
Fractional retention of deposition on leaves			0.25				
Garden size (m^2)					207.3		

Table A-3. Consumption Rates from the Literature

Parameter	EPA 1997	Yu et al 1993 and 2001	Kennedy and Strenge 1992	NRC 1977 Average	NRC 1977 MEI	Idaho 2003	Hanford 2004	NTS 2000	ORNL 1997
Breathing rate (m^3/yr)	5548	8400		8000	8000	8400	5457	3,767-36,792	8000
Consumption Rate									
Soil (kg/yr)	0.037	0.0365	0.05			0.4	0.015	0.018	0.037
Leafy vegetable (kg/yr)	16.7	14	11	64	64	18	17.8	18	
Other vegetables (kg/yr)	79.2	160	51	190	520	176	172.3	73	90
Meat (kg/yr)	26	63	59	95	110	85	27.4	31	
Finfish (kg/yr)	2.2	5.4	10	6.9	21		9.9		
Seafood (kg/yr)	4	0.9		1	5				
Milk (L/yr)	73.7	92	100	110	310	112	110	95	
Water (L/y)	507	510		370	730	258	730	493	730
Fodder(beef cow) (kg/d)		68	27	50	50	12		47	
Fodder – (milk cow) (kg/d)		55	36	50	50	16		47	
Fraction of milk-cow intake from pasture		1						4E-04	
Fraction of beef-cow intake from pasture		1						4E-04	
Water (beef cow) (L/d)		50	50				50		
Water (milk cow) (L/d)		160	60				60		
Exposure Time									
Shoreline (hrs/yr)				8.3	12		11		
Swimming (hrs/yr)	12						9.1		
Boating (hrs/yr)							9.1		
Showering (min/d)	10						15		
Fraction of yr working in garden (/yr)		0.25	0.01				0.14	0.01	0.01
Fraction of yr residing in home (/yr)	0.7	0.5			0.5			0.3	0.5
Fraction of time cattle on pasture		1							
Transport (days)									
Vegetables		14	14	14	14				
Feed-milk-man transport time		1	1	2	4				
Meat		20	20	20					
Drinking water		1							

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APPENDIX B. COMPREHENSIVE BIOACCUMULATION FACTORS

Table B-1. Comprehensive Updated Soil-to-Vegetable Transfer Factors

		Current Analyses		Updated Soil-to-Vegetable Transfer Factors				Update/Current Use Ratio[*]	
Z	Element	Intruder	All Pathways	Updated Value	Reference	Min	Max	Intruder	All Pathways
89	Ac	1.50E-04	2.50E-03	6.83E-05	PNNL-13421	6.69E-05	3.50E-03	0.5	0.03
47	Ag	4.28E-02	1.50E-01	1.18E-02[†]	PNNL-13421	2.54E-04	1.50E-01	0.006	0.002
13	Al	2.78E-04	4.00E-03	1.27E-04	ORNL-5786	1.24E-04	4.00E-03	0.5	0.03
95	Am	1.07E-04	2.50E-04	6.83E-05	PNNL-13421	2.15E-06	3.32E-02	0.6	0.3
18	Ar	0		0	NUREG-5512	0	0	NA	NA
33	As	2.57E-03		1.17E-03	PNNL-13421	1.17E-03	8.00E-02	0.5	NA
85	At	6.42E-02	2.00E-01	2.93E-02	ORNL-5786	2.87E-02	2.00E-01	0.5	0.1
79	Au	4.28E-02	2.50E-04	3.51E-03	PNNL-13421	2.50E-04	1.00E-01	0.1	14.0
5	B			3.90E-01	ORNL-5786	1.00E-02	4.00E+00	NA	NA
56	Ba	6.42E-03		2.93E-03	PNNL-13421	2.87E-03	4.00E-02	0.5	NA
4	Be	6.42E-04	4.00E-03	2.93E-04	PNNL-13421	2.87E-04	4.00E-03	0.5	0.1
83	Bi	2.14E-03	1.00E-01	9.75E-02	PNNL-13421	9.56E-04	1.00E-01	45.6	1.0
97	Bk		5.90E-05	1.00E-03	NCRP 123	5.90E-05	1.00E-03	NA	16.9
35	Br	6.42E-01		2.93E-01	PNNL-13421	2.93E-01	7.60E-01	0.5	NA
6	C	5.60E-01	5.50E+00	1.37E-01	PNNL-13421	1.37E-01	5.50E+00	0.2	0.02
20	Ca	1.50E-01	5.00E-01	6.83E-02	PNNL-13421	6.69E-02	5.00E-01	0.5	0.1
48	Cd	6.42E-02	3.00E-01	2.93E-02	PNNL-13421	2.87E-02	5.00E-01	0.5	0.1
58	Ce	1.71E-03		3.90E-03	PNNL-13421	7.65E-04	3.00E-02	2.3	NA
98	Cf		1.00E-03	6.83E-05	PNNL-13421	6.50E-06	1.00E-02	NA	0.1
17	Cl	3.00E+01	2.00E+01	1.37E+01	PNNL-13421	3.00E-01	7.00E+01	0.5	0.7
96	Cm	6.42E-06	2.50E-03	8.39E-05	PNNL-13421	2.15E-06	2.50E-03	13.1	0.0
27	Co	3.00E-03	9.40E-03	1.31E-02	PNNL-13421	1.34E-03	2.34E-01	4.4	1.4
24	Cr	1.93E-03		8.78E-04	PNNL-13421	2.50E-04	1.00E-02	0.5	NA
55	Cs	1.28E-02	1.00E-02	9.00E-01	Friday et al. 1996	2.15E-04	9.00E-01	70.1	90.0
29	Cu	1.07E-01		4.88E-02	PNNL-13421	4.88E-02	1.30E-01	0.5	NA
66	Dy	1.71E-03		3.90E-03	PNNL-13421	7.80E-04	3.90E-03	2.3	NA
68	Er	1.71E-03		3.90E-03	PNNL-13421	7.80E-04	3.90E-03	2.3	NA
99	Es		5.90E-05	1.00E-03	NCRP 123	5.90E-05	1.00E-03	NA	16.9
63	Eu	1.71E-03		3.90E-03	PNNL-13421	7.65E-04	4.00E-03	2.3	NA
9	F	2.57E-03		1.17E-03	PNNL-13421	1.17E-03	2.00E-02	0.5	NA
26	Fe	4.28E-04	6.60E-04	9.75E-03	PNNL-13421	1.91E-04	9.75E-03	22.8	14.8
100	Fm			2.00E-03	NCRP 123	2.00E-03	2.00E-03	NA	NA
87	Fr	1.28E-02	3.00E-02	5.85E-03	ORNL-5786	5.73E-03	3.00E-02	0.5	0.2
31	Ga	1.71E-04	3.00E-03	7.80E-05	PNNL-13421	7.65E-05	3.00E-03	0.5	0.03

[*]Values greater than two orders of magnitude from the currently used values (update/current ratio > 100 or <0.01) are geometrically averaged to create the "updated value".

[†]Geometric mean of PNNL-13421 site-specific value (2.54E-04) and currently used intruder and all pathways values.

Table B-1. Comprehensive Updated Soil-to-Vegetable Transfer Factors (continued)

Z	Element	Current Analyses		Updated Soil-to-Vegetable Transfer Factors				Update/Current Use Ratio*	
		Intruder	All Pathways	Updated Value	Reference	Min	Max	Intruder	All Pathways
64	Gd	1.71E-03	2.00E-03	3.90E-03	PNNL-13421	7.65E-04	4.00E-03	2.3	2.0
32	Ge	3.42E-02	1.00E-01	1.56E-02	ORNL-5786	1.53E-02	4.00E-01	0.5	0.2
1	H	4.80E+00		4.80E+00	Reg. Guide 1.109	0	6.92E+00	1.0	NA
108	Ha			2.00E-03	NCRP 123	2.00E-03	2.00E-03	NA	NA
2	He			0	NCRP 123	0	0	NA	NA
72	Hf	3.64E-04	1.00E-04	1.95E-04	PNNL-13421	1.00E-04	3.00E-03	0.5	2.0
80	Hg	8.56E-02	3.80E-01	3.90E-02	PNNL-13421	3.82E-02	3.80E-01	0.5	0.1
67	Ho	1.71E-03	2.50E-03	3.90E-03	PNNL-13421	7.65E-04	4.00E-03	2.3	1.6
53	I	2.14E-02	2.00E-02	7.80E-03	PNNL-13421	6.63E-05	5.00E-02	0.4	0.4
49	In		3.00E-03	7.80E-05	PNNL-13421	7.65E-05	3.00E-03	NA	0.0
77	Ir	6.42E-03	3.00E-02	2.93E-03	PNNL-13421	2.87E-03	3.00E-02	0.5	0.1
19	K	2.35E-01	3.00E-01	1.07E-01	PNNL-13421	1.05E-01	5.50E-01	0.5	0.4
36	Kr			0	NUREG-5512	0	0	NA	NA
57	La	1.71E-03	2.50E-03	6.83E-05	PNNL-13421	6.83E-05	2.50E-03	0.04	0.03
3	Li	1.71E-03		7.80E-04	ORNL-5786	7.80E-04	1.71E-03	0.5	NA
103	Lr			2.00E-03	NCRP 123	2.00E-03	2.00E-03	NA	NA
71	Lu	1.71E-03	2.50E-03	7.80E-04	ORNL-5786	7.65E-04	2.50E-03	0.5	0.3
101	Md			2.00E-03	NCRP 123	2.00E-03	2.00E-03	NA	NA
12	Mg	2.35E-01		1.07E-01	PNNL-13421	3.00E-02	2.35E-01	0.5	NA
25	Mn	2.14E-02	2.90E-02	3.90E-02	PNNL-13421	9.56E-03	3.00E-01	1.8	1.3
42	Mo	2.57E-02	1.20E-01	1.56E-01	PNNL-13421	1.15E-02	8.00E-01	6.1	1.3
7	N	1.28E+01		3.50E-01*	PNNL-13421	9.56E-03	1.28E+01	0.0007	NA
11	Na	2.35E-02		5.85E-02	PNNL-13421	1.05E-02	3.00E-01	2.5	NA
41	Nb	2.14E-03	9.40E-03	4.88E-03	PNNL-13421	9.56E-04	1.70E-02	2.3	0.5
60	Nd	1.71E-03		3.90E-03	PNNL-13421	7.80E-04	3.90E-03	2.3	NA
10	Ne			0	NCRP 123	0	0	NA	NA
28	Ni	2.57E-02	1.90E-02	1.17E-02	PNNL-13421	3.51E-03	3.51E-01	0.5	0.6
102	No			2.00E-03	NCRP 123	2.00E-03	2.00E-03	NA	NA
93	Np	4.28E-03	2.50E-03	2.54E-03	PNNL-13421	1.38E-04	2.73E-02	0.6	1.0
8	O			6.00E-01	NCRP 123	6.00E-01	6.00E-01	NA	NA
76	Os	1.50E-03		6.83E-04	PNNL-13421	6.83E-04	3.00E-02	0.5	NA
15	P	1.50E+00	1.10E+00	6.83E-01	PNNL-13421	6.69E-01	3.50E+00	0.5	0.6
91	Pa	1.07E-04	1.00E-02	4.18E-04†	PNNL-13421	4.78E-05	1.00E-02	0.6	0.007
82	Pb	3.85E-03	1.00E-02	1.17E-03	PNNL-13421	2.54E-05	1.00E-02	0.3	0.1
46	Pd	1.71E-02	1.00E-01	7.80E-03	PNNL-13421	7.65E-03	1.00E-01	0.5	0.08
61	Pm	1.71E-03		3.90E-03	PNNL-13421	7.65E-04	4.00E-03	2.3	NA
84	Po	1.71E-04	1.00E-03	1.37E-03	PNNL-13421	7.65E-05	7.00E-03	8.0	1.4
59	Pr	1.71E-03		3.90E-03	PNNL-13421	7.65E-04	3.90E-03	2.3	NA
78	Pt	1.07E-02	2.40E-02	4.88E-03	ORNL-5786	4.78E-03	1.00E-01	0.5	0.2

*Geometric mean of PNNL-13421 site-specific value (9.56E-03) and currently used intruder and all pathways values.
†Geometric mean of PNNL-13421 site-specific value (6.83E-05) and currently used intruder and all pathways values.

Table B-1. Comprehensive Updated Soil-to-Vegetable Transfer Factors (continued)

Z	Element	Current Analyses		Updated Soil-to-Vegetable Transfer Factors				Update/Current Use Ratio*	
		Intruder	All Pathways	Updated Value	Reference	Min	Max	Intruder	All Pathways
94	Pu	1.93E-05	2.50E-04	2.15E-04	PNNL-13421	7.41E-07	1.09E-02	11.1	0.9
88	Ra	6.42E-03	4.00E-02	4.64E-03*	PNNL-13421	3.90E-04	4.00E-02	0.06	0.0098
37	Rb	3.00E-02	1.30E-01	1.76E-01	PNNL-13421	1.34E-02	9.00E-01	5.9	1.4
75	Re	1.50E-01	2.10E+02	1.29E+00†	PNNL-13421	6.83E-02	2.10E+02	0.5	0.0003
104	Rf			3.00E-03	NCRP 123	3.00E-03	3.00E-03	NA	NA
45	Rh	1.71E-02		7.80E-03	PNNL-13421	7.65E-03	1.30E+01	0.5	NA
86	Rn			0	NUREG-5512	0	0	NA	NA
44	Ru	8.56E-03	5.00E-02	7.80E-03	PNNL-13421	3.82E-03	5.00E-02	0.9	0.2
16	S	6.42E-01		2.93E-01	PNNL-13421	2.87E-01	6.42E-01	0.5	NA
51	Sb	1.28E-02	1.10E-02	2.49E-03‡	PNNL-13421	2.15E-05	1.30E-02	0.009	0.01
21	Sc	4.28E-04	2.00E-03	1.95E-04	PNNL-13421	1.91E-04	2.00E-03	0.5	0.1
34	Se	1.07E-02	1.30E+00	5.14E-02§	PNNL-13421	4.78E-03	1.30E+00	0.9	0.008
14	Si	3.00E-02	8.80E-02	1.37E-02	PNNL-13421	1.34E-02	8.80E-02	0.5	0.2
62	Sm	1.71E-03	2.50E-03	3.90E-03	PNNL-13421	7.65E-04	4.00E-03	2.3	1.6
50	Sn	2.57E-03	2.50E-03	1.17E-03	PNNL-13421	1.15E-03	3.00E-01	0.5	0.5
38	Sr	1.07E-01	1.70E-02	9.75E-02	PNNL-13421	1.70E-02	2.73E+00	0.9	5.7
73	Ta	1.07E-03	2.50E-03	4.88E-03	PNNL-13421	4.78E-04	2.00E-02	4.6	2.0
65	Tb	1.71E-03		3.90E-03	PNNL-13421	7.80E-04	3.90E-03	2.3	NA
43	Tc	6.42E-01	2.50E-01	4.68E-02	PNNL-13421	4.68E-02	5.46E+00	0.07	0.2
52	Te	1.71E-03	1.30E+00	1.20E-02**	PNNL-13421	7.65E-04	1.30E+00	0.5	0.001
90	Th	3.64E-05	4.20E-03	6.44E-05	PNNL-13421	5.85E-06	4.20E-03	1.8	0.02
22	Ti	1.28E-03	1.00E-04	5.85E-04	ORNL-5786	1.00E-04	3.00E-03	0.5	5.9
81	Tl	1.71E-04	1.00E-04	7.80E-05	PNNL-13421	7.65E-05	2.00E-01	0.5	0.8
69	Tm	1.71E-03		7.80E-04	ORNL-5786	7.80E-04	2.00E-03	0.5	NA
92	U	1.71E-03	2.50E-03	2.34E-03	PNNL-13421	2.73E-04	2.73E-02	1.4	0.9
23	V	1.28E-03	1.40E-03	5.85E-04	ORNL-5786	5.73E-04	3.00E-03	0.5	0.4
74	W	4.28E-03		5.00E-02††	PNNL-13421	1.91E-03	8.00E-01	136.7	NA
54	Xe			0	NUREG-5512	0	0	NA	NA
39	Y	2.57E-03	2.60E-03	1.95E-03	PNNL-13421	1.15E-03	3.00E-01	0.8	0.8
70	Yb	1.71E-03		7.80E-04	ORNL-5786	7.80E-04	2.00E-03	0.5	NA
30	Zn	3.85E-01		6.83E-02	PNNL-13421	6.83E-02	2.34E+00	0.2	NA
40	Zr	2.14E-04	1.70E-04	1.95E-04	PNNL-13421	9.56E-05	1.00E-03	0.9	1.1

[*] Geometric mean of PNNL-13421 site-specific value (3.90E-04) and currently used intruder and all pathways values.
[†] Geometric mean of PNNL-13421 site-specific value (6.83E-02) and currently used intruder and all pathways values.
[‡] Geometric mean of PNNL-13421 site-specific value (1.09E-04) and currently used intruder and all pathways values.
[§] Geometric mean of PNNL-13421 site-specific value (9.75E-03) and currently used intruder and all pathways values.
[**] Geometric mean of PNNL-13421 site-specific value (7.80E-04) and currently used intruder and all pathways values.
[††] Geometric mean of PNNL-13421 site-specific value (5.85E-01) and currently used intruder and all pathways values.

Table B-2. Comprehensive Updated Feed-to-Milk Transfer Factors (d/L)

Z	Element	Current Analyses	Updated Feed-to-Milk Transfer Factors				
			Updated Factor	Reference	Min	Max	Update/Current Use Ratio*
89	Ac	2.00E-05	2.00E-05	PNNL-13421	2.00E-06	2.06E-05	1.0
47	Ag	5.00E-02	1.58E-03†	PNNL-13421	5.00E-05	5.00E-02	0.001
13	Al	2.00E-04	2.06E-04	ORNL-5786	2.00E-04	2.06E-04	1.0
95	Am	5.00E-06	1.50E-06	PNNL-13421	4.00E-07	5.00E-06	0.3
33	As		6.00E-05	PNNL-13421	6.00E-05	1.00E-04	NA
85	At	1.00E-02	1.03E-02	ORNL-5786	1.00E-02	1.03E-02	1.0
79	Au	5.00E-06	5.50E-06	PNNL-13421	5.00E-06	1.00E-05	1.1
5	B		1.55E-03	ORNL-5786	1.50E-03	3.00E-03	NA
56	Ba		4.80E-04	PNNL-13421	3.50E-04	8.00E-03	NA
4	Be	2.00E-06	9.00E-07	PNNL-13421	9.00E-07	2.00E-06	0.5
83	Bi	5.00E-04	5.00E-04	PNNL-13421	5.00E-04	1.00E-03	1.0
97	Bk	4.00E-07	2.00E-06	NCRP 1996	4.00E-07	2.00E-06	5.0
35	Br		2.00E-02	PNNL-13421	2.00E-02	2.06E-02	NA
6	C	1.20E-02	1.20E-02	Reg. Guide 1.109	1.05E-02	1.20E-02	1.0
20	Ca	3.00E-03	3.00E-03	PNNL-13421	3.00E-03	1.03E-02	1.0
48	Cd	1.20E-04	1.00E-03	PNNL-13421	1.20E-04	2.00E-03	8.3
58	Ce		3.00E-05	PNNL-13421	2.00E-05	1.00E-04	NA
98	Cf	7.50E-07	1.50E-06	PNNL-13421	7.50E-07	2.00E-06	2.0
17	Cl	2.00E-02	1.70E-02	PNNL-13421	1.50E-02	2.00E-02	0.9
96	Cm	5.00E-06	2.00E-05	PNNL-13421	2.00E-06	2.06E-05	4.0
27	Co	1.00E-03	3.00E-04	PNNL-13421	3.00E-04	2.06E-03	0.3
24	Cr		1.00E-05	PNNL-13421	1.00E-05	2.20E-03	NA
55	Cs	1.20E-02	7.90E-03	PNNL-13421	7.00E-03	1.20E-02	0.7
29	Cu		2.00E-03	PNNL-13421	1.50E-03	1.40E-02	NA
66	Dy		3.00E-05	PNNL-13421	2.00E-05	6.00E-05	NA
68	Er		3.00E-05	PNNL-13421	2.00E-05	6.00E-05	NA
99	Es	4.00E-07	2.00E-06	NCRP 1996	4.00E-07	2.00E-06	5.0
63	Eu		3.00E-05	PNNL-13421	2.00E-05	6.00E-05	NA
9	F		1.00E-03	PNNL-13421	1.00E-03	7.00E-03	NA
26	Fe	1.20E-03	3.00E-05	PNNL-13421	3.00E-05	1.20E-03	0.03
87	Fr	8.00E-03	2.06E-02	ORNL-5786	8.00E-03	2.06E-02	2.6
31	Ga	1.00E-05	5.00E-05	PNNL-13421	1.00E-05	5.15E-05	5.0
64	Gd	6.00E-05	3.00E-05	PNNL-13421	2.00E-05	6.00E-05	0.5
32	Ge	7.00E-02	7.21E-02	ORNL-5786	1.00E-02	7.21E-02	1.0
1	H		1.50E-02	PNNL-13421	0	1.50E-02	NA
105	Ha		5.00E-06	NCRP 1996	5.00E-06	5.00E-06	NA

*Values greater than two orders of magnitude from the currently used values (update/current ratio > 100 or <0.01) are geometrically averaged to create the “updated value”.

†Geometric mean of PNNL-13421 site-specific value (5.00E-05) and currently used value.

Table B-2. Comprehensive Updated Feed-to-Milk Transfer Factors (d/L) (continued)

Z	Element	Current Analyses	Updated Feed-to-Milk Transfer Factors				Update/Current Use Ratio*
			Updated Factor	Reference	Min	Max	
2	He		0	NCRP 1996	0	0	NA
72	Hf	5.50E-07	5.50E-07	PNNL-13421	5.50E-07	2.50E-05	1.0
80	Hg	5.00E-04	4.70E-04	PNNL-13421	4.50E-04	5.00E-04	0.9
67	Ho	2.00E-05	3.00E-05	PNNL-13421	2.00E-05	6.00E-05	1.5
53	I	6.00E-03	9.00E-03	PNNL-13421	6.00E-03	1.20E-02	1.5
49	In	2.00E-04	2.00E-04	PNNL-13421	1.00E-04	2.00E-04	1.0
77	Ir	2.00E-06	2.00E-06	PNNL-13421	2.00E-06	2.06E-06	1.0
19	K	7.00E-03	7.20E-03	PNNL-13421	7.00E-03	7.21E-03	1.0
57	La	5.00E-06	2.00E-05	PNNL-13421	5.00E-06	6.00E-05	4.0
3	Li		2.06E-02	ORNL-5786	2.06E-02	5.00E-02	NA
103	Lr		5.00E-06	NCRP 1996	5.00E-06	5.00E-06	NA
71	Lu	2.00E-05	2.06E-05	ORNL-5786	2.00E-05	6.00E-05	1.0
101	Md		5.00E-06	NCRP 1996	5.00E-06	5.00E-06	NA
12	Mg		3.90E-03	PNNL-13421	3.90E-03	8.00E-03	NA
25	Mn	2.50E-04	3.00E-05	PNNL-13421	3.00E-05	3.61E-04	0.1
42	Mo	7.50E-03	1.70E-03	PNNL-13421	1.50E-03	7.50E-03	0.2
7	N		2.50E-02	PNNL-13421	1.00E-02	2.58E-02	NA
11	Na		1.60E-02	PNNL-13421	1.60E-02	4.00E-02	NA
41	Nb	2.50E-03	3.20E-05*	PNNL-13421	4.10E-07	2.06E-02	0.0002
60	Nd		3.00E-05	PNNL-13421	5.00E-06	6.00E-05	NA
28	Ni	6.70E-03	1.60E-02	PNNL-13421	1.00E-03	2.00E-02	2.4
102	No		5.00E-06	NCRP 1996	5.00E-06	5.00E-06	NA
93	Np	5.00E-06	5.00E-06	PNNL-13421	5.00E-06	1.00E-05	1.0
76	Os		5.00E-03	PNNL-13421	1.00E-04	3.50E+00	NA
15	P	2.50E-02	1.60E-02	PNNL-13421	1.50E-02	2.50E-02	0.6
91	Pa	5.00E-06	5.00E-06	PNNL-13421	5.00E-06	5.15E-06	1.0
82	Pb	3.00E-04	2.60E-04	PNNL-13421	2.50E-04	3.00E-04	0.9
46	Pd	5.00E-03	1.00E-02	PNNL-13421	1.00E-04	1.03E-02	2.0
61	Pm		3.00E-05	PNNL-13421	2.00E-05	6.00E-05	NA
84	Po	3.40E-04	3.40E-04	PNNL-13421	3.40E-04	4.00E-04	1.0
59	Pr		3.00E-05	PNNL-13421	5.00E-06	6.00E-05	NA
78	Pt	5.00E-03	5.15E-03	ORNL-5786	1.00E-04	5.15E-03	1.0
94	Pu	2.00E-06	1.10E-06	PNNL-13421	1.00E-07	2.00E-06	0.6
88	Ra	1.00E-03	1.30E-03	PNNL-13421	4.50E-04	1.30E-03	1.3
37	Rb	3.00E-02	1.20E-02	PNNL-13421	1.00E-02	3.00E-02	0.4
75	Re	1.40E-04	1.50E-03	PNNL-13421	1.40E-04	2.00E-03	10.7
104	Rf		2.00E-05	NCRP 1996	2.00E-05	2.00E-05	NA
45	Rh		1.00E-02	PNNL-13421	5.00E-04	1.03E-02	NA
86	Rn		0	NCRP 1996	0	0	NA
44	Ru	1.00E-06	3.30E-06	PNNL-13421	6.00E-07	2.00E-05	3.3

*Geometric mean of PNNL-13421 site-specific value (4.10E-07) and currently used value.

Table B-2. Comprehensive Updated Feed-to-Milk Transfer Factors (d/L) (continued)

Z	Element	Current Analyses	Updated Feed-to-Milk Transfer Factors				
			Updated Factor	Reference	Min	Max	Update/Current Use Ratio*
16	S		1.60E-02	PNNL-13421	1.50E-02	2.00E-02	NA
51	Sb	1.50E-03	2.50E-05	PNNL-13421	2.50E-05	1.50E-03	0.02
21	Sc	6.00E-05	5.00E-06	PNNL-13421	5.00E-06	6.00E-05	0.08
34	Se	4.50E-02	4.00E-03	PNNL-13421	4.00E-03	4.50E-02	0.09
14	Si	2.00E-05	2.00E-05	PNNL-13421	2.00E-05	2.06E-05	1.0
62	Sm	5.00E-06	3.00E-05	PNNL-13421	5.00E-06	6.00E-05	6.0
50	Sn	2.50E-03	1.00E-03	PNNL-13421	1.00E-03	2.50E-03	0.4
38	Sr	8.00E-04	2.80E-03	PNNL-13421	8.00E-04	2.80E-03	3.5
73	Ta	3.00E-06	4.10E-07	PNNL-13421	4.10E-07	5.00E-06	0.1
65	Tb		3.00E-05	PNNL-13421	2.00E-05	6.00E-05	NA
43	Tc	2.50E-02	1.87E-03*	PNNL-13421	2.30E-05	2.50E-02	0.006
52	Te	1.00E-03	4.50E-04	PNNL-13421	2.00E-04	1.00E-03	0.5
90	Th	5.00E-06	5.00E-06	PNNL-13421	5.00E-06	5.15E-06	1.0
22	Ti	5.50E-07	7.53E-05†	ORNL-5786	5.50E-07	1.03E-02	18,727
81	Tl	1.00E-02	2.00E-03	PNNL-13421	1.00E-03	1.00E-02	0.2
69	Tm		2.06E-05	ORNL-5786	2.06E-05	6.00E-05	NA
92	U	5.00E-04	4.00E-04	PNNL-13421	4.00E-04	6.18E-04	0.8
23	V	2.00E-05	2.06E-05	ORNL-5786	2.00E-05	5.00E-04	1.0
74	W		3.00E-04	PNNL-13421	3.00E-04	5.00E-04	NA
39	Y	1.00E-05	2.00E-05	PNNL-13421	1.00E-05	2.00E-03	2.0
70	Yb		2.06E-05	ORNL-5786	2.06E-05	6.00E-05	NA
30	Zn		1.00E-02	PNNL-13421	1.00E-02	3.90E-02	NA
40	Zr	5.00E-06	5.50E-07	PNNL-13421	5.50E-07	3.09E-05	0.1

*Geometric mean of PNNL-13421 site-specific value (1.40E-04) and currently used value.
†Geometric mean of ORNL-5786 site-specific value (1.03E-02) and currently used value.

Table B-3. Comprehensive Updated Feed-to-Meat Bioaccumulation Factors (d/kg)

Z	Element	Current SRS Value	Updated Feed-to-Meat Transfer Factors				Update/Current Use Ratio*
			Updated Value	Reference	Min	Max	
89	Ac	2.0E-05	4.00E-04	PNNL-13421	2.00E-05	4.00E-04	20.0
47	Ag	1.7E-02	3.00E-03	PNNL-13421	3.00E-03	1.70E-02	0.2
13	Al	5.0E-04	1.50E-03	ORNL-5786	5.00E-04	1.50E-03	3.0
95	Am	2.0E-04	4.00E-05	PNNL-13421	3.50E-06	2.00E-04	0.2
33	As		2.00E-03	PNNL-13421	1.50E-03	2.00E-02	NA
85	At	1.0E-02	1.00E-02	ORNL-5786	1.00E-02	1.00E-02	1.0
79	Au	2.0E-04	5.00E-03	PNNL-13421	2.00E-04	8.00E-03	25.0
5	B		8.00E-04	ORNL-5786	8.00E-04	8.00E-04	NA
56	Ba		2.00E-04	PNNL-13421	1.50E-04	3.00E-02	NA
4	Be	1.0E-03	1.00E-03	PNNL-13421	1.00E-03	5.00E-03	1.0
83	Bi	2.0E-03	4.00E-04	PNNL-13421	4.00E-04	2.00E-03	0.2
97	Bk	2.0E-05	2.50E-05	NCRP 123	2.00E-05	4.00E-05	1.3
35	Br		2.50E-02	PNNL-13421	2.00E-02	5.00E-02	NA
6	C	3.1E-02	3.10E-02	NRC 1997	3.10E-02	4.89E-02	1.0
20	Ca	1.6E-03	2.00E-03	PNNL-13421	7.00E-04	2.00E-03	1.3
48	Cd	5.3E-04	4.00E-04	PNNL-13421	4.00E-04	1.00E-03	0.8
58	Ce		2.00E-05	PNNL-13421	2.00E-05	1.20E-03	NA
98	Cf	6.0E-05	4.00E-05	PNNL-13421	4.00E-05	5.00E-03	0.7
17	Cl	6.0E-02	2.00E-02	PNNL-13421	2.00E-02	8.00E-02	0.3
96	Cm	2.0E-04	4.00E-05	PNNL-13421	3.50E-06	2.00E-04	0.2
27	Co	1.3E-02	1.00E-02	PNNL-13421	1.00E-02	3.00E-02	0.8
24	Cr		9.00E-03	PNNL-13421	2.40E-03	3.00E-02	NA
55	Cs	4.0E-03	5.00E-02	PNNL-13421	4.00E-03	5.00E-02	12.5
29	Cu		9.00E-03	PNNL-13421	8.00E-03	1.00E-02	NA
66	Dy		2.00E-05	PNNL-13421	2.00E-05	5.50E-03	NA
68	Er		2.00E-05	PNNL-13421	2.00E-05	4.00E-03	NA
99	Es	2.0E-05	2.50E-05	NCRP 123	2.00E-05	2.50E-05	1.3
63	Eu		2.00E-05	PNNL-13421	2.00E-05	5.00E-03	NA
9	F		1.50E-01	PNNL-13421	2.00E-02	1.50E-01	NA
26	Fe	4.0E-02	2.00E-02	PNNL-13421	2.00E-02	4.00E-02	0.5
100	Fm		2.00E-04	NCRP 123	2.00E-04	2.00E-04	NA
87	Fr	3.0E-02	2.50E-03	ORNL-5786	2.50E-03	3.00E-02	0.08
31	Ga	3.0E-04	5.00E-04	PNNL-13421	3.00E-04	5.00E-04	1.7
64	Gd	2.0E-03	2.00E-05	PNNL-13421	2.00E-05	3.50E-03	0.01
32	Ge	7.0E-01	7.00E-01	ORNL-5786	2.00E-01	7.00E-01	1.0
1	H			Not Used in Model	0	1.20E-02	NA
105	Ha		5.00E-06	NCRP 123	5.00E-06	5.00E-06	NA

*Values greater than two orders of magnitude from the currently used values (update/current ratio > 100 or <0.01) are geometrically averaged to create the "updated value".

Table B-3. Comprehensive Updated Feed-to-Meat Bioaccumulation Factors (continued)

Z	Element	Current SRS Value	Updated Feed-to-Meat Transfer Factors				Update/Current Use Ratio*
			Updated Value	Reference	Min	Max	
72	Hf	1.0E-06	3.16E-05*	PNNL-13421	1.00E-06	1.00E-03	1,000
80	Hg	1.0E-01	2.50E-01	PNNL-13421	1.00E-02	2.50E-01	2.5
67	Ho	4.5E-03	3.00E-04†	PNNL-13421	2.00E-05	4.50E-03	0.004
53	I	2.9E-03	4.00E-02	PNNL-13421	2.90E-03	4.00E-02	13.8
49	In	4.0E-03	8.00E-03	PNNL-13421	4.00E-03	8.00E-03	2.0
77	Ir	2.0E-03	1.50E-03	PNNL-13421	1.50E-03	2.00E-03	0.8
19	K	2.0E-02	2.00E-02	PNNL-13421	2.00E-02	2.00E-02	1.0
57	La	2.0E-04	2.00E-03	PNNL-13421	2.00E-04	2.00E-03	10.0
3	Li		1.00E-02	ORNL-5786	1.00E-02	2.00E-02	NA
103	Lr		2.00E-04	NCRP 123	2.00E-04	2.00E-04	NA
71	Lu	4.5E-03	4.50E-03	ORNL-5786	2.00E-03	4.50E-03	1.0
12	Mg		2.00E-02	PNNL-13421	3.00E-03	2.00E-02	NA
25	Mn	8.0E-04	5.00E-04	PNNL-13421	4.00E-04	1.00E-03	0.6
42	Mo	8.0E-03	1.00E-03	PNNL-13421	1.00E-03	8.00E-03	0.1
7	N		7.50E-02	PNNL-13421	1.00E-02	7.50E-02	NA
11	Na		8.00E-02	PNNL-13421	3.00E-02	8.00E-02	NA
41	Nb	2.8E-01	2.90E-04‡	PNNL-13421	3.00E-07	2.80E-01	0.000001
60	Nd		2.00E-05	PNNL-13421	2.00E-05	3.30E-03	NA
28	Ni	5.3E-03	5.00E-03	PNNL-13421	5.00E-03	5.30E-02	0.9
102	No		2.00E-04	NCRP 123	2.00E-04	2.00E-04	NA
93	Np	2.0E-04	1.00E-03	PNNL-13421	5.50E-05	1.00E-03	5.0
76	Os		4.00E-01	PNNL-13421	2.00E-03	4.00E-01	NA
15	P	4.6E-02	5.00E-02	PNNL-13421	4.60E-02	2.00E-01	1.1
91	Pa	5.0E-03	4.47E-04§	PNNL-13421	5.00E-06	5.00E-03	0.008
82	Pb	8.0E-04	4.00E-04	PNNL-13421	3.00E-04	8.00E-04	0.5
46	Pd	1.0E-03	4.00E-03	PNNL-13421	2.00E-04	4.00E-03	4.0
61	Pm		2.00E-05	PNNL-13421	2.00E-05	5.00E-03	NA
84	Po	5.0E-03	5.00E-03	PNNL-13421	9.50E-05	5.00E-03	1.0
59	Pr		2.00E-05	PNNL-13421	2.00E-05	4.70E-03	NA
78	Pt	4.0E-03	4.00E-03	ORNL-5786	2.00E-04	4.00E-03	1.0
94	Pu	1.4E-05	1.00E-05	PNNL-13421	5.00E-07	1.00E-04	0.7
88	Ra	1.0E-03	9.00E-04	PNNL-13421	2.50E-04	1.00E-03	0.9
37	Rb	3.1E-02	1.00E-02	PNNL-13421	1.00E-02	3.10E-02	0.3
75	Re	1.0E-04	8.00E-03	PNNL-13421	1.00E-04	1.00E-02	80.0
45	Rh		2.00E-03	PNNL-13421	1.00E-03	2.00E-03	NA
86	Rn		0	NCRP 123	0	0	NA
44	Ru	4.0E-01	5.00E-02	PNNL-13421	2.00E-03	4.00E-01	0.1

*Geometric mean of PNNL-13421 site-specific value (1.00E-03) and currently used value.
†Geometric mean of PNNL-13421 site-specific value (2.00E-05) and currently used value.
‡Geometric mean of PNNL-13421 site-specific value (3.00E-07) and currently used value.
§Geometric mean of PNNL-13421 site-specific value (4.00E-05) and currently used value.

Table B-3. Comprehensive Updated Feed-to-Meat Bioaccumulation Factors (continued)

Z	Element	Current SRS Value	Updated Feed-to-Meat Transfer Factors				Update/Current Use Ratio*
			Updated Value	Reference	Min	Max	
16	S		2.00E-01	PNNL-13421	1.00E-01	2.00E-01	NA
51	Sb	4.0E-03	1.00E-03	PNNL-13421	4.00E-05	4.00E-03	0.3
21	Sc	2.0E-03	1.50E-02	PNNL-13421	2.00E-03	1.50E-02	7.5
34	Se	1.5E-02	1.50E-02	PNNL-13421	1.50E-02	1.00E-01	1.0
14	Si	4.0E-05	4.00E-05	PNNL-13421	4.00E-05	3.00E-04	1.0
62	Sm	5.0E-03	3.16E-04*	PNNL-13421	2.00E-05	5.00E-03	0.004
50	Sn	8.0E-02	8.00E-02	PNNL-13421	1.00E-02	8.00E-02	1.0
38	Sr	6.0E-04	8.00E-03	PNNL-13421	3.00E-04	1.00E-02	13.3
73	Ta	6.0E-04	1.34E-05†	PNNL-13421	3.00E-07	6.00E-04	0.0005
65	Tb		2.00E-05	PNNL-13421	2.00E-05	4.50E-03	NA
43	Tc	4.0E-01	6.32E-03‡	PNNL-13421	1.00E-04	4.00E-01	0.0003
52	Te	7.7E-02	7.00E-03	PNNL-13421	7.00E-03	7.70E-02	0.09
90	Th	2.0E-04	4.00E-05	PNNL-13421	6.00E-06	2.00E-04	0.2
22	Ti	1.0E-06	1.73E-04§	ORNL-5786	1.00E-06	3.00E-02	30,000
81	Tl	2.0E-02	4.00E-02	PNNL-13421	2.00E-03	4.00E-02	2.0
69	Tm		4.50E-03	ORNL-5786	2.00E-03	4.50E-03	NA
92	U	3.4E-04	3.00E-04	PNNL-13421	2.00E-04	8.00E-04	0.9
23	V	2.5E-03	2.50E-03	ORNL-5786	2.50E-03	1.00E-02	1.0
74	W		4.00E-02	PNNL-13421	1.30E-03	4.50E-02	NA
39	Y	4.6E-03	1.00E-03	PNNL-13421	3.00E-04	8.00E-03	0.2
70	Yb		4.00E-03	ORNL-5786	2.00E-03	4.00E-03	NA
30	Zn		1.00E-01	PNNL-13421	3.00E-02	1.00E-01	NA
40	Zr	3.4E-02	1.84E-04**	PNNL-13421	1.00E-06	3.40E-02	0.00003

*Geometric mean of PNNL-13421 site-specific value (2.00E-05) and currently used value.
†Geometric mean of PNNL-13421 site-specific value (3.00E-07) and currently used value.
‡Geometric mean of PNNL-13421 site-specific value (1.00E-04) and currently used value.
§Geometric mean of PNNL-13421 site-specific value (3.00E-02) and currently used value.
**Geometric mean of PNNL-13421 site-specific value (1.00E-06) and currently used value.

Table B-4. Comprehensive Updated Water-to-Fish Bioaccumulation Factors (L/kg)

Z	Element	Current SRS Value	Updated Water-to-Fish Bioaccumulation Factors				Update/Current Use Ratio
			Updated Value	Reference	Min	Max	
89	Ac	2.5E+01	2.50E+01	PNNL-13421	1.50E+01	2.50E+01	1.0
47	Ag	2.3E+00	5.00E+00	PNNL-13421	2.30E+00	5.00E+00	2.2
13	Al	1.0E+01	5.00E+02	NCRP 123	1.00E+01	5.00E+02	50.0
95	Am	2.5E+01	3.00E+01	PNNL-13421	2.10E+01	2.40E+03	1.2
33	As		1.70E+03	PNNL-13421	1.00E+02	1.70E+03	NA
85	At	1.5E+01	1.50E+01	NCRP 123	1.50E+01	1.50E+01	1.0
79	Au	3.5E+01	3.30E+01	PNNL-13421	3.30E+01	3.50E+01	0.9
56	Ba		4.00E+00	PNNL-13421	4.00E+00	2.00E+02	NA
4	Be	2.0E+00	1.00E+02	PNNL-13421	2.00E+00	1.00E+02	50.0
83	Bi	1.5E+01	1.50E+01	PNNL-13421	1.00E+01	1.50E+01	1.0
97	Bk	2.5E+01	2.50E+01	NCRP 123	2.50E+01	2.50E+01	1.0
35	Br		4.00E+02	PNNL-13421	4.00E+02	4.20E+02	NA
6	C	4.6E+03	5.00E+04	PNNL-13421	4.60E+03	5.00E+04	10.9
20	Ca	4.0E+01	4.00E+01	PNNL-13421	4.00E+01	1.00E+03	1.0
48	Cd	2.0E+02	2.00E+02	PNNL-13421	2.00E+02	2.00E+02	1.0
58	Ce		3.00E+01	PNNL-13421	1.00E+00	5.00E+02	NA
98	Cf	2.5E+01	2.50E+01	PNNL-13421	2.50E+01	2.50E+01	1.0
17	Cl	5.0E+01	5.00E+01	PNNL-13421	5.00E+01	1.00E+03	1.0
96	Cm	2.5E+01	3.00E+01	PNNL-13421	2.10E+01	2.50E+02	1.2
27	Co	5.0E+01	3.00E+02	PNNL-13421	5.00E+01	3.30E+02	6.0
24	Cr		4.00E+00	PNNL-13421	4.00E+00	2.00E+02	NA
55	Cs	3.0E+03	3.00E+03	Jannik 2003	2.00E+03	4.70E+03	1.0
29	Cu		2.00E+02	PNNL-13421	5.00E+01	2.00E+02	NA
66	Dy		3.00E+01	PNNL-13421	3.00E+01	3.00E+01	NA
68	Er		3.00E+01	PNNL-13421	3.00E+01	3.00E+01	NA
99	Es	1.0E+01	2.50E+01	NCRP 123	1.00E+01	2.50E+01	2.5
63	Eu		3.00E+01	PNNL-13421	2.50E+01	5.00E+01	NA
9	F		1.00E+01	PNNL-13421	1.00E+01	1.00E+01	NA
26	Fe	1.0E+02	2.00E+02	PNNL-13421	1.00E+02	2.00E+03	2.0
87	Fr	3.0E+01	3.00E+01	NCRP 123	3.00E+01	3.00E+01	1.0
31	Ga	3.3E+02	4.00E+02	PNNL-13421	3.33E+02	4.00E+02	1.2
64	Gd	2.5E+01	3.00E+01	PNNL-13421	2.50E+01	3.00E+01	1.2
32	Ge	3.3E+03	4.00E+03	NCRP 123	3.33E+03	4.00E+03	1.2
2	He		1.00E+00	PNNL-13421	1.00E+00	1.00E+00	NA
1	H	9.0E-01	1.00E+00	NCRP 123	9.00E-01	1.00E+00	1.1
72	Hf	3.3E+00	3.00E+02	PNNL-13421	3.33E+00	3.00E+02	90.1
80	Hg	1.0E+03	1.00E+03	PNNL-13421	1.00E+03	1.00E+03	1.0
67	Ho	2.5E+01	3.00E+01	PNNL-13421	2.50E+01	3.00E+01	1.2
53	I	1.5E+01	4.00E+01	PNNL-13421	1.50E+01	5.00E+02	2.7
49	In	1.0E+04	1.00E+04	PNNL-13421	1.00E+04	1.00E+05	1.0
77	Ir	1.0E+01	1.00E+01	PNNL-13421	1.00E+01	1.00E+01	1.0

Table B-4.Comprehensive Updated Water-to-Fish Bioaccumulation Factors (L/kg) (continued)

Z	Element	Current SRS Value	Updated Water-to-Fish Bioaccumulation Factors				Update/Current Use Ratio
			Updated Value	Reference	Min	Max	
19	K	1.0E+03	1.00E+03	PNNL-13421	1.00E+03	1.00E+04	1.0
57	La	2.5E+01	3.00E+01	PNNL-13421	2.50E+01	3.00E+01	1.2
71	Lu	2.5E+01	2.50E+01	NCRP 123	2.50E+01	2.50E+01	1.0
12	Mg		5.00E+01	PNNL-13421	5.00E+01	5.00E+01	NA
25	Mn	1.0E+02	4.00E+02	PNNL-13421	1.00E+02	4.00E+02	4.0
42	Mo	1.0E+01	1.00E+01	PNNL-13421	1.00E+01	1.00E+01	1.0
7	N		2.00E+05	PNNL-13421	1.50E+05	2.00E+05	NA
11	Na		2.00E+01	PNNL-13421	8.00E+00	1.00E+02	NA
41	Nb	3.0E+04	3.00E+02	PNNL-13421	2.00E+02	3.00E+04	0.0
60	Nd		3.00E+01	PNNL-13421	2.50E+01	1.00E+02	NA
28	Ni	1.0E+02	1.00E+02	PNNL-13421	1.00E+02	1.00E+02	1.0
93	Np	1.0E+02	2.10E+01	PNNL-13421	1.00E+01	2.50E+02	0.2
8	O		1.00E+00	PNNL-13421	1.00E+00	1.00E+00	NA
76	Os	1.0E+05	1.00E+03*	PNNL-13421	1.00E+01	1.00E+05	0.0001
15	P		5.00E+04	PNNL-13421	1.50E+03	1.00E+05	NA
91	Pa	1.1E+01	1.00E+01	PNNL-13421	1.00E+01	1.13E+01	0.9
82	Pb	3.0E+02	3.00E+02	PNNL-13421	1.00E+02	3.00E+02	1.0
46	Pd	1.0E+01	1.00E+01	PNNL-13421	1.00E+01	1.00E+01	1.0
61	Pm		3.00E+01	PNNL-13421	2.50E+01	3.00E+01	NA
84	Po	5.0E+02	5.00E+01	PNNL-13421	5.00E+01	5.00E+02	0.1
59	Pr		3.00E+01	PNNL-13421	2.50E+01	1.00E+02	NA
78	Pt	1.0E+02	3.50E+01	NCRP 123	3.50E+01	1.00E+02	0.4
94	Pu	3.5E+00	3.00E+01	PNNL-13421	3.50E+00	4.70E+03	8.6
88	Ra	5.0E+01	5.00E+01	PNNL-13421	5.00E+01	7.00E+01	1.0
37	Rb	2.0E+03	2.00E+03	PNNL-13421	2.00E+03	2.00E+03	1.0
75	Re	1.2E+02	1.20E+02	PNNL-13421	1.19E+02	1.20E+04	1.0
45	Rh		1.00E+01	PNNL-13421	1.00E+01	1.00E+01	NA
45	Rn	5.7E+01	0	NCRP 123	0	5.70E+01	NA
44	Ru	1.0E+01	1.00E+02	PNNL-13421	1.00E+01	1.00E+02	10.0
16	S		8.00E+02	PNNL-13421	7.50E+02	1.00E+03	NA
51	Sb	1.0E+00	1.00E+02	PNNL-13421	1.00E+00	2.00E+02	100.0
21	Sc	1.0E+02	1.00E+02	PNNL-13421	1.00E+02	1.00E+02	1.0
34	Se	1.7E+02	1.70E+02	PNNL-13421	1.70E+02	2.00E+02	1.0
14	Si	2.5E+00	2.00E+01	PNNL-13421	2.50E+00	2.00E+01	8.0
62	Sm	2.5E+01	3.00E+01	PNNL-13421	2.50E+01	3.00E+01	1.2
50	Sn	3.0E+03	3.00E+03	PNNL-13421	3.00E+03	3.00E+03	1.0
38	Sr	3.0E+01	6.00E+01	PNNL-13421	3.00E+01	5.01E+02	2.0
73	Ta	3.0E+04	3.00E+02	PNNL-13421	1.00E+02	3.00E+04	0.01
65	Tb		3.00E+01	PNNL-13421	2.50E+01	3.00E+01	NA
43	Tc	1.5E+01	2.00E+01	PNNL-13421	1.50E+01	2.00E+01	1.3

*Geometric mean of PNNL-13421 site-specific value (1.00E+01) and currently used value.

Table B-4.Comprehensive Updated Water-to-Fish Bioaccumulation Factors (L/kg) (continued)

Z	Element	Current SRS Value	Updated Water-to-Fish Bioaccumulation Factors				Update/Current Use Ratio
			Updated Value	Reference	Min	Max	
52	Te	4.0E+02	4.00E+02	PNNL-13421	4.00E+02	4.00E+02	1.0
90	Th	3.0E+01	1.00E+02	PNNL-13421	3.00E+01	1.00E+02	3.3
22	Ti	1.0E+03	1.00E+03	NCRP 123	1.00E+03	1.00E+03	1.0
81	Tl	1.0E+04	1.00E+04	PNNL-13421	1.00E+04	1.00E+04	1.0
92	U	2.0E+00	1.00E+01	PNNL-13421	2.00E+00	5.00E+01	5.0
23	V	1.0E+01	2.00E+02	NCRP 123	1.00E+01	2.00E+02	20.0
74	W		1.00E+01	PNNL-13421	1.00E+01	1.20E+03	NA
39	Y	2.5E+01	3.00E+01	PNNL-13421	2.50E+01	3.00E+01	1.2
30	Zn		3.50E+02	PNNL-13421	3.50E+02	2.50E+03	NA
40	Zr	3.3E+00	3.00E+02	PNNL-13421	3.30E+00	3.00E+02	90.9

Table B-5. Soil-to-Vegetable Transfer Factors from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2-4*0.195	ORNL-5786 (Baes et al. 1984) Figure 2.2*0.195	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.16*0.195	NCRP 123 (NCRP 1996) Table 5.2	IAEA 364 Table VI 95% Root *0.195		CDC 2006 (Table 8-3*0.195)	RESRAD Ver. 6 (Yu et al. 2001) Table D.3	Reg Guide 1.109 (NRC 1977) Table E-1
						Low End	High End			
89	Ac	6.83E-05	6.83E-05	6.83E-05	1.00E-03				2.50E-03	
47	Ag	2.54E-04	1.95E-02	2.54E-04	4.00E-03				1.50E-01	1.50E-01
13	Al		1.27E-04		4.00E-03				4.00E-03	
95	Am	6.83E-05	4.88E-05	8.00E-05	1.00E-03	2.15E-06	3.32E-02	1.64E-04	1.00E-03	
18	Ar			0	0				0	
33	As	1.17E-03		1.17E-03	8.00E-02				8.00E-02	
85	At		2.93E-02		2.00E-01					
79	Au	3.51E-03	1.95E-02	1.95E-02	1.00E-01				1.00E-01	
5	B		3.90E-01		1.00E-02					
56	Ba	2.93E-03	2.93E-03	2.93E-03	1.00E-02				5.00E-03	5.00E-03
4	Be	2.93E-04	2.93E-04	2.93E-04	4.00E-03				4.00E-03	
83	Bi	9.75E-02	9.75E-04	9.75E-04	1.00E-01				1.00E-01	
97	Bk				1.00E-03					
35	Br	2.93E-01		2.93E-01	4.00E-01				7.60E-01	
6	C	1.37E-01		1.37E-01					5.50E+00	5.50E+00
20	Ca	6.83E-02	6.83E-02	6.83E-02	5.00E-01				5.00E-01	
48	Cd	2.93E-02	2.93E-02	2.93E-02	5.00E-01				3.00E-01	
58	Ce	3.90E-03	7.80E-04	7.80E-04	2.00E-03			5.85E-03	2.00E-03	2.50E-03
98	Cf	6.83E-05		1.95E-03	1.00E-03				1.00E-03	
17	Cl	1.37E+01	1.37E+01	1.37E+01	2.00E+01				2.00E+01	
96	Cm	8.39E-05	2.93E-06	4.68E-05	1.00E-03	2.15E-06	4.68E-04		1.00E-03	
27	Co	1.31E-02	1.37E-03	7.80E-03	8.00E-02	2.34E-03	2.34E-01	2.15E-02	8.00E-02	9.40E-03
24	Cr	8.78E-04		8.78E-04	1.00E-02				2.50E-04	2.50E-04
55	Cs	2.54E-02	5.85E-03	9.56E-03	2.00E-01	2.15E-04	2.15E-02	1.76E-01	4.00E-02	1.00E-02

Table B-5. Soil-to-Vegetable Transfer Factors from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2-4*0.195	ORNL-5786 (Baes et al. 1984) Figure 2.2*0.195	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.16*0.195	NCRP 123 (NCRP 1996) Table 5.2	IAEA 364 Table VI 95% Root *0.195		CDC 2006 (Table 8-3*0.195)	RESRAD Ver. 6 (Yu et al. 2001) Table D.3	Reg Guide 1.109 (NRC 1977) Table E-1
						Low End	High End			
29	Cu	4.88E-02		4.88E-02	5.00E-02				1.30E-01	1.20E-01
66	Dy	3.90E-03		7.80E-04	2.00E-03					
68	Er	3.90E-03		7.80E-04	2.00E-03					
99	Es				1.00E-03					
63	Eu	3.90E-03	7.80E-04	7.80E-04	2.00E-03				2.50E-03	
9	F	1.17E-03		1.17E-03	2.00E-02				2.00E-02	
26	Fe	9.75E-03	1.95E-04	1.95E-04	1.00E-03				1.00E-03	6.60E-04
100	Fm				2.00E-03					
87	Fr		5.85E-03		3.00E-02					
31	Ga	7.80E-05	7.80E-05	7.80E-05	3.00E-03					
64	Gd	3.90E-03	7.80E-04	7.80E-04	2.00E-03				2.50E-03	
32	Ge		1.56E-02		4.00E-01				4.00E-01	
1	H								4.80E+00	4.80E+00
108	Ha				2.00E-03					
2	He				0					
72	Hf	1.95E-04	1.66E-04	1.66E-04	3.00E-03					
80	Hg	3.90E-02	3.90E-02	3.90E-02	3.00E-01				3.80E-01	
67	Ho	3.90E-03	7.80E-04	7.80E-04	2.00E-03				2.60E-03	
53	I	7.80E-03	9.75E-03	9.75E-03	2.00E-02	6.63E-05	6.63E-03	3.90E-03	2.00E-02	2.00E-02
49	In	7.80E-05	7.80E-05	7.80E-05	3.00E-03				3.00E-03	
77	Ir	2.93E-03	2.93E-03	2.93E-03	3.00E-02				3.00E-02	
19	K	1.07E-01	1.07E-01	1.07E-01	3.00E-01				3.00E-01	
36	Kr			0	0				0	
57	La	6.83E-05	7.80E-04	1.25E-04	2.00E-03				2.50E-03	2.50E-03
3	Li		7.80E-04		1.00E-03					
103	Lr				2.00E-03					

Table B-5. Soil-to-Vegetable Transfer Factors from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2-4*0.195	ORNL-5786 (Baes et al. 1984) Figure 2.2*0.195	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.16*0.195	NCRP 123 (NCRP 1996) Table 5.2	IAEA 364 Table VI 95% Root *0.195		CDC 2006 (Table 8-3*0.195)	RESRAD Ver. 6 (Yu et al. 2001) Table D.3	Reg Guide 1.109 (NRC 1977) Table E-1
						Low End	High End			
71	Lu		7.80E-04		2.00E-03					
101	Md				2.00E-03					
12	Mg	1.07E-01		1.07E-01	3.00E-02					
25	Mn	3.90E-02	9.75E-03	2.93E-02	3.00E-01				3.00E-01	2.90E-02
42	Mo	1.56E-01	1.17E-02	1.17E-02	1.00E-01				1.30E-01	1.20E-01
7	N	9.56E-03		5.85E+00	7.50E+00				7.50E+00	
11	Na	5.85E-02	1.07E-02	1.07E-02	5.00E-02				5.00E-02	5.20E-02
41	Nb	4.88E-03	9.75E-04	9.75E-04	1.00E-02			3.32E-03	1.00E-02	9.40E-03
60	Nd	3.90E-03		7.80E-04	2.00E-03				2.40E-03	2.40E-03
10	Ne				0					
28	Ni	1.17E-02	1.17E-02	1.17E-02	5.00E-02	3.51E-03	3.51E-01		5.00E-02	1.90E-02
102	No				2.00E-03					
93	Np	2.54E-03	1.95E-03	1.83E-03	2.00E-02	1.38E-04	2.73E-02		2.00E-02	2.50E-03
8	O				6.00E-01					
76	Os	6.83E-04		6.83E-04	3.00E-02					
15	P	6.83E-01	6.83E-01	6.83E-01	1.00E+00			6.83E-01	1.00E+00	1.10E+00
91	Pa	6.83E-05	4.88E-05	4.88E-05	1.00E-02				1.00E-02	
82	Pb	1.17E-03	1.76E-03	6.24E-04	4.00E-03	2.54E-05	2.54E-03		1.00E-02	
46	Pd	7.80E-03	7.80E-03	7.80E-03	1.00E-01				1.00E-01	
61	Pm	3.90E-03	7.80E-04	7.80E-04	2.00E-03				2.50E-03	
84	Po	1.37E-03	7.80E-05	1.76E-03	1.00E-03				1.00E-03	
59	Pr	3.90E-03	7.80E-04	7.80E-04	2.00E-03				2.50E-03	2.50E-03
78	Pt		4.88E-03		1.00E-01					
94	Pu	2.15E-04	8.78E-06	3.90E-05	1.00E-03	7.41E-07	1.09E-02	1.60E-04	1.00E-03	
88	Ra	3.90E-04	2.93E-03	6.24E-04	4.00E-02	4.29E-04	1.07E-02		4.00E-02	
37	Rb	1.76E-01	1.37E-02	1.37E-02	2.00E-01				1.30E-01	1.30E-01

Table B-5. Soil-to-Vegetable Transfer Factors from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2-4*0.195	ORNL-5786 (Baes et al. 1984) Figure 2.2*0.195	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.16*0.195	NCRP 123 (NCRP 1996) Table 5.2	IAEA 364 Table VI 95% Root *0.195		CDC 2006 (Table 8-3*0.195)	RESRAD Ver. 6 (Yu et al. 2001) Table D.3	Reg Guide 1.109 (NRC 1977) Table E-1
						Low End	High End			
75	Re	6.83E-02		6.83E-02	2.00E-01					
104	Rf				3.00E-03					
45	Rh	7.80E-03	7.80E-03	7.80E-03	3.00E-02				1.30E-01	1.30E+01
86	Rn			0	0				0	
44	Ru	7.80E-03	3.90E-03	3.90E-03	3.00E-02			7.80E-03	3.00E-02	5.00E-02
16	S	2.93E-01	2.93E-01	2.93E-01	6.00E-01			2.93E-01	6.00E-01	
51	Sb	1.09E-04	5.85E-03	1.09E-04	1.00E-02	2.15E-05	5.46E-04		1.00E-02	
21	Sc	1.95E-04	1.95E-04	1.95E-04	2.00E-03				2.00E-03	
34	Se	9.75E-03	4.88E-03	4.88E-03	1.00E-01				1.00E-01	
14	Si	1.37E-02	1.37E-02	1.37E-02	2.00E-02					
62	Sm	3.90E-03	7.80E-04	7.80E-04	2.00E-03				2.50E-03	
50	Sn	1.17E-03	1.17E-03	1.17E-03	3.00E-01				2.50E-03	
38	Sr	9.75E-02	4.88E-02	1.58E-01	3.00E-01	2.73E-02	2.73E+00	3.32E-01	3.00E-01	1.70E-02
73	Ta	4.88E-03	4.88E-04	4.88E-04	2.00E-03				2.00E-02	
65	Tb	3.90E-03		7.80E-04	2.00E-03				2.60E-03	
43	Tc	4.68E-02	2.93E-01	2.15E-01	5.00E+00	4.68E-01	4.68E-01	5.46E+00	5.00E+00	2.50E-01
52	Te	7.80E-04	7.80E-04	7.80E-04	1.00E-01				6.00E-01	1.30E+00
90	Th	6.44E-05	1.66E-05	2.34E-05	1.00E-03	5.85E-06	1.46E-03	1.35E-03	1.00E-03	
22	Ti		5.85E-04		1.00E-03					
81	Tl	7.80E-05	7.80E-05	7.80E-05	2.00E-01				2.00E-01	
69	Tm		7.80E-04		2.00E-03					
92	U	2.34E-03	7.80E-04	2.73E-03	2.00E-03	2.73E-04	2.73E-02	2.15E-03	2.50E-03	
23	V		5.85E-04		2.00E-03					
74	W	5.85E-01	1.95E-03	1.95E-03	8.00E-01				1.80E-02	1.80E-02
54	Xe			0	0				0	
39	Y	1.95E-03	1.17E-03	1.17E-03	2.00E-03			1.95E-03	2.50E-03	2.60E-03
70	Yb		7.80E-04		2.00E-03					

Table B-5. Soil-to-Vegetable Transfer Factors from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2-4*0.195	ORNL-5786 (Baes et al. 1984) Figure 2.2*0.195	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.16*0.195	NCRP 123 (NCRP 1996) Table 5.2	IAEA 364 Table VI 95% Root *0.195		CDC 2006 (Table 8-3*0.195)	RESRAD Ver. 6 (Yu et al. 2001) Table D.3	Reg Guide 1.109 (NRC 1977) Table E-1
						Low End	High End			
30	Zn	6.83E-02		1.15E-01	4.00E-01			2.34E+00	4.00E-01	4.00E-01
40	Zr	1.95E-04	9.75E-05	9.75E-05	1.00E-03			1.95E-04	1.00E-03	1.70E-04

Table B-6. Feed-to-Milk Transfer Factors (d/L) from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.8	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.24	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XII	CDC 2006 (Table 8-6)	Resrad Ver. 6 (Yu et al. 2001) Table D.4	Reg Guide 1.109 (NRC 1977) Table E-1
89	Ac	2.00E-05	2.0E-05	2.1E-05	2.0E-06			2.0E-05	
47	Ag	5.00E-05	2.0E-02	2.1E-02	6.0E-03	5.0E-05		2.5E-02	5.0E-02
13	Al			2.1E-04	2.0E-04			2.0E-04	
95	Am	1.50E-06	4.0E-07	4.1E-07	2.0E-06	1.5E-06	1.50E-06	2.0E-06	
33	As	6.00E-05	6.0E-05	6.2E-05	1.0E-04			1.0E-04	
85	At			1.0E-02	1.0E-02				
79	Au	5.50E-06	5.5E-06	5.7E-06	1.0E-05			1.0E-05	
5	B			1.5E-03	3.0E-03				
56	Ba	4.80E-04	3.5E-04	3.6E-04	5.0E-04	4.8E-04		5.0E-04	4.0E-04
4	Be	9.00E-07	9.0E-07	9.3E-07	2.0E-06			2.0E-06	
83	Bi	5.00E-04	5.0E-04	5.2E-04	1.0E-03			5.0E-04	
97	Bk				2.0E-06				
35	Br	0.02	2.0E-02	2.1E-02	2.0E-02			2.0E-02	
6	C							1.2E-02	1.2E-02
20	Ca	3.00E-03	1.0E-02	1.0E-02	3.0E-03	3.0E-03		3.0E-03	
48	Cd	1.00E-03	1.0E-03	1.0E-03	2.0E-03			1.0E-03	
58	Ce	3.00E-05	2.0E-05	2.1E-05	3.0E-05	3.0E-05	3.00E-05	3.0E-05	1.0E-04
98	Cf	1.50E-06	7.5E-07		2.0E-06			7.5E-07	
17	Cl	1.70E-02	1.5E-02	1.5E-02	2.0E-02	1.7E-02		2.0E-02	
96	Cm	2.00E-05	2.0E-05	2.1E-05	2.0E-06			2.0E-06	
27	Co	3.00E-04	2.0E-03	2.1E-03	2.0E-03	3.0E-04	3.00E-04	2.0E-03	1.0E-03
24	Cr	1.00E-05	1.5E-03	1.5E-03	2.0E-03	1.0E-05		2.0E-03	2.2E-03
55	Cs	7.90E-03	7.0E-03	7.2E-03	1.0E-02	7.9E-03	7.90E-03	8.0E-03	1.2E-02
29	Cu	2.00E-03	1.5E-03	1.5E-03	2.0E-03			2.0E-03	1.4E-02
66	Dy	3.00E-05	2.0E-05	2.1E-05	6.0E-05				
68	Er	3.00E-05	2.0E-05	2.1E-05	6.0E-05				
99	Es				2.0E-06				
63	Eu	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	

Table B-6. Feed-to-Milk Transfer Factors (d/L) from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.8	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.24	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XII	CDC 2006 (Table 8-6)	Resrad Ver. 6 (Yu et al. 2001) Table D.4	Reg Guide 1.109 (NRC 1977) Table E-1
9	F	1.00E-03	1.0E-03	1.0E-03	7.0E-03			7.0E-03	
26	Fe	3.00E-05	2.5E-04	2.6E-04	3.0E-04	3.0E-05		3.0E-04	1.2E-03
87	Fr			2.1E-02	8.0E-03				
31	Ga	5.00E-05	5.0E-05	5.2E-05	1.0E-05				
64	Gd	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	
32	Ge			7.2E-02	1.0E-02			1.0E-02	
1	H	1.50E-02				1.5E-02		1.0E-02	1.0E-02
105	Ha				5.0E-06				
2	He				0				
72	Hf	5.50E-07	5.0E-06	5.2E-06	2.5E-05				
80	Hg	4.70E-04	4.5E-04	4.6E-04	5.0E-04	4.7E-04		5.0E-04	
67	Ho	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	
53	I	9.00E-03	1.0E-02	1.0E-02	1.0E-02	1.0E-02	1.00E-02	1.0E-02	6.0E-03
49	In	2.00E-04	1.0E-04	1.0E-04	2.0E-04			2.0E-04	
77	Ir	2.00E-06	2.0E-06	2.1E-06	2.0E-06			2.0E-06	
19	K	7.20E-03	7.0E-03	7.2E-03	7.0E-03	7.2E-03		7.0E-03	
57	La	2.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	5.0E-06
3	Li			2.1E-02	5.0E-02				
103	Lr				5.0E-06				
71	Lu			2.1E-05	6.0E-05				
101	Md				5.0E-06				
12	Mg	3.90E-03	4.0E-03	4.1E-03	8.0E-03	3.9E-03			
25	Mn	3.00E-05	3.5E-04	3.6E-04	3.0E-04	3.0E-05		3.0E-04	2.5E-04
42	Mo	1.70E-03	1.5E-03	1.5E-03	2.0E-03	1.7E-03		1.7E-03	7.5E-03
7	N	2.50E-02	2.5E-02	2.6E-02	1.0E-02			1.0E-02	
11	Na	1.60E-02	3.5E-02	3.6E-02	4.0E-02	1.6E-02		4.0E-02	4.0E-02
41	Nb	4.10E-07	2.0E-02	2.1E-02	2.0E-06	4.1E-07	4.10E-07	2.0E-06	2.5E-03
60	Nd	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	5.0E-06
28	Ni	1.60E-02	1.0E-03	1.0E-03	2.0E-02	1.6E-02		2.0E-02	6.7E-03
102	No				5.0E-06				
93	Np	5.00E-06	5.0E-06	5.2E-06	1.0E-05	5.0E-06		5.0E-06	5.0E-06

Table B-6. Feed-to-Milk Transfer Factors (d/L) from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.8	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.24	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XII	CDC 2006 (Table 8-6)	Resrad Ver. 6 (Yu et al. 2001) Table D.4	Reg Guide 1.109 (NRC 1977) Table E-1
76	Os	5.00E-03	5.0E-03	5.2E-03	1.0E-04		3.50E+00		
15	P	1.60E-02	1.5E-02	1.5E-02	2.0E-02	1.6E-02	1.60E-02	1.6E-02	2.5E-02
91	Pa	5.00E-06	5.0E-06	5.2E-06	5.0E-06			5.0E-06	
82	Pb	2.60E-04	2.5E-04	2.6E-04	3.0E-04			3.0E-04	
46	Pd	1.00E-02	1.0E-02	1.0E-02	1.0E-04			5.0E-03	
61	Pm	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	
84	Po	3.40E-04	3.5E-04	3.6E-04	4.0E-04	3.4E-04		3.4E-04	
59	Pr	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	5.0E-06
78	Pt			5.2E-03	1.0E-04				
94	Pu	1.10E-06	1.0E-07	1.0E-07	1.0E-06	1.1E-06	1.10E-06	1.0E-06	
88	Ra	1.30E-03	4.5E-04	4.6E-04	1.0E-03	1.3E-03		1.0E-03	
37	Rb	1.20E-02	1.0E-02	1.0E-02	1.0E-02	1.2E-02		1.0E-02	3.0E-02
75	Re	1.50E-03	1.5E-03	1.5E-03	2.0E-03				
104	Rf				2.0E-05				
45	Rh	1.00E-02	1.0E-02	1.0E-02	5.0E-04			5.0E-03	1.0E-02
86	Rn				0			0	
44	Ru	3.30E-06	6.0E-07	6.2E-07	2.0E-05	3.3E-06	3.30E-06	3.3E-06	1.0E-06
16	S	1.60E-02	1.5E-02	1.5E-02	2.0E-02	1.6E-02	1.60E-02	2.0E-02	
51	Sb	2.50E-05	1.0E-04	1.0E-04	1.0E-04	2.5E-05		1.0E-04	
21	Sc	5.00E-06	5.0E-06	5.2E-06	6.0E-05			5.0E-06	
34	Se	4.00E-03	4.0E-03	4.1E-03	1.0E-02			1.0E-02	
14	Si	2.00E-05	2.0E-05	2.1E-05	2.0E-05				
62	Sm	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	
50	Sn	1.00E-03	1.0E-03	1.0E-03	1.0E-03			1.0E-03	
38	Sr	2.80E-03	1.5E-03	1.5E-03	2.0E-03	2.8E-03		2.0E-03	8.0E-04
73	Ta	4.10E-07	3.0E-06	3.1E-06	5.0E-06			5.0E-06	
65	Tb	3.00E-05	2.0E-05	2.1E-05	6.0E-05			2.0E-05	
43	Tc	1.40E-04	1.0E-02	1.0E-02	1.0E-03	2.3E-05	2.30E-05	1.0E-03	2.5E-02
52	Te	4.50E-04	2.0E-04	2.1E-04	5.0E-04	4.5E-04		5.0E-04	1.0E-03
90	Th	5.00E-06	5.0E-06	5.2E-06	5.0E-06		5.00E-06	5.0E-06	
22	Ti			1.0E-02	1.0E-02				

Table B-6. Feed-to-Milk Transfer Factors (d/L) from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.8	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.24	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XII	CDC 2006 (Table 8-6)	Resrad Ver. 6 (Yu et al. 2001) Table D.4	Reg Guide 1.109 (NRC 1977) Table E-1
81	Tl	2.00E-03	2.0E-03	2.1E-03	1.0E-03			3.0E-03	
69	Tm			2.1E-05	6.0E-05				
92	U	4.00E-04	6.0E-04	6.2E-04	4.0E-04	4.0E-04	4.00E-04	6.0E-04	
23	V			2.1E-05	5.0E-04				
74	W	3.00E-04	3.0E-04	3.1E-04	3.0E-04			3.0E-04	5.0E-04
39	Y	2.00E-05	2.0E-05	2.1E-05	6.0E-05		2.00E-05	2.0E-05	1.0E-05
70	Yb			2.1E-05	6.0E-05				
30	Zn	1.00E-02	1.0E-02	1.0E-02	1.0E-02		1.00E-02	1.0E-02	3.9E-02
40	Zr	5.50E-07	3.0E-05	3.1E-05	6.0E-07	5.5E-07	5.50E-07	6.0E-07	5.0E-06

Table B-7. Feed-to-Meat Bioaccumulation Factors (d/kg) from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.6	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.25	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XVI	RESRAD Ver. 6 (Yu et al. 2001) Table D.4	CDC 2006 (Table 8-6)	Reg Guide 1.109 (NRC 1977) Table E-1
89	Ac	4.00E-04	2.5E-05	2.5E-05	2.0E-05		2.00E-05		
47	Ag	3.00E-03	3.0E-03	3.0E-03	3.0E-03	3.00E-03	3.00E-03		1.7E-02
13	Al			1.5E-03	5.0E-04		5.00E-04		
95	Am	4.00E-05	3.5E-06	3.5E-06	5.0E-05	4.00E-05	5.00E-05	4.00E-05	
33	As	2.00E-03	2.0E-03	2.0E-03	2.0E-02		1.50E-03		
85	At			1.0E-02	1.0E-02				
79	Au	5.00E-03	8.0E-03	8.0E-03	5.0E-03		5.00E-03		
5	B			8.0E-04	8.0E-04				
56	Ba	2.00E-04	1.5E-04	1.5E-04	2.0E-04	2.00E-04	2.00E-04		3.2E-03
4	Be	1.00E-03	1.0E-03	1.0E-03	5.0E-03		1.00E-03		
83	Bi	4.00E-04	4.0E-04	4.0E-04	2.0E-03		2.00E-03		
97	Bk				2.5E-05				
35	Br	2.50E-02	2.5E-02	2.5E-02	5.0E-02		2.00E-02		
6	C						3.10E-02		3.1E-02
20	Ca	2.00E-03	7.0E-04	7.0E-04	2.0E-03	2.00E-03	1.60E-03		
48	Cd	4.00E-04	5.5E-04	5.5E-04	1.0E-03	4.00E-04	4.00E-04		
58	Ce	2.00E-05	7.5E-04	7.5E-04	2.0E-05	2.00E-05	2.00E-05	2.00E-05	1.2E-03
98	Cf	4.00E-05	5.0E-03		6.0E-05		6.00E-05		
17	Cl	2.00E-02	8.0E-02	8.0E-02	4.0E-02	2.00E-02	6.00E-02		
96	Cm	4.00E-05	3.5E-06	3.5E-06	2.0E-05		2.00E-05		
27	Co	1.00E-02	2.0E-02	2.0E-02	3.0E-02	1.00E-02	2.00E-02	1.00E-02	1.3E-02
24	Cr	9.00E-03	5.5E-03	5.5E-03	3.0E-02	9.00E-03	9.00E-03		2.4E-03
55	Cs	5.00E-02	2.0E-02	2.0E-02	5.0E-02	5.00E-02	3.00E-02	5.00E-02	4.0E-03
29	Cu	9.00E-03	1.0E-02	1.0E-02	1.0E-02	9.00E-03	1.00E-02		8.0E-03
66	Dy	2.00E-05	5.5E-03	5.5E-03	2.0E-03				

Table B-7. Feed-to-Meat Bioaccumulation Factors (d/kg) from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.6	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.25	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XVI	RESRAD Ver. 6 (Yu et al. 2001) Table D.4	CDC 2006 (Table 8-6)	Reg Guide 1.109 (NRC 1977) Table E-1
68	Er	2.00E-05	4.0E-03	4.0E-03	2.0E-03				
99	Es				2.5E-05				
63	Eu	2.00E-05	5.0E-03	5.0E-03	2.0E-03		2.00E-03		
9	F	1.50E-01	1.5E-01	1.5E-01	2.0E-02		2.00E-02		
26	Fe	2.00E-02	2.0E-02	2.0E-02	3.0E-02	2.00E-02	2.00E-02		4.0E-02
100	Fm				2.0E-04				
87	Fr			2.5E-03	3.0E-02				
31	Ga	5.00E-04	5.0E-04	5.0E-04	3.0E-04				
64	Gd	2.00E-05	3.5E-03	3.5E-03	2.0E-03		2.00E-03		
32	Ge			7.0E-01	2.0E-01		2.00E-01		
1	H						1.20E-02		1.2E-02
105	Ha				5.0E-06				
72	Hf	1.00E-03	1.0E-03	1.0E-03	4.0E-04				
80	Hg	2.50E-01	2.5E-01	2.5E-01	1.0E-02		1.00E-01		
67	Ho	2.00E-05	4.5E-03	4.5E-03	2.0E-03		2.00E-03		
53	I	4.00E-02	7.0E-03	7.0E-03	4.0E-02	4.00E-02	7.00E-03	4.00E-02	2.9E-03
49	In	8.00E-03	8.0E-03	8.0E-03	4.0E-03		4.00E-03		
77	Ir	1.50E-03	1.5E-03	1.5E-03	2.0E-03		2.00E-03		
19	K	2.00E-02	2.0E-02	2.0E-02	2.0E-02	2.00E-02	2.00E-02		
57	La	2.00E-03	3.0E-04	3.0E-04	2.0E-03		2.00E-03		2.0E-04
3	Li			1.0E-02	2.0E-02				
103	Lr				2.0E-04				
71	Lu			4.5E-03	2.0E-03				
12	Mg	2.00E-02	5.0E-03	5.0E-03	3.0E-03	2.00E-02			
25	Mn	5.00E-04	4.0E-04	4.0E-04	1.0E-03	5.00E-04	5.00E-04		8.0E-04
42	Mo	1.00E-03	6.0E-03	6.0E-03	1.0E-03	1.00E-03	1.00E-03		8.0E-03
7	N	7.50E-02	7.5E-02	7.5E-02	1.0E-02		1.00E-02		

Table B-7. Feed-to-Meat Bioaccumulation Factors (d/kg) from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.6	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.25	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XVI	RESRAD Ver. 6 (Yu et al. 2001) Table D.4	CDC 2006 (Table 8-6)	Reg Guide 1.109 (NRC 1977) Table E-1
11	Na	8.00E-02	5.5E-02	5.5E-02	8.0E-02	8.00E-02	8.00E-02		3.0E-02
41	Nb	3.00E-07	2.5E-01	2.5E-01	3.0E-07	3.00E-07	3.00E-07	3.00E-07	2.8E-01
60	Nd	2.00E-05	3.0E-04	3.0E-04	2.0E-03		2.00E-03		3.3E-03
28	Ni	5.00E-03	6.0E-03	6.0E-03	5.0E-03	5.00E-03	5.00E-03		5.3E-02
102	No				2.0E-04				
93	Np	1.00E-03	5.5E-05	5.5E-05	1.0E-03	1.00E-03	1.00E-03		2.0E-04
76	Os	4.00E-01	4.0E-01	4.0E-01	2.0E-03				
15	P	5.00E-02	5.5E-02	5.5E-02	5.0E-02	5.00E-02	5.00E-02	2.00E-01	4.6E-02
91	Pa	4.00E-05	1.0E-05	1.0E-05	5.0E-06		5.00E-03		
82	Pb	4.00E-04	3.0E-04	3.0E-04	8.0E-04	4.00E-04	8.00E-04		
46	Pd	4.00E-03	4.0E-03	4.0E-03	2.0E-04		1.00E-03		
61	Pm	2.00E-05	5.0E-03	5.0E-03	2.0E-03		2.00E-03		
84	Po	5.00E-03	3.0E-04	9.5E-05	5.0E-03	5.00E-03	5.00E-03		
59	Pr	2.00E-05	3.0E-04	3.0E-04	2.0E-03		2.00E-03		4.7E-03
78	Pt			4.0E-03	2.0E-04				
94	Pu	1.00E-05	5.0E-07	5.0E-07	1.0E-04	1.00E-05	1.00E-04	1.00E-05	
88	Ra	9.00E-04	2.5E-04	2.5E-04	1.0E-03	9.00E-04	1.00E-03		
37	Rb	1.00E-02	1.5E-02	1.5E-02	3.0E-02	1.00E-02	1.50E-02		3.1E-02
75	Re	8.00E-03	8.0E-03	8.0E-03	1.0E-02				
45	Rh	2.00E-03	2.0E-03	2.0E-03	2.0E-03		1.00E-03		1.5E-03
86	Rn				0		0		
44	Ru	5.00E-02	2.0E-03	2.0E-03	2.0E-03	5.00E-02	2.00E-03	5.00E-02	4.0E-01
16	S	2.00E-01	1.0E-01	1.0E-01	2.0E-01		2.00E-01	2.00E-01	
51	Sb	1.00E-03	1.0E-03	1.0E-03	1.0E-03	4.00E-05	1.00E-03		
21	Sc	1.50E-02	1.5E-02	1.5E-02	2.0E-03		1.50E-02		
34	Se	1.50E-02	1.5E-02	1.5E-02	1.0E-01		1.00E-01		
14	Si	4.00E-05	4.0E-05	4.0E-05	3.0E-04				

Table B-7. Feed-to-Meat Bioaccumulation Factors (d/kg) from Other Sources (continued)

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.6	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.18	ORNL-5786 (Baes et al. 1984) Figure 2.25	NCRP 123 Vol I (NCRP 1996) Table 5.2	IAEA 364 Table XVI	RESRAD Ver. 6 (Yu et al. 2001) Table D.4	CDC 2006 (Table 8-6)	Reg Guide 1.109 (NRC 1977) Table E-1
62	Sm	2.00E-05	5.0E-03	5.0E-03	2.0E-03		2.00E-03		
50	Sn	8.00E-02	8.0E-02	8.0E-02	1.0E-02		1.00E-02		
38	Sr	8.00E-03	3.0E-04	3.0E-04	1.0E-02	8.00E-03	8.00E-03	8.00E-03	6.0E-04
73	Ta	3.00E-07	6.0E-04	6.0E-04	5.0E-06		5.00E-06		
65	Tb	2.00E-05	4.5E-03	4.5E-03	2.0E-03		2.00E-03		
43	Tc	1.00E-04	8.5E-03	8.5E-03	1.0E-04	1.00E-04	1.00E-04	1.00E-04	4.0E-01
52	Te	7.00E-03	1.5E-02	1.5E-02	7.0E-03	7.00E-03	7.00E-03		7.7E-02
90	Th	4.00E-05	6.0E-06	6.0E-06	1.0E-04		1.00E-04	4.00E-05	
22	Ti			3.0E-02	2.0E-02				
81	Tl	4.00E-02	4.0E-02	4.0E-02	2.0E-02		2.00E-02		
69	Tm			4.5E-03	2.0E-03				
92	U	3.00E-04	2.0E-04	2.0E-04	8.0E-04	3.00E-04	3.40E-04	3.00E-04	
23	V			2.5E-03	1.0E-02				
74	W	4.00E-02	4.5E-02	4.5E-02	4.0E-02	4.00E-02	4.00E-02		1.3E-03
39	Y	1.00E-03	3.0E-04	3.0E-04	2.0E-03	1.00E-03	2.00E-03	1.00E-03	4.6E-03
70	Yb			4.0E-03	2.0E-03				
30	Zn	1.00E-01	1.0E-01	1.0E-01	1.0E-01	1.00E-01	1.00E-01	1.00E-01	3.0E-02
40	Zr	1.00E-06	5.5E-03	5.5E-03	1.0E-06	1.00E-06	1.00E-06	1.00E-06	3.4E-02

Table B-8. Water-to-Fish Bioaccumulation Factors (L/kg) from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.10	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.19	NCRP 123 (NCRP 1996) Table 5.2	RESRAD Ver. 6 (Yu et al. 2001) Table D.5	Reg Guide 1.109 (NRC 1977) Table A-3	CDC 2006 (Table 8-7)	Friday et al. 1996
89	Ac	2.50E+01	2.50E+01		1.50E+01			
47	Ag	5.00E+00	2.30E+00		5.00E+00			
13	Al			5.00E+02	5.00E+02			
95	Am	3.00E+01	2.50E+02		3.00E+01		2.40E+03	2.45E+02
33	As	1.70E+03	1.00E+02		3.00E+02			
85	At			1.50E+01				
79	Au	3.30E+01		3.50E+01	3.50E+01			
56	Ba	4.00E+00	2.00E+02		4.00E+00	4.00E+00		
4	Be	1.00E+02	2.00E+00		1.00E+02			
83	Bi	1.50E+01	1.50E+01		1.50E+01			
97	Bk			2.50E+01				
35	Br	4.00E+02	4.20E+02		4.20E+02	4.20E+02		
6	C	5.00E+04	4.60E+03		5.00E+04	4.60E+03		
20	Ca	4.00E+01	4.00E+01		1.00E+03			
48	Cd	2.00E+02	2.00E+02		2.00E+02			
58	Ce	3.00E+01	5.00E+02		3.00E+01	1.00E+00	3.00E+01	
98	Cf	2.50E+01	2.50E+01		2.50E+01			
17	Cl	5.00E+01	5.00E+01		1.00E+03			
96	Cm	3.00E+01	2.50E+02		3.00E+01			
27	Co	3.00E+02	3.30E+02		3.00E+02	5.00E+01	3.00E+02	
24	Cr	4.00E+00	2.00E+02		2.00E+02	2.00E+02		
55	Cs	2.00E+03	2.00E+03		2.00E+03	2.00E+03	4.70E+03	
29	Cu	2.00E+02	5.00E+01		2.00E+02	5.00E+01		

Table B-8. Water-to-Fish Bioaccumulation Factors (L/kg) from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.10	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.19	NCRP 123 (NCRP 1996) Table 5.2	RESRAD Ver. 6 (Yu et al. 2001) Table D.5	Reg Guide 1.109 (NRC 1977) Table A-3	CDC 2006 (Table 8-7)	Friday et al. 1996
66	Dy	3.00E+01						
68	Er	3.00E+01						
99	Es			2.50E+01				
63	Eu	3.00E+01	2.50E+01		5.00E+01			
9	F	1.00E+01	1.00E+01		1.00E+01			
26	Fe	2.00E+02	2.00E+03		2.00E+02	1.00E+02		
87	Fr			3.00E+01				
31	Ga	4.00E+02						
64	Gd	3.00E+01	2.50E+01		2.50E+01			
32	Ge			4.00E+03	4.00E+03			
2	He	1.00E+00	1.00E+00					
1	H			1.00E+00	1.00E+00	9.00E-01		
72	Hf	3.00E+02						
80	Hg	1.00E+03	1.00E+03		1.00E+03			
67	Ho	3.00E+01	2.50E+01		2.50E+01			
53	I	4.00E+01	5.00E+02		4.00E+01	1.50E+01	4.00E+01	
49	In	1.00E+04	1.00E+05		1.00E+04			
77	Ir	1.00E+01	1.00E+01		1.00E+01			
19	K	1.00E+03	1.00E+03	1.00E+04	1.00E+03			
57	La	3.00E+01	2.50E+01		3.00E+01	2.50E+01		
71	Lu			2.50E+01				
12	Mg	5.00E+01						
25	Mn	4.00E+02	4.00E+02		4.00E+02	4.00E+02		
42	Mo	1.00E+01	1.00E+01		1.00E+01	1.00E+01		
7	N	2.00E+05	1.50E+05		1.50E+05			
11	Na	2.00E+01	1.00E+02		2.00E+01	1.00E+02		
41	Nb	3.00E+02	2.00E+02		3.00E+02	3.00E+04	3.00E+02	

Table B-8. Water-to-Fish Bioaccumulation Factors (L/kg) from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.10	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.19	NCRP 123 (NCRP 1996) Table 5.2	RESRAD Ver. 6 (Yu et al. 2001) Table D.5	Reg Guide 1.109 (NRC 1977) Table A-3	CDC 2006 (Table 8-7)	Friday et al. 1996
60	Nd	3.00E+01	2.50E+01		1.00E+02	2.50E+01		
28	Ni	1.00E+02	1.00E+02		1.00E+02	1.00E+02		
93	Np	2.10E+01	2.50E+02		3.00E+01	1.00E+01		
8	O	1.00E+00						
76	Os	1.00E+01	1.00E+01					
15	P	5.00E+04	7.00E+04		5.00E+04	1.00E+05	5.00E+04	
91	Pa	1.00E+01	1.10E+01		1.00E+01			
82	Pb	3.00E+02	1.00E+02		3.00E+02			
46	Pd	1.00E+01	1.00E+01		1.00E+01			
61	Pm	3.00E+01	2.50E+01		3.00E+01			
84	Po	5.00E+01	5.00E+02		1.00E+02			
59	Pr	3.00E+01	2.50E+01		1.00E+02	2.50E+01		
78	Pt			3.50E+01				
94	Pu	3.00E+01	2.50E+02		3.00E+01		4.70E+03	1.40E+03
88	Ra	5.00E+01	7.00E+01		5.00E+01			
37	Rb	2.00E+03	2.00E+03		2.00E+03	2.00E+03		
75	Re	1.20E+02	1.20E+02	1.20E+04				
45	Rh	1.00E+01	1.00E+01		1.00E+01	1.00E+01		
45	Rn			0				
44	Ru	1.00E+02	1.00E+02		1.00E+01	1.00E+01	1.00E+01	
16	S	8.00E+02	7.50E+02		1.00E+03		8.00E+02	
51	Sb	1.00E+02	2.00E+02		1.00E+01			
21	Sc	1.00E+02	1.00E+02		1.00E+02			
34	Se	1.70E+02	1.70E+02		2.00E+02			
14	Si	2.00E+01						
62	Sm	3.00E+01	2.50E+01		2.50E+01			
50	Sn	3.00E+03	3.00E+03		3.00E+03			

Table B-8. Water-to-Fish Bioaccumulation Factors (L/kg) from Other Sources

Z	Element	PNNL-13421 (Staven et al. 2003) Table 2.10	NUREG CR-5512 (Kennedy and Strenge 1992) Table 6.19	NCRP 123 (NCRP 1996) Table 5.2	RESRAD Ver. 6 (Yu et al. 2001) Table D.5	Reg Guide 1.109 (NRC 1977) Table A-3	CDC 2006 (Table 8-7)	Friday et al. 1996
38	Sr	6.00E+01	5.00E+01		6.00E+01	3.00E+01	4.50E+02	5.01E+02
73	Ta	3.00E+02			1.00E+02			
65	Tb	3.00E+01	2.50E+01		2.50E+01			
43	Tc	2.00E+01	1.50E+01		2.00E+01	1.50E+01	2.00E+01	
52	Te	4.00E+02	4.00E+02		4.00E+02	4.00E+02		
90	Th	1.00E+02	1.00E+02		1.00E+02		1.00E+02	
22	Ti			1.00E+03				
81	Tl	1.00E+04			1.00E+04			
92	U	1.00E+01	5.00E+01		1.00E+01		1.00E+01	
23	V			2.00E+02				
74	W	1.00E+01	1.20E+03		1.20E+03	1.20E+03		
39	Y	3.00E+01	2.50E+01		3.00E+01	2.50E+01	3.00E+01	
30	Zn	3.50E+02	2.50E+03		1.00E+03	2.00E+03	1.00E+03	
40	Zr	3.00E+02	2.00E+02		3.00E+02	3.30E+00	3.00E+02	

Table B-9. Bioaccumulation Factors from Other DOE Facilities

Z	Element	Soil-to-Vegetable				Milk (d/L)			Meat (d/kg)			Fish (L/kg)
		Idaho	Hanford	ORNL	NTS	Idaho	Hanford	NTS	Idaho	Hanford	NTS	Hanford
89	Ac	2.50E-03	3.50E-03	1.50E-04	3.50E-04	2.0E-05	2.0E-05	2.0E-05	2.00E-05	2.50E-05	2.50E-05	2.5E+01
47	Ag	1.50E-01	1.30E-03			2.5E-02	5.0E-05		3.00E-03	3.00E-03		5.0E+00
13	Al		6.50E-04	2.80E-04	4.00E-03		2.0E-04	2.0E-04		1.50E-03	5.00E-04	5.0E+02
95	Am	1.00E-03	4.30E-04	1.10E-04	4.10E-04	2.0E-06	1.5E-06	4.0E-07	5.00E-05	4.00E-05	3.50E-06	2.1E+01
33	As		6.00E-03				6.0E-05			2.00E-03		2.4E+02
85	At	2.00E-01				1.0E-02			1.00E-02			
5	B		4.00E+00				1.5E-03			8.00E-04		
56	Ba	4.00E-02	3.00E-02		1.50E-02	8.0E-03	4.8E-04	3.5E-04	3.00E-02	2.00E-04	1.50E-04	4.0E+00
4	Be	4.00E-03	1.50E-03	6.50E-04	1.50E-03	2.0E-06	9.0E-07	9.0E-07	1.00E-03	1.00E-03	1.00E-03	1.0E+02
83	Bi	1.00E-01	5.00E-03	2.20E-03	5.00E-03	5.0E-04	5.0E-04	5.0E-04	2.00E-03	4.00E-04	4.00E-04	1.0E+01
97	Bk		4.10E-04				1.5E-06			4.00E-05		2.5E+01
6	C	5.50E+00	7.00E-01	5.60E-01	7.00E-01	1.2E-02	1.1E-02		3.10E-02	4.89E-02		5.0E+04
20	Ca		3.50E-01	1.50E-01	3.50E-01		3.0E-03	1.0E-02		2.00E-03	7.00E-04	4.0E+01
48	Cd	3.00E-01	1.50E-01	6.50E-02	1.50E-01	1.0E-03	1.0E-03	1.0E-03	4.00E-04	4.00E-04	5.50E-04	2.0E+02
58	Ce		3.00E-02				3.0E-05			2.00E-05		3.0E+01
98	Cf	1.00E-03	1.00E-02	6.50E-06		7.5E-07	7.5E-07		6.00E-05	5.00E-03		2.5E+01
17	Cl		7.00E+01	3.00E-01	7.00E+01		1.7E-02	1.5E-02		2.00E-02	8.00E-02	5.0E+01
96	Cm	1.00E-03	4.60E-04	6.50E-06	2.40E-04	2.0E-06	2.0E-05	2.0E-05	2.00E-05	3.50E-06	3.50E-06	2.1E+01
27	Co	8.00E-02	6.80E-02	3.00E-03	4.00E-02	2.0E-03	3.0E-04	2.0E-03	2.00E-02	1.00E-02	2.00E-02	3.0E+02
55	Cs	4.00E-02	1.30E-01	1.30E-02	4.90E-02	8.0E-03	7.9E-03	7.0E-03	3.00E-02	5.00E-02	2.00E-02	2.0E+03
63	Eu	2.50E-03	4.00E-03	1.70E-03	4.00E-03	2.0E-05	2.0E-05	2.0E-05	2.00E-03	5.00E-03	5.00E-03	5.0E+01
9	F		6.00E-03				1.0E-03			1.50E-01		1.0E+01
26	Fe		4.00E-03				3.0E-05			2.00E-02		2.0E+02
87	Fr	3.00E-02				8.0E-03			3.00E-02			
64	Gd	2.50E-03	4.00E-03		4.00E-03	2.0E-05	2.0E-05	2.0E-05	2.00E-03	3.50E-03	3.50E-03	2.5E+01
1	H	4.80E+00	0	4.80E+00	6.92E+00	1.0E-02	0		1.20E-02	0		1.0E+00
80	Hg		2.00E-01				4.7E-04			2.50E-01		1.0E+03
67	Ho	2.60E-03	4.00E-03		4.00E-03	2.0E-05	2.0E-05	2.0E-05	2.00E-03	4.50E-03	4.50E-03	2.5E+01
53	I	2.00E-02	2.00E-02	2.20E-02	5.00E-02	1.0E-02	1.2E-02	1.0E-02	7.00E-03	4.00E-02	7.00E-03	4.0E+01

Table B-9. Bioaccumulation Factors from Other DOE Facilities (continued)

Z	Element	Soil-to-Vegetable				Milk (d/L)			Meat (d/kg)			Fish (L/kg)
		Idaho	Hanford	ORNL	NTS	Idaho	Hanford	NTS	Idaho	Hanford	NTS	Hanford
49	In	3.00E-03	4.00E-04			2.0E-04	1.0E-04		4.00E-03	8.00E-03		1.0E+05
19	K		5.50E-01	2.40E-01	5.50E-01		7.2E-03	7.0E-03		2.00E-02	2.00E-02	1.0E+03
57	La	2.50E-03				2.0E-05			2.00E-03			
25	Mn		2.80E-01				3.0E-05			5.00E-04		4.0E+02
42	Mo		8.00E-01				1.7E-03			1.00E-03		1.0E+01
11	Na		3.00E-01				1.6E-02			8.00E-02		8.0E+00
41	Nb	1.00E-02	1.70E-02	2.20E-03	5.00E-03	2.0E-06	4.1E-07	2.0E-02	3.00E-07	3.00E-07	2.50E-01	3.0E+02
28	Ni	5.00E-02	6.00E-02	2.60E-02	6.00E-02	2.0E-02	1.6E-02	1.0E-03	5.00E-03	5.00E-03	6.00E-03	1.0E+02
93	Np	2.00E-02	1.40E-02	4.30E-03	9.40E-03	5.0E-06	5.0E-06	5.0E-06	1.00E-03	1.00E-03	5.50E-05	2.1E+01
15	P		3.50E+00				1.6E-02			5.00E-02		1.5E+03
91	Pa	1.00E-02	2.50E-04	1.10E-04	2.50E-04	5.0E-06	5.0E-06	5.0E-06	5.00E-03	1.00E-05	1.00E-05	1.0E+01
82	Pb	1.00E-02	6.20E-03	3.90E-03	3.20E-03	3.0E-04	2.5E-04	2.5E-04	8.00E-04	4.00E-04	3.00E-04	3.0E+02
46	Pd	1.00E-01	4.00E-02	1.70E-02	4.00E-02	5.0E-03	1.0E-02	1.0E-02	1.00E-03	4.00E-03	4.00E-03	1.0E+01
61	Pm	2.50E-03	4.00E-03			2.0E-05	2.0E-05		2.00E-03	5.00E-03		3.0E+01
84	Po	1.00E-03	7.00E-03	1.70E-04		3.4E-04	3.4E-04		5.00E-03	5.00E-03		5.0E+01
94	Pu	1.00E-03	6.00E-05	1.90E-05	2.00E-04	1.0E-06	1.1E-06	1.0E-07	1.00E-04	1.00E-05	5.00E-07	2.1E+01
88	Ra	4.00E-02	2.50E-03	6.50E-04	3.20E-03	1.0E-03	1.3E-03	4.5E-04	1.00E-03	9.00E-04	2.50E-04	5.0E+01
37	Rb	1.30E-01	9.00E-01	3.00E-02	7.00E-02	1.0E-02	1.2E-02	1.0E-02	1.50E-02	1.00E-02	1.50E-02	2.0E+03
75	Re		3.50E-01				1.5E-03			8.00E-03		1.2E+02
86	Rn	0				0			0			
44	Ru		4.00E-02				3.3E-06			5.00E-02		1.0E+01
51	Sb	1.00E-02	5.60E-04	1.30E-02			2.5E-05		1.00E-03	4.00E-05		1.0E+02
34	Se	1.00E-01	2.50E-01	1.10E-02	2.50E-02	1.0E-02	4.0E-03	4.0E-03	1.00E-01	1.50E-02	1.50E-02	1.7E+02
14	Si		7.00E-02				2.0E-05			4.00E-05		2.0E+01
62	Sm	2.50E-03	4.00E-03	1.70E-03	4.00E-03	2.0E-05	2.0E-05	2.0E-05	2.00E-03	5.00E-03	5.00E-03	2.5E+01
50	Sn	2.50E-03	6.00E-03	2.60E-03	6.00E-03	1.0E-03	1.0E-03	1.0E-03	1.00E-02	8.00E-02	8.00E-02	3.0E+03
38	Sr	3.00E-01	6.10E-01	1.10E-01	8.10E-01	2.0E-03	2.8E-03	1.5E-03	8.00E-03	8.00E-03	3.00E-04	6.0E+01
43	Tc	5.00E+00	7.70E-01	6.50E-01	1.10E+00	1.0E-03	1.4E-04	1.0E-02	1.00E-04	1.00E-04	8.50E-03	2.0E+01
52	Te	6.00E-01	4.00E-03			5.0E-04	4.5E-04		7.00E-03	7.00E-03		4.0E+02
90	Th	1.00E-03	2.50E-04	3.70E-05	1.20E-04	5.0E-06	5.0E-06	5.0E-06	1.00E-04	6.00E-06	6.00E-06	1.0E+02
22	Ti		3.00E-03				1.0E-02			3.00E-02		1.0E+03

Table B-9. Bioaccumulation Factors from Other DOE Facilities (continued)

Z	Element	Soil-to-Vegetable				Milk (d/L)			Meat (d/kg)			Fish (L/kg)
		Idaho	Hanford	ORNL	NTS	Idaho	Hanford	NTS	Idaho	Hanford	NTS	Hanford
81	Tl	2.00E-01	4.00E-04			3.0E-03	2.0E-03		2.00E-03	4.00E-02		1.0E+04
92	U	2.50E-03	1.20E-02	1.70E-03	1.40E-02	6.0E-04	4.0E-04	6.0E-04	3.40E-04	3.00E-04	2.00E-04	1.0E+01
23	V		3.00E-03				2.0E-05			2.50E-03		2.0E+02
39	Y	3.00E-01	1.00E-02	2.60E-03		2.0E-03	2.0E-05		8.00E-03	1.00E-03		3.0E+01
40	Zr	1.00E-03	1.00E-03	2.20E-04	5.00E-04	6.0E-07	5.5E-07	3.0E-05	1.00E-06	1.00E-06	5.50E-03	3.0E+02

Baseline Parameter Update For Human Health Input And Transfer Factors For Radiological Performance Assessments At The Savannah River Site

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