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**Land and Water Use Characteristics  
and Human Health Input Parameters  
for use in  
Environmental Dosimetry and Risk Assessments  
at the  
Savannah River Site**

**2016 Update**

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## **EXECUTIVE SUMMARY**

Operations at the Savannah River Site (SRS) result in releases of small amounts of radioactive materials to the atmosphere and to the Savannah River. For regulatory compliance purposes, potential offsite radiological doses are estimated annually using computer models that follow U.S. Nuclear Regulatory Commission (NRC) regulatory guides. Within the regulatory guides, default values are provided for many of the dose model parameters, but the use of applicant site-specific values is encouraged. Detailed surveys of land-use and water-use parameters were conducted in 1991 and 2010. They are being updated in this report. These parameters include local characteristics of meat, milk and vegetable production; river recreational activities; and meat, milk and vegetable consumption rates, as well as other human usage parameters required in the SRS dosimetry models. In addition, the preferred elemental bioaccumulation factors and transfer factors (to be used in human health exposure calculations at SRS) are documented.

The intent of this report is to establish a standardized source for these parameters that is up to date with existing data, and that is maintained via review of future-issued national references (to evaluate the need for changes as new information is released). These reviews will continue to be added to this document by revision.

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## 1.0 Introduction

### 1.1 Background

Operations at the Savannah River Site (SRS) result in releases of small amounts of radioactive materials to the atmosphere and to the Savannah River. For regulatory compliance purposes, potential offsite radiological doses are estimated annually using computer models that follow U.S. Nuclear Regulatory Commission (NRC) regulatory guides (NRC 1977a and 1977b). Within the regulatory guides, default values are provided for many of the dose model parameters, but the use of site-specific values by the applicant is encouraged (NRC 1977a).

Detailed surveys of land and water use parameters were conducted by Hamby (1991) and by Jannik et al. (2010) and are being updated here. These parameters include local characteristics of meat, milk and vegetable production; river recreational activities; and meat, milk and vegetable consumption rates, as well as other human usage parameters required in the SRS dosimetry models. In addition, the preferred elemental bioaccumulation factors and transfer factors (to be used in human health exposure calculations at SRS) are documented.

In Lee and Coffield (2008), many of the SRS input parameters utilized in dosimetry calculations were compared to a number of other DOE facilities and generic national/global references, to establish relevance of the parameters selected and/or to verify the regional differences of the U.S. Southeast. The parameters selected were applicable to SRS performance assessments (PAs) and were specifically chosen to be expected values (along with identifying a range for these values) versus the conservative specification of parameters for estimating an annual dose to the maximum exposed individual (MEI). However, because of its thoroughness and direct applicability to annual SRS dose compliance calculations, many of the parameters documented in Lee and Coffield (2008) are adopted in this report.

### 1.2 Purpose

The purpose of this report is to review, and update as needed, the input parameters and environmental bioaccumulation and transfer factors used in human health exposure calculations at SRS, for determining compliance with applicable U.S. Department of Energy (DOE) Orders (DOE 1999 and 2013) and U.S. Environmental Protection Agency (EPA) National Emission Standards for Hazardous Air Pollutants' (NESHAP) regulations (EPA 2002). The reason for the update is to utilize more currently issued information, validate currently used information, and correct minor inconsistencies between other modeling efforts performed at SRS.

The intent of this report is to establish a standardized source for these parameters that is up to date with existing data, and maintained via review of future-issued national references (to evaluate the need for changes as new information is released). These reviews will continue to be added to this document by revision.

### 1.3 Major Changes Since 2010 Assessment

#### 1.3.1 Representative Person Concept

DOE O 458.1 (DOE 2013) states that compliance with the DOE annual dose limit of 100 mrem (1 mSv), regarding a member of the public, may be demonstrated by calculating dose to the maximally exposed individual (MEI) or to a representative person. Historically, the MEI concept was used for dose compliance at SRS, using adult dose coefficients and adult male usage parameters. Beginning in 2012, SRS now uses the representative person concept for dose compliance.

In DOE O 458.1, the representative person is defined as, "...an individual receiving a dose that is representative of the more highly exposed individuals in the population." This term is equivalent of, and replaces, "...average member of the critical group." However, in the *International Commission on Radiological Protection (ICRP) Report 101* (ICRP 2006), the definition is extended to include the, "...average value for the more highly exposed group OR the 95th percentile of appropriate national or regional data." The 'OR' is highlighted for emphasis. At SRS, the representative person concept (which is based on a reference person at the 95th percentile of national usage data) is now used as a replacement for the MEI concept.

The reference person is weighted, based on sex and age; and this weighting is based on the six age groups documented in Report 89 (ICRP 2002): Infant (0 years), 1 year, 5 years, 10 years, 15 years, and Adult. The various age- and gender-specific intake rates from USEPA (2011) were proportioned to correspond with these respective age groupings. SRS also developed usage parameters at the 50th percentile, which are used in calculating dose to a "typical" person for determining collective doses.

The SRS-specific reference and typical-person usage parameters were developed by Stone and Jannik (2013) and are adopted in this report. The subsequent effect on SRS compliance dose results, due to changing from the MEI to the Representative Person concept, also are documented in Stone and Jannik (2013).

## 2.0 Discussion

### 2.1 Physical Parameters

Physical parameters are defined as those whose value would not change, if a different group of receptors were considered. For the purposes of this report, these parameters include agricultural production factors and aquatic food harvest factors. The other physical input parameters are determined by SRS's geographical location, the geophysical characteristics of the site, and the element-specific transfer and bioaccumulation factors. After review of applicable state (Georgia and South Carolina) and federal (US Department of Agriculture) data, all SRS agricultural and river transport physical parameters remained unchanged or changed less than 15 percent from the 2010 values. Therefore, the current agricultural productivity and Savannah River transport physical parameters (to be used in SRS dose assessments) remained unchanged and are listed in the column labeled "2010/2016 Values" in Table 1.

The International Atomic Energy Agency (IAEA) published (in Technical Reports Series No. 472) updated recommended transfer factors for a limited number of elements (IAEA 2010). With only a few exceptions (noted in the discussions to follow), these element-specific transfer values were used in the 2010 version of this report and remain unchanged in this report. For the elements not included in IAEA No. 472, the values documented in Lee and Coffield (2008) are used. The soil-to-vegetable, feed-to-milk, and feed-to-meat transfer factors are provided in Table 2 and Table 3, respectively. The water-to-fish bioaccumulation factors and water-to-saltwater invertebrates' bioaccumulation factors are provided in Table 5 and Table 6, respectively.

During this updated study, the physical parameters that were determined to differ from Hamby (1991) or Lee and Coffield (2008) are discussed below. The parameters that remained the same are also documented in Table 1 through Table 6, but without additional comment.

#### 2.1.1 Agricultural Productivity and Production

The agricultural productivity factors for vegetables, meat, and milk are weighted averages based on the 2007 U.S. Department of Agriculture (USDA) National Agricultural Statistics (USDA 2009). The annual production rates (that occur within a 50-mile radius of SRS) of this produce are based on this report. The 2002 USDA agricultural statistics were also considered to confirm agricultural production trends (USDA 2004).

##### 2.1.1.1 Vegetable Productivity and Production

Based on USDA (2009), the South Carolina and Georgia weighted average vegetable productivity was determined to be 2.2 kg/m<sup>2</sup>. This value, which includes leafy and non-leafy vegetables, is over 200 percent more than the Hamby (1991) and Lee and Coffield (2008) reported value of 0.7 kg/m<sup>2</sup>. However, it is comparable to the NRC (1977) default value of 2.0 kg/m<sup>2</sup>, and it is essentially the same as the USDA (2004) dataset.

Based on USDA (2009), the combined leafy and non-leafy vegetable commercial production (within 50 miles of SRS) was estimated to be 6.7E+05 kg/yr (1.4E+05 kg/yr for leafy vegetables and 5.3E+05 kg/yr for other vegetables). For the purposes of this report, the total combined vegetable production value was increased by a factor of 10 (revised up to 6.7E+06 kg/yr) to account for unreported and non-commercial (individual use) production of vegetables in the area. This conservative factor is based on professional judgment and on personal discussions with county agents and other professionals in the field. The updated production value of 6.7E+06 kg/yr is about 85 percent less than the Hamby (1991) estimated value of 4.7E+07 kg/yr. The USDA (2004) estimated combined total was 7.1E+06 kg/yr (including the factor of 10 for unreported production), which indicates a continuing downward trend in vegetable

production in the SRS area. The non-leafy vegetable production, as a function of distance and sector from the center of SRS, is provided in Table 7.

*2.1.1.2 Pasture Grass Productivity*

Based on USDA (2009), the South Carolina and Georgia weighted average pasture grass productivity was determined to be 0.7 kg/m<sup>2</sup>. This value is about 60 percent less than the Hamby (1991) and Lee and Coffield (2008) reported value of 1.8 kg/m<sup>2</sup>. However, it is the same as the NRC (1977) default value, and it is essentially the same as the value estimated using the USDA (2002) dataset.

*2.1.1.3 Meat (Beef) Productivity and Production*

Because poultry and pork production are almost exclusively indoor operations, only beef production is considered for the meat pathway. Based on USDA (2009), the South Carolina and Georgia weighted average meat productivity was determined to be 0.01 kg/m<sup>2</sup>. This value was not considered in the Hamby (1991) and Lee and Coffield (2008) reports. However, it is used in the LADTAP XL Irridose spreadsheet for population dose assessments, to determine the amount of beef production on a given irrigated area. The 0.01 kg/m<sup>2</sup> value was determined based on the daily consumption rate of forage by beef cattle (36 kg/d), the current pasture grass productivity (0.7 kg/m<sup>2</sup>), and an assumed edible meat amount per beef cow (200 kg). The following equation details the calculation:

$$\frac{\frac{200 \text{ kg/yr}}{36 \text{ kg/d} * 365 \text{ d/yr}}}{\frac{1 \text{ m}^2}{0.7 \text{ kg}}} = 0.01 \text{ kg/m}^2 \quad (1)$$

Based on USDA (2009), the commercial beef production (within 50 miles of SRS) was estimated to be 6.1E+06 kg/yr. For the purposes of this report, the commercial beef production value was increased by a factor of 1.25 (revised up to 7.6E+06 kg/yr) to account for unreported and non-commercial (individual use) production of beef in the area. Again, this factor is based on professional judgment and on personal discussions with county agents and other professionals in the field. The beef production value of 7.6E+06 kg/yr is about 50 percent less than the Hamby (1991) estimated value of 1.5E+07 kg/yr. The USDA (2004) estimated total was 1.3E+07 kg/yr (including the factor of 1.25 for unreported production), which indicates a continuing downward trend in beef production in the SRS area. The beef production, as a function of distance and sector, is provided in Table 8.

*2.1.1.4 Milk Productivity and Production*

Based on USDA (2009), the South Carolina and Georgia weighted average milk productivity was determined to be 0.34 L/m<sup>2</sup>. This value was not considered in the Hamby (1991) and Lee and Coffield (2008) reports. However, it is used in the LADTAP XL Irridose spreadsheet for population dose assessments, to determine the amount of milk production on a given irrigated area. The 0.34 kg/m<sup>2</sup> value was determined based on the daily consumption rate of forage by milk cows (52 kg/d), the current pasture grass productivity (0.7 kg/m<sup>2</sup>), and an assumed daily milk production amount per milk cow (25 L/d). The following equation details the calculation:

$$\frac{\frac{25 \text{ L/d}}{52 \text{ kg/d}}}{\frac{1 \text{ m}^2}{0.7 \text{ kg}}} = 0.34 \text{ L/m}^2 \quad (2)$$

Based on USDA (2009), the commercial milk production (within 50 miles of SRS) was estimated to be  $6.8E+07$  L/yr. For the purposes of this report, the commercial milk production value was increased by a factor of 1.25 (revised up to  $8.5E+07$  L/yr) to account for unreported and non-commercial (individual use) production of milk in the area. Again, this factor is based on professional judgment and on personal discussions with county agents and other professionals in the field. The updated milk production value of  $8.5E+07$  L/yr is about 23 percent less than the Hamby (1991) estimated value of  $1.1E+08$  L/yr. The USDA (2004) estimated total was  $1.0E+08$  L/yr (including the factor of 1.25 for unreported production), which indicates a continuing downward trend in milk production in the SRS area. The milk production, as a function of distance and sector, is provided in Table 9.

### *2.1.2 Soil to Vegetable Transfer Factors*

In IAEA (2010), a selection of element-specific, soil-to-plant (vegetable) transfer factors are provided for a variety of plant groups. Based on USDA (2007), the estimated percentage breakdown of the major plant groups that are commercially produced in the SRS area is as follows:

- Leafy vegetables           20%
- Legumes                    15%
- Tubers and Roots         10%
- Non-leafy                 55%

These percentages were used to calculate a weighted-average element-specific transfer factor, which is documented in Table 2. For the elements not included in IAEA (2010), the values documented in Lee and Coffield (2008) were used. The soil-to-vegetable transfer factors remain unchanged in this report and are provided in the Table 2 column labeled “2010/2016 Values.”

### *2.1.3 Feed to Milk Transfer Factors*

In IAEA (2010), a selection of element-specific transfer coefficients to cow’s milk (feed-to-milk) are provided. For the elements not included in IAEA (2010), the values documented in Lee and Coffield (2008) were used. The milk transfer coefficients remain unchanged in this report and are provided in the Table 3 column labeled “2010/2016 Values.”

### *2.1.4 Feed to Meat Transfer Factors*

In IAEA (2010), a selection of element-specific transfer coefficients to beef (feed-to-meat) are provided. For the elements not included in IAEA (2010), the values documented in Lee and Coffield (2008) were used. The meat transfer coefficients remain unchanged in this report and are provided in the Table 4 column labeled “2010/2016 Values.”

### *2.1.5 Water to Fish Bioaccumulation Factors*

In IAEA (2010), a selection of element-specific concentrations ratios (bioaccumulation factors) for freshwater fish tissue are provided. For the elements not included in IAEA (2010), the values documented in Lee and Coffield (2008) were used, as discussed below. Exceptions to this rule, which are described below, are plutonium, cesium, and carbon. The fish bioaccumulation factors remain unchanged in this report and are provided in the Table 5 column labeled “2010/2016 Values.”

As discussed in section 4.0 (Conclusions), the plutonium bioaccumulation factor recommended in IAEA (2010) is 21,000 L/kg. This is several orders of magnitude greater than the previous IAEA value, which (as documented in Lee and Coffield (2008)) is 30 L/kg. The 21,000 L/kg bioaccumulation value for plutonium seems unreasonable, based on the professional judgement of the authors and other national experts. Therefore, the Lee and Coffield (2008) value of 30 L/kg will continue to be used, until the IAEA (2010) value is verified or changed.

The SRS site-specific bioaccumulation factor for cesium of 3,000 L/kg (Jannik 2003) is used in this update, in lieu of the IAEA (2010) value of 2,500 L/kg. The site-specific value is slightly more conservative than the IAEA (2010) value and is considered the best available data for SRS.

Also, the SRS-determined bioaccumulation factor for carbon of 3 L/kg (Hinton et al. 2009) is used in lieu of the IAEA (2010) value of 400,000 L/kg. Hinton et al. (2009) used a systems-model approach to study the carbon mass balance in an SRS stream. This study showed that most of the carbon in fish does not come from the water in which they live; the assumption on which the IAEA-referenced elemental bioaccumulation factors are based.

#### *2.1.6 Water to Saltwater Invertebrates Bioaccumulation Factors*

Recommended concentration ratios for saltwater invertebrates were not addressed in IAEA (2010). Also, because the saltwater invertebrate pathway is not applicable to Performance Assessments at SRS, they were not addressed in Lee and Coffield (2008). Therefore, the values presented in PNNL (2003) continue to be used in this report and are provided in the Table 6 column labeled “2010/2016 Values.” In PNNL (2003), saltwater bioaccumulation factors are provided for crustaceans and mollusks. To be conservative, the larger of the two values was used.

## 2.2 Behavioral Parameters

Behavioral parameters are defined as those whose value depends on the receptor’s behavior and the defined exposure scenario. For the purposes of this report, these parameters include the metabolic characteristics of the receptor. As discussed, in 2013 SRS changed to using the Representative Person concept for DOE (2013) compliance dose calculations. The 2010 MEI usage parameters have been updated to reference person usage parameters at the 95<sup>th</sup> percentile, and the average individual usage parameters have been updated to the typical person usage parameters at the 50<sup>th</sup> percentile. A complete description of these changes is provided in Stone and Jannik (2013).

### *2.2.1 Typical Person, Reference Person, and Population Usage Parameters*

A summary of the current and updated behavioral and metabolic parameters for the typical person and general population are listed in Table 10, and a summary for the reference person is in Table 11. The parameters that remained the same are also documented in Table 10 and Table 11, but without additional comment.

#### *2.2.1.1 Shoreline, Swimming, and Boating Exposure Time*

After review of applicable state (Georgia and South Carolina) recreation data, the average individual recreational exposure usage rates for shoreline usage, swimming, and boating in the SRS area remained unchanged. As shown in Table 12, these exposure times were estimated to be 10 hr/yr, 7 hr/yr, and 22 hr/yr, respectively. These values are based on 2005 data from the Georgia Department of Natural Resources (GDNR 2005), the South Carolina Department of Parks and Recreation (SCDPR 2005), and on the estimated hours per occasion from Hamby (1991). The reference person recreation exposure times were conservatively set at twice the per capita values.

Based on these recreational usage rates, the weighted population exposure times for shoreline usage, swimming, and boating were determined. These are provided in Table 13. These values are based on the SC and GA state usage available fractions from Hamby (1991), the 2000 census population fraction in the SC (0.6) and GA (0.4) counties within 50 miles of SRS, and on the projected 2010 total population (1.4E+06 people) in those counties. Because the projected 2010 census data was within 15 percent of the actual 2010 data, in this assessment, these values remain unchanged.

*2.2.1.2 Population Served by Downriver Drinking Water Plants*

In 2009, the operators of the three public drinking water plants (located downriver of SRS) estimated that the following populations were served:

- Beaufort-Jasper Water and Sewer Authority (Chelsea Plant) 82,900 people
- Beaufort-Jasper Water and Sewer Authority (Purrysburg Plant) 64,200 people
- City of Savannah Industrial and Domestic Water Supply Plant 35,000 people

These totals will be updated annually for use in the SRS Annual Site Environmental Report.

### **3.0 Summary**

Detailed surveys of land-use and water-use parameters in the SRS area were conducted by Hamby (1991) and Jannik et al. (2010). These have been updated in this report. These parameters include local characteristics of meat, milk and vegetable production; river recreational activities; and meat, milk and vegetable consumption rates, as well as other human usage parameters required in the SRS dosimetry models. In addition, the preferred elemental bioaccumulation factors and transfer factors (to be used in human health exposure calculations at SRS) have been documented in this report.



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## **APPENDIX**

### **Usage Parameters, Transfer Factors, and Bioaccumulation Factors** *(Tables 1 – 13)*

**Table 1. SRS Agricultural and River Transport Physical Parameters for Dose Calculations**

Parameter	Units	1977	1991	2008	2010/2016
		NRC Default	Hamby	Lee and Coffield	Jannik et al.
Beef-cow forage consumption (wet)	kg/d	50	36	36	36
Milk-cow forage consumption (wet)	kg/d	50	52	52	52
Pasture-grass exposure time to irrigation	d	30	30	30	30
Vegetable crop exposure time to irrigation	d	60	70	70	70
Vegetable garden productivity	kg/m <sup>2</sup>	2	0.7	0.7	2.2
Agricultural productivity (produce/veg.)	kg/m <sup>2</sup>	2	0.7	0.7	2.2
Agricultural productivity (pasture grass)	kg/m <sup>2</sup>	0.7	1.8	1.8	0.7
Agricultural productivity (edible beef.)	kg/m <sup>2</sup>	-	-	-	0.01
Agricultural productivity (milk)	L/m <sup>2</sup>	-	-	-	0.15
Irrigation rate	L/d/m <sup>2</sup>		3.4	3.6	3.6
Transport time (feed-milk-man)	d	4	3	3	3
Transport time (produce for avg/pop)	d	14	14	6	6
Transport time (produce for MEI)	d	1	1	N/A	1
Time from slaughter to consumption	d	20	6	6	6
Holdup time (pasture grass, forage)	d	0	0	0	0
Holdup time (stored feed)	d	90	90	N/A	90
Fraction of time milk-cow on pasture	-	0.75	1	1	1
Fraction of time beef-cow on pasture	-	0.75	1	1	1
Fraction of intake from pasture (milk cow)	-	1 (b)	0.56	0.56	0.56
Fraction of intake from pasture (beef-cow)	-	1 (b)	0.75	0.75	0.75
Fraction of veg. from local farm (avg/pop)	-	1	1	0.308	0.308
Fraction of meat from local farm (avg/pop)	-	1	1	0.319	0.319
Fraction of milk from local farm (avg/pop)	-	1	1	0.254	0.254
Fraction of veg. from local farm (MEI)	-	1	1	N/A	1
Fraction of meat from local farm (MEI)	-	1	1	N/A	1

**Table 1. SRS Agricultural and River Transport Physical Parameters for Dose Calculations (continued)**

Parameter	Units	1977	1991	2008	2010/2016
		NRC Default	Hamby	Lee and Coffield	Jannik et al.
Fraction of milk from local farm (MEI)	-	1	1	N/A	1
Fraction of intake from contaminated water	-	1	1	1	1
Cattle consumption rate of water (meat)	L/d	50	50	28	28
Cattle consumption rate of water (milk)	L/d	60	60	50	50
Buildup time in soil	d	5475	7300	183	9125
Areal density of soil	kg/m <sup>2</sup>	240	240	240	240
Soil density	kg/m <sup>3</sup>	N/A	N/A	1.6	1.6
Weathering removal constant	1/d	0.0495	0.0495	0.0495	0.0495
Fractional retention of leaves	-	0.25	0.25	0.25	0.25
Depth of garden	cm	-	-	15	15
Edible sport fish harvest	kg/yr	-	3.50E+04	N/A	8.22E+03
Edible commercial fish harvest	kg/yr	-	2.70E+03	N/A	5.70E+04
Edible commercial invertebrate harvest	kg/yr	-	2.45E+05	N/A	3.80E+05
Edible fraction of harvest - fish (whole)	-	-	0.5	N/A	0.5
Edible fraction of harvest - crab (whole)	-	-	0.14	N/A	0.14
Edible fraction of harvest - shrimp (tail only)	-	-	0.9	N/A	0.9
Edible fraction of harvest - oysters (meat)	-	-	1	N/A	1
Edible fraction of harvest - clams (meat)	-	-	1	N/A	1
River dilution in estuary	-	-	3	N/A	3
River Transport Time for Recreation	d	-	1	N/A	1
River Transport Time for MEI (RM 118.8)	d	-	1.5	N/A	1.5
River Transport Time for Fish	d	-	2	N/A	2
River Transport Time for Irrigation	d	-	2	N/A	2
River Transport Time for Drinking Water	d	-	4	N/A	4
River Transport Time for Sport Fish	d	-	10	N/A	10
River Transport Time for Commercial Fish	d	-	13	N/A	13
River Transport Time for Invertibrates	d	-	13	N/A	13
Shoreline width factor	-	0.2	0.2	N/A	0.2

Table 2. Soil-to-Vegetable Transfer Factors

Element	Z	Current SRS Value	2008 Value	2010 Weighted Value	2003 Weighted Value	2010/2016 Values
			Lee and Coffield	IAEA #472	PNNL-13421	Jannik, et al.
Ac	89	2.5E-03	6.83E-05		6.11E-05	6.11E-05
Ag	47	1.5E-01	1.18E-02	1.19E-04		1.19E-04
Al	13	4.0E-03	1.27E-04			1.27E-04
Am	95	2.5E-04	6.83E-05	7.3E-05		7.33E-05
Ar	18		1.00E-20			1.00E-20
As	33		1.17E-03		2.73E-03	2.73E-03
At	85		2.93E-02			2.93E-02
Au	79		3.51E-03		2.64E-03	2.64E-03
B	5		3.90E-01			3.90E-01
Ba	56	5.0E-03	2.93E-03	9.75E-04		9.75E-04
Be	4	4.0E-03	2.93E-04		6.83E-04	6.83E-04
Bi	83	1.0E-01	9.75E-02		9.75E-02	9.75E-02
Bk	97	5.9E-05	1.00E-03			1.00E-03
Br	35		2.93E-01		2.93E-01	2.93E-01
C	6	5.5E+00	1.37E-01		1.37E-01	1.37E-01
Ca	20	5.0E-01	6.83E-02	3.9E+00		3.90E+00
Cd	48	3.0E-01	2.93E-02	1.5E-01		1.49E-01
Ce	58	2.5E-03	3.90E-03	1.6E-03		1.63E-03
Cf	98	1.0E-03	6.83E-05		6.11E-05	6.11E-05
Cl	17	2.0E+01	1.37E+01	3.5E+00		3.49E+00
Cm	96	2.5E-03	8.39E-05	1.3E-04		1.27E-04
Co	27	9.4E-03	1.31E-02	2.5E-02		2.48E-02
Cr	24	2.5E-04	8.78E-04	2.0E-04		1.95E-04
Cs	55	1.0E-02	9.00E-01	6.9E-03		6.85E-03
Cu	29	1.2E-01	4.88E-02	1.6E-01		1.56E-01
Dy	66		3.90E-03		3.90E-03	3.90E-03
Er	68		3.90E-03		3.90E-03	3.90E-03
Es	99	5.9E-05	1.00E-03			1.00E-03

**Note:** 1.00E-20 is equivalent to 0.00.

Table 2. Soil-to-Vegetable Transfer Factors (*continued*)

Element	Z	Current SRS Value	2008 Value	2010 Weighted Value	2003 Weighted Value	2010/2016 Values
			Lee and Coffield	IAEA #472	PNNL-13421	Jannik, et al.
Eu	63	2.5E-03	3.90E-03		3.90E-03	3.90E-03
F	9		1.17E-03		3.65E-03	3.65E-03
Fe	26	6.6E-04	9.75E-03	1.10E-02		1.10E-02
Fm	100		2.00E-03			2.00E-03
Fr	87		5.85E-03			5.85E-03
Ga	31		7.80E-05		2.43E-04	2.43E-04
Gd	64	2.0E-03	3.90E-03		3.90E-03	3.90E-03
Ge	32	1.0E-01	1.56E-02			1.56E-02
H	1	not used	4.80E+00			4.80E+00
Ha	108		2.00E-03			2.00E-03
He	2		1.00E-20			1.00E-20
Hf	72	1.0E-04	1.95E-04		1.95E-04	1.95E-04
Hg	80	3.8E-01	3.90E-02		9.03E-02	9.03E-02
Ho	67	2.5E-03	3.90E-03		3.90E-03	3.90E-03
I	53	2.0E-02	7.80E-03	1.3E-02		1.32E-02
In	49	3.0E-03	7.80E-05		2.43E-04	2.43E-04
Ir	77	3.0E-02	2.93E-03		4.76E-03	4.76E-03
K	19	3.0E-01	1.07E-01	2.5E-01		2.54E-01
Kr	36		1.00E-20			1.00E-20
La	57	2.5E-03	6.83E-05	9.09E-04		9.09E-04
Li	3		7.80E-04			7.80E-04
Lr	103		2.00E-03			2.00E-03
Lu	71	2.5E-03	7.80E-04			7.80E-04
Md	101		2.00E-03			2.00E-03
Mg	12		1.07E-01		1.28E-01	1.28E-01
Mn	25	2.9E-02	3.90E-02	6.39E-02		6.39E-02
Mo	42	1.2E-01	1.56E-01	8.7E-02		8.71E-02
N	7		3.50E-01		7.43E-03	7.43E-03
Na	11	5.0E-02	5.85E-02	5.85E-03		5.85E-03

**Note:** 1.00E-20 is equivalent to 0.00.

Table 2. Soil-to-Vegetable Transfer Factors (*continued*)

Element	Z	Current SRS Value	2008 Value	2010 Weighted Value	2003 Weighted Value	2010/2016 Values
			Lee and Coffield	IAEA #472	PNNL-13421	Jannik, et al.
Nb	41	9.4E-03	4.88E-03	2.2E-03		2.18E-03
Nd	60		3.90E-03	3.9E-03		3.90E-03
Ne	10		1.00E-20			1.00E-20
Ni	28	1.9E-02	1.17E-02		2.18E-02	2.18E-02
No	102		2.00E-03			2.00E-03
Np	93	2.5E-03	2.54E-03	3.91E-03		3.91E-03
O	8		6.00E-01			6.00E-01
Os	76		6.83E-04		6.45E-03	6.45E-03
P	15	1.1E+00	6.83E-01	1.95E-01		1.95E-01
Pa	91	1.0E-02	4.18E-04		6.11E-05	6.11E-05
Pb	82	1.0E-02	1.17E-03	5.2E-03		5.18E-03
Pd	46	1.0E-01	7.80E-03		1.28E-02	1.28E-02
Pm	61	2.5E-03	3.90E-03	2.3E-02		2.32E-02
Po	84	1.0E-03	1.37E-03	4.3E-04		4.30E-04
Pr	59		3.90E-03	3.9E-03		3.90E-03
Pt	78	2.4E-02	4.88E-03			4.88E-03
Pu	94	2.5E-04	2.15E-04	2.0E-05		1.97E-05
Ra	88	4.0E-02	4.64E-03	1.2E-02		1.19E-02
Rb	37	1.3E-01	1.76E-01	1.4E-01		1.39E-01
Re	75	2.1E+02	1.29E+00		1.21E-01	1.21E-01
Rf	104		3.00E-03			3.00E-03
Rh	45		7.80E-03	1.76E-01		1.76E-01
Rn	86		1.00E-20			1.00E-20
Ru	44	5.0E-02	7.80E-03	6.29E-03		6.29E-03
S	16	5.9E-01	2.93E-01		2.93E-01	2.93E-01
Sb	51	1.1E-02	2.49E-03	2.6E-04		2.61E-04
Sc	21		1.95E-04		4.24E-04	4.24E-04

**Note:** 1.00E-20 is equivalent to 0.00.



**Table 2. Soil-to-Vegetable Transfer Factors (continued)**

Element	Z	Current SRS Value	2008 Value	2010 Weighted Value	2003 Weighted Value	2010/2016 Values
			Lee and Coffield	IAEA #472	PNNL-13421	Jannik, et al.
Se	34	1.3E+00	5.14E-02		1.89E-02	1.89E-02
Si	14	8.8E-02	1.37E-02		2.65E-02	2.65E-02
Sm	62	2.5E-03	3.90E-03		3.90E-03	3.90E-03
Sn	50	2.5E-03	1.17E-03		2.27E-03	2.27E-03
Sr	38	1.7E-02	9.75E-02	1.2E-01		1.23E-01
Ta	73	2.5E-03	4.88E-03		4.88E-03	4.88E-03
Tb	65		3.90E-03		3.90E-03	3.90E-03
Tc	43	2.5E-01	4.68E-02	1.79E+01		1.79E+01
Te	52	1.3E+00	1.20E-02	5.9E-02		5.85E-02
Th	90	4.2E-03	6.44E-05	3.1E-04		3.14E-04
Ti	22	1.0E-04	5.85E-04			5.85E-04
Tl	81		7.80E-05		2.43E-04	2.43E-04
Tm	69		7.80E-04			7.80E-04
U	92	2.5E-03	2.34E-03	6.69E-03		6.69E-03
V	23	1.4E-03	5.85E-04			5.85E-04
W	74		5.00E-02	2.0E-02		1.95E-02
Xe	54		1.00E-20			1.00E-20
Y	39	2.6E-03	1.95E-03	3.90E-04		3.90E-04
Yb	70		7.80E-04			7.80E-04
Zn	30	4.0E-01	6.83E-02	1.71E-01		1.71E-01
Zr	40	1.7E-04	1.95E-04	7.8E-04		7.80E-04

**Note:** 1.00E-20 is equivalent to 0.00.

**Table 3. Feed-to-Milk Transfer Factors**

Element	Z	SRS Current Value	2008 Value	2010 Value	2010/2016 Values
			Lee and Coffield	IAEA #472	Jannik et al.
Ac	89	2.0E-05	2.00E-05		2.00E-05
Ag	47	5.0E-02	1.58E-03		1.58E-03
Al	13	2.0E-04	2.06E-04		2.06E-04
Am	95	5.0E-06	1.50E-06	4.20E-07	4.20E-07
As	33		6.00E-05		6.00E-05
At	85		1.03E-02		1.03E-02
Au	79		5.50E-06		5.50E-06
B	5		1.55E-03		1.55E-03
Ba	56	4.0E-04	4.80E-04	1.60E-04	1.60E-04
Be	4	2.0E-06	9.00E-07	8.30E-07	8.30E-07
Bi	83	5.0E-04	5.00E-04		5.00E-04
Bk	97	4.0E-07	2.00E-06		2.00E-06
Br	35		2.00E-02		2.00E-02
C	6	1.2E-02	1.20E-02		1.20E-02
Ca	20	3.0E-03	3.00E-03	1.00E-02	1.00E-02
Cd	48	1.2E-04	1.00E-03	1.90E-04	1.90E-04
Ce	58	6.0E-04	3.00E-05	2.00E-05	2.00E-05
Cf	98	7.5E-07	1.50E-06		1.50E-06
Cl	17	2.0E-02	1.70E-02		1.70E-02
Cm	96	5.0E-06	2.00E-05		2.00E-05
Co	27	1.0E-03	3.00E-04	1.10E-04	1.10E-04
Cr	24	2.2E-03	1.00E-05	4.30E-04	4.30E-04
Cs	55	1.2E-02	7.90E-03	4.60E-03	4.60E-03
Cu	29	1.4E-02	2.00E-03		2.00E-03
Dy	66		3.00E-05		3.00E-05
Er	68		3.00E-05		3.00E-05
Es	99	4.0E-07	2.00E-06		2.00E-06
Eu	63	5.0E-06	3.00E-05		3.00E-05
F	9		1.00E-03		1.00E-03
Fe	26	1.2E-03	3.00E-05	3.50E-05	3.50E-05
Fr	87		2.06E-02		2.06E-02
Ga	31		5.00E-05		5.00E-05
Gd	64	6.0E-05	3.00E-05		3.00E-05
Ge	32	7.0E-02	7.21E-02		7.21E-02
H	1	not used	1.50E-02		1.50E-02
Ha	105		5.00E-06		5.00E-06
He	2		1.00E-20		1.00E-20
Hf	72	5.5E-07	5.50E-07		5.50E-07
Hg	80	5.0E-04	4.70E-04		4.70E-04
Ho	67	2.0E-05	3.00E-05		3.00E-05
I	53	6.0E-03	9.00E-03	5.40E-03	5.40E-03
In	49	2.0E-04	2.00E-04		2.00E-04
Ir	77	2.0E-06	2.00E-06		2.00E-06
K	19	7.0E-03	7.20E-03		7.20E-03
La	57	5.0E-06	2.00E-05		2.00E-05
Li	3		2.06E-02		2.06E-02
Lr	103		5.00E-06		5.00E-06
Lu	71	2.0E-05	2.06E-05		2.06E-05
Md	101		5.00E-06		5.00E-06

**Table 3. Feed-to-Milk Transfer Factors (continued)**

Element	Z	SRS Current Value	2008 Value	2010 Value	2010/2016 Values
			Lee and Coffield	IAEA #472	Jannik et al.
Mg	12		3.90E-03		3.90E-03
Mn	25	2.5E-04	3.00E-05	4.10E-05	4.10E-05
Mo	42	7.5E-03	1.70E-03	1.10E-03	1.10E-03
N	7		2.50E-02		2.50E-02
Na	11	4.0E-02	1.60E-02	1.30E-02	1.30E-02
Nb	41	2.5E-03	3.20E-05	4.10E-07	4.10E-07
Nd	60		3.00E-05		3.00E-05
Ni	28	6.7E-03	1.60E-02	9.50E-04	9.50E-04
No	102		5.00E-06		5.00E-06
Np	93	5.0E-06	5.00E-06		5.00E-06
Os	76		5.00E-03		5.00E-03
P	15	2.5E-02	1.60E-02	2.00E-02	2.00E-02
Pa	91	5.0E-06	5.00E-06		5.00E-06
Pb	82	3.0E-04	2.60E-04	1.90E-04	1.90E-04
Pd	46	5.0E-03	1.00E-02		1.00E-02
Pm	61	5.0E-06	3.00E-05		3.00E-05
Po	84	3.4E-04	3.40E-04	2.10E-04	2.10E-04
Pr	59		3.00E-05		3.00E-05
Pt	78	5.0E-03	5.15E-03		5.15E-03
Pu	94	2.0E-06	1.10E-06	1.00E-05	1.00E-05
Ra	88	1.0E-03	1.30E-03	3.80E-04	3.80E-04
Rb	37	3.0E-02	1.20E-02		1.20E-02
Re	75	1.4E-04	1.50E-03		1.50E-03
Rf	104		2.00E-05		2.00E-05
Rh	45		1.00E-02		1.00E-02
Rn	86		1.00E-20		1.00E-20
Ru	44	1.0E-06	3.30E-06	9.40E-06	9.40E-06
S	16	1.8E-02	1.60E-02	7.90E-03	7.90E-03
Sb	51	1.5E-03	2.50E-05	3.80E-05	3.80E-05
Sc	21		5.00E-06		5.00E-06
Se	34	4.5E-02	4.00E-03	4.00E-03	4.00E-03
Si	14	2.0E-05	2.00E-05		2.00E-05
Sm	62	5.0E-06	3.00E-05		3.00E-05
Sn	50	2.5E-03	1.00E-03		1.00E-03
Sr	38	8.0E-04	2.80E-03	1.30E-03	1.30E-03
Ta	73	3.0E-06	4.10E-07		4.10E-07
Tb	65		3.00E-05		3.00E-05
Tc	43	2.5E-02	1.87E-03		1.87E-03
Te	52	1.0E-03	4.50E-04	3.40E-04	3.40E-04
Th	90	5.0E-06	5.00E-06		5.00E-06
Ti	22	5.5E-07	7.53E-05		7.53E-05
Tl	81		2.00E-03		2.00E-03
Tm	69		2.06E-05		2.06E-05
U	92	5.0E-04	4.00E-04	1.80E-03	1.80E-03
V	23	2.0E-05	2.06E-05		2.06E-05
W	74		3.00E-04	1.90E-04	1.90E-04
Y	39	1.0E-05	2.00E-05		2.00E-05
Yb	70		2.06E-05		2.06E-05
Zn	30	3.9E-02	1.00E-02	2.70E-03	2.70E-03
Zr	40	5.0E-06	5.50E-07	3.60E-06	3.60E-06

**Table 4. Feed-to-Meat Transfer Factors**

Element	Z	SRS Current Value	2008 Value	2010 Value	2010/2016 Values
			Lee and Coffield	IAEA #472	Jannik et al.
Ac	89	2.0E-05	4.00E-04		4.00E-04
Ag	47	1.7E-02	3.00E-03		3.00E-03
Al	13	5.0E-04	1.50E-03		1.50E-03
Am	95	2.0E-04	4.00E-05	5.00E-04	5.00E-04
As	33		2.00E-03		2.00E-03
At	85		1.00E-02		1.00E-02
Au	79		5.00E-03		5.00E-03
B	5		8.00E-04		8.00E-04
Ba	56	3.2E-03	2.00E-04	1.40E-04	1.40E-04
Be	4	1.0E-03	1.00E-03		1.00E-03
Bi	83	2.0E-03	4.00E-04		4.00E-04
Bk	97	2.0E-05	2.50E-05		2.50E-05
Br	35		2.50E-02		2.50E-02
C	6	3.1E-02	3.10E-02		3.10E-02
Ca	20	1.6E-03	2.00E-03	1.30E-02	1.30E-02
Cd	48	5.3E-04	4.00E-04	5.80E-03	5.80E-03
Ce	58	1.2E-03	2.00E-05		2.00E-05
Cf	98	6.0E-05	4.00E-05		4.00E-05
Cl	17	6.0E-02	2.00E-02	1.70E-02	1.70E-02
Cm	96	2.0E-04	4.00E-05		4.00E-05
Co	27	1.3E-02	1.00E-02	4.30E-04	4.30E-04
Cr	24	2.4E-03	9.00E-03		9.00E-03
Cs	55	4.0E-03	5.00E-02	2.20E-02	2.20E-02
Cu	29	8.0E-03	9.00E-03		9.00E-03
Dy	66		2.00E-05		2.00E-05
Er	68		2.00E-05		2.00E-05
Es	99	2.0E-05	2.50E-05		2.50E-05
Eu	63	4.8E-03	2.00E-05		2.00E-05
F	9		1.50E-01		1.50E-01
Fe	26	4.0E-02	2.00E-02	1.40E-02	1.40E-02
Fm	100		2.00E-04		2.00E-04
Fr	87		2.50E-03		2.50E-03
Ga	31		5.00E-04		5.00E-04
Gd	64	2.0E-03	2.00E-05		2.00E-05
Ge	32	7.0E-01	7.00E-01		7.00E-01
H	1	not used	0.00E+00		0.00E+00
Ha	105		5.00E-06		5.00E-06
Hf	72	1.0E-06	3.16E-05		3.16E-05
Hg	80	1.0E-01	2.50E-01		2.50E-01
Ho	67	4.5E-03	3.00E-04		3.00E-04
I	53	2.9E-03	4.00E-02	6.70E-03	6.70E-03
In	49	4.0E-03	8.00E-03		8.00E-03
Ir	77	2.0E-03	1.50E-03		1.50E-03
K	19	2.0E-02	2.00E-02		2.00E-02
La	57	2.0E-04	2.00E-03	1.30E-04	1.30E-04
Li	3	4.5E-03	1.00E-02		1.00E-02
Lr	103		2.00E-04		2.00E-04
Lu	71		4.50E-03		4.50E-03
Mg	12		2.00E-02		2.00E-02
Mn	25	8.0E-04	5.00E-04	6.00E-04	6.00E-04

**Table 4. Feed-to-Meat Transfer Factors (continued)**

Element	Z	SRS Current Value	2008 Value	2010 Value	2010/2016 Values
			Lee and Coffield	IAEA #472	Jannik et al.
Mo	42	8.0E-03	1.00E-03	1.00E-03	1.00E-03
N	7		7.50E-02		7.50E-02
Na	11	3.0E-02	8.00E-02	1.50E-02	1.50E-02
Nb	41	2.8E-01	2.90E-04	2.60E-07	2.60E-07
Nd	60		2.00E-05		2.00E-05
Ni	28	5.3E-03	5.00E-03		5.00E-03
No	102		2.00E-04		2.00E-04
Np	93	2.0E-04	1.00E-03		1.00E-03
Os	76		4.00E-01		4.00E-01
P	15	4.6E-02	5.00E-02	5.50E-02	5.50E-02
Pa	91	5.0E-03	4.47E-04		4.47E-04
Pb	82	8.0E-04	4.00E-04	7.00E-04	7.00E-04
Pd	46	1.0E-03	4.00E-03		4.00E-03
Pm	61	4.8E-03	2.00E-05		2.00E-05
Po	84	5.0E-03	5.00E-03		5.00E-03
Pr	59		2.00E-05		2.00E-05
Pt	78	4.0E-03	4.00E-03		4.00E-03
Pu	94	1.4E-05	1.00E-05	1.10E-06	1.10E-06
Ra	88	1.0E-03	9.00E-04	1.70E-03	1.70E-03
Rb	37	3.1E-02	1.00E-02		1.00E-02
Re	75	1.0E-04	8.00E-03		8.00E-03
Rh	45		2.00E-03		2.00E-03
Rn	86		1.00E-20		1.00E-20
Ru	44	4.0E-01	5.00E-02	3.30E-03	3.30E-03
S	16	1.0E-01	2.00E-01		2.00E-01
Sb	51	4.0E-03	1.00E-03	1.20E-03	1.20E-03
Sc	21		1.50E-02		1.50E-02
Se	34	1.5E-02	1.50E-02		1.50E-02
Si	14	4.0E-05	4.00E-05		4.00E-05
Sm	62	5.0E-03	3.16E-04		3.16E-04
Sn	50	8.0E-02	8.00E-02		8.00E-02
Sr	38	6.0E-04	8.00E-03	1.30E-03	1.30E-03
Ta	73	6.0E-04	1.34E-05		1.34E-05
Tb	65		2.00E-05		2.00E-05
Tc	43	4.0E-01	6.32E-03		6.32E-03
Te	52	7.7E-02	7.00E-03	7.00E-03	7.00E-03
Th	90	2.0E-04	4.00E-05	2.30E-04	2.30E-04
Ti	22	1.0E-06	1.73E-04		1.73E-04
Tl	81		4.00E-02		4.00E-02
Tm	69		4.50E-03		4.50E-03
U	92	3.4E-04	3.00E-04	3.90E-04	3.90E-04
V	23	2.5E-03	2.50E-03		2.50E-03
W	74		4.00E-02		4.00E-02
Y	39	4.6E-03	1.00E-03		1.00E-03
Yb	70		4.00E-03		4.00E-03
Zn	30	3.0E-02	1.00E-01	1.60E-01	1.60E-01
Zr	40	3.4E-02	1.84E-04	1.20E-06	1.20E-06

**Table 5. Water-to-Fish Bioaccumulation Factors**

Element	Z	SRS Current Value	2008 Value	2010 Value	2010/2016 Values
			Lee and Coffield	IAEA #472	Jannik et al.
Ac	89	2.5E+01	2.50E+01		2.50E+01
Ag	47	2.3E+00	5.00E+00	1.10E+02	1.10E+02
Al	13	1.0E+01	5.00E+02	5.10E+01	5.10E+01
Am	95	2.5E+01	3.00E+01	2.40E+02	2.40E+02
As	33		1.70E+03	3.30E+02	3.30E+02
At	85	1.5E+01	1.50E+01		1.50E+01
Au	79	3.5E+01	3.30E+01	2.40E+02	2.40E+02
Ba	56		4.00E+00	1.20E+00	1.20E+00
Be	4	2.0E+00	1.00E+02		1.00E+02
Bi	83	1.5E+01	1.50E+01		1.50E+01
Bk	97	2.5E+01	2.50E+01		2.50E+01
Br	35		4.00E+02	9.10E+01	9.10E+01
C	6	4.6E+03	5.00E+04	4.00E+05	3.00E+00
Ca	20	4.0E+01	4.00E+01	1.20E+01	1.20E+01
Cd	48	2.0E+02	2.00E+02		2.00E+02
Ce	58		3.00E+01	2.50E+01	2.50E+01
Cf	98	2.5E+01	2.50E+01		2.50E+01
Cl	17	5.0E+01	5.00E+01	4.70E+01	4.70E+01
Cm	96	2.5E+01	3.00E+01		3.00E+01
Co	27	5.0E+01	3.00E+02	7.60E+01	7.60E+01
Cr	24		4.00E+00	4.00E+01	4.00E+01
Cs	55	3.0E+03	3.00E+03	2.50E+03	3.00E+03
Cu	29		2.00E+02	2.30E+02	2.30E+02
Dy	66		3.00E+01	6.50E+02	6.50E+02
Er	68		3.00E+01		3.00E+01
Es	99	1.0E+01	2.50E+01		2.50E+01
Eu	63		3.00E+01	1.30E+02	1.30E+02
F	9		1.00E+01		1.00E+01
Fe	26	1.0E+02	2.00E+02	1.70E+02	1.70E+02
Fr	87	3.0E+01	3.00E+01		3.00E+01
Ga	31	3.3E+02	4.00E+02		4.00E+02
Gd	64	2.5E+01	3.00E+01		3.00E+01
Ge	32	3.3E+03	4.00E+03		4.00E+03
He	2		1.00E+00		1.00E+00
H	1	9.0E-01	1.00E+00		1.00E+00
Hf	72	3.3E+00	3.00E+02	1.10E+03	1.10E+03
Hg	80	1.0E+03	1.00E+03	6.10E+03	6.10E+03
Ho	67	2.5E+01	3.00E+01		3.00E+01
I	53	1.5E+01	4.00E+01	3.00E+01	3.00E+01
In	49	1.0E+04	1.00E+04		1.00E+04
Ir	77	1.0E+01	1.00E+01		1.00E+01
K	19	1.0E+03	1.00E+03	3.20E+03	3.20E+03
La	57	2.5E+01	3.00E+01	3.70E+01	3.70E+01
Lu	71	2.5E+01	2.50E+01		2.50E+01
Mg	12		5.00E+01	3.70E+01	3.70E+01
Mn	25	1.0E+02	4.00E+02	2.40E+02	2.40E+02
Mo	42	1.0E+01	1.00E+01	1.90E+00	1.90E+00
N	7		2.00E+05		2.00E+05
Na	11		2.00E+01	7.60E+01	7.60E+01

**Table 5. Water-to-Fish Bioaccumulation Factors (continued)**

Element	Z	SRS Current Value	2008 Value	2010 Value	2010/2016 Values
			Lee and Coffield	IAEA #472	Jannik et al.
Nb	41	3.0E+04	3.00E+02		3.00E+02
Nd	60		3.00E+01		3.00E+01
Ni	28	1.0E+02	1.00E+02	2.10E+01	2.10E+01
Np	93	1.0E+02	2.10E+01		2.10E+01
O	8		1.00E+00		1.00E+00
Os	76	1.0E+05	1.00E+03		1.00E+03
P	15		5.00E+04	1.40E+05	1.40E+05
Pa	91	1.1E+01	1.00E+01		1.00E+01
Pb	82	3.0E+02	3.00E+02	2.50E+01	2.50E+01
Pd	46	1.0E+01	1.00E+01		1.00E+01
Pm	61		3.00E+01		3.00E+01
Po	84	5.0E+02	5.00E+01	3.60E+01	3.60E+01
Pr	59		3.00E+01		3.00E+01
Pt	78	1.0E+02	3.50E+01		3.50E+01
Pu	94	3.5E+00	3.00E+01	2.1E+04*	3.00E+01
Ra	88	5.0E+01	5.00E+01	4.00E+00	4.00E+00
Rb	37	2.0E+03	2.00E+03	4.90E+03	4.90E+03
Re	75	1.2E+02	1.20E+02		1.20E+02
Rh	45		1.00E+01		1.00E+01
Rn	86	5.7E+01	7.55E-10		7.55E-10
Ru	44	1.0E+01	1.00E+02	5.50E+01	5.50E+01
S	16		8.00E+02		8.00E+02
Sb	51	1.0E+00	1.00E+02	3.70E+01	3.70E+01
Sc	21	1.0E+02	1.00E+02	1.90E+02	1.90E+02
Se	34	1.7E+02	1.70E+02	6.00E+03	6.00E+03
Si	14	2.5E+00	2.00E+01		2.00E+01
Sm	62	2.5E+01	3.00E+01		3.00E+01
Sn	50	3.0E+03	3.00E+03		3.00E+03
Sr	38	3.0E+01	6.00E+01	2.90E+00	2.90E+00
Ta	73	3.0E+04	3.00E+02		3.00E+02
Tb	65		3.00E+01	4.10E+02	4.10E+02
Tc	43	1.5E+01	2.00E+01		2.00E+01
Te	52	4.0E+02	4.00E+02	1.50E+02	1.50E+02
Th	90	3.0E+01	1.00E+02	6.00E+00	6.00E+00
Ti	22	1.0E+03	1.00E+03	1.90E+02	1.90E+02
Tl	81	1.0E+04	1.00E+04	9.00E+02	9.00E+02
U	92	2.0E+00	1.00E+01	9.60E-01	9.60E-01
V	23	1.0E+01	2.00E+02	9.70E+01	9.70E+01
W	74		1.00E+01		1.00E+01
Y	39	2.5E+01	3.00E+01	4.00E+01	4.00E+01
Zn	30		3.50E+02	3.40E+03	3.40E+03
Zr	40	3.3E+00	3.00E+02	2.20E+01	2.20E+01

\*At this time, the plutonium value of 21,000 L/kg is considered suspect.

**Table 6. Water to Saltwater Invertebrates Bioaccumulation Factors**

Element	Z	SRS Current Value	2008 Value	2003 Value	2010/2016 Values
			Lee and Coffield	PNNL 13421	Jannik et al.
Ac	89	1.00E+03	N/A	1.00E+03	1.00E+03
Ag	47	3.33E+03	N/A	3.50E+02	3.50E+02
Al	13	6.00E+01	N/A		6.00E+01
Am	95	1.00E+03	N/A	3.60E+02	3.60E+02
As	33		N/A	3.00E+02	3.00E+02
Ba	56	1.00E+02	N/A	1.00E+00	1.00E+00
Be	4	2.00E+02	N/A	1.00E+04	1.00E+04
Bi	83	1.00E+01	N/A	1.00E+03	1.00E+03
Bk	97	1.00E+03	N/A		1.00E+03
Br	35		N/A	1.00E+01	1.00E+01
C	6	1.40E+03	N/A	2.00E+04	2.00E+04
Ca	20	1.25E+01	N/A	5.00E+00	5.00E+00
Cd	48	2.50E+05	N/A	5.00E+03	5.00E+03
Ce	58	6.00E+02	N/A	5.00E+02	5.00E+02
Cf	98	1.00E+03	N/A	5.00E+02	5.00E+02
Cl	17	1.90E-02	N/A	1.00E+00	1.00E+00
Cm	96	1.00E+03	N/A	4.60E+02	4.60E+02
Co	27	1.00E+03	N/A	2.00E+03	2.00E+03
Cr	24	2.00E+03	N/A	5.00E+02	5.00E+02
Cs	55	2.50E+01	N/A	3.00E+01	3.00E+01
Cu	29	1.70E+03	N/A	5.00E+03	5.00E+03
Dy	66		N/A	1.00E+03	1.00E+03
Er	68		N/A	5.00E+02	5.00E+02
Es	99	1.00E+01	N/A	7.00E+03	7.00E+03
Eu	63	1.00E+03	N/A	1.00E+03	1.00E+03
F	9		N/A	4.00E+00	4.00E+00
Fe	26	2.00E+04	N/A	5.00E+03	5.00E+03
Fr	87		N/A		3.00E+01
Ga	31		N/A	1.00E+04	1.00E+04
Gd	64	1.00E+03	N/A	2.00E+03	2.00E+03
Ge	32	1.57E+04	N/A		4.00E+03
He	2		N/A	1.00E+00	1.00E+00
H	1	9.30E-01	N/A		9.30E-01
Hf	72	2.00E+01	N/A	1.00E+03	1.00E+03
Hg	80	3.33E+04	N/A	2.00E+04	2.00E+04
Ho	67	1.00E+03	N/A	1.00E+03	1.00E+03
I	53	5.00E+01	N/A	5.00E+01	5.00E+01
In	49		N/A	1.00E+04	1.00E+04
Ir	77	2.00E+03	N/A	1.00E+02	1.00E+02
K	19	6.58E+00	N/A		6.58E+00
La	57	1.00E+03	N/A	1.00E+02	1.00E+02
Lu	71	1.00E+03	N/A		1.00E+03
Mn	25	1.00E+04	N/A	8.00E+02	8.00E+02
Mo	42	1.00E+01	N/A	2.00E+01	2.00E+01
N	7		N/A	1.00E+00	1.00E+00
Na	11	1.90E-01	N/A	1.00E+00	1.00E+00
Nb	41	1.00E+02	N/A	5.00E+01	5.00E+01
Ni	28	2.50E+02	N/A	5.00E+02	5.00E+02
Np	93	1.00E+01	N/A	1.00E+01	1.00E+01



**Table 6. Water to Saltwater Invertebrates Bioaccumulation Factors (continued)**

Element	Z	SRS Current Value	2008 Value	2003 Value	2010/2016 Values
			Lee and Coffield	PNNL 13421	Jannik et al.
P	15	3.00E+04	N/A	3.80E+04	3.80E+04
Pa	91	1.00E+01	N/A	1.00E+01	1.00E+01
Pb	82	1.00E+03	N/A	1.00E+03	1.00E+03
Pd	46	2.00E+03	N/A	3.00E+02	3.00E+02
Pm	61	1.00E+03	N/A	1.00E+03	1.00E+03
Po	84	2.00E+04	N/A	5.00E+04	5.00E+04
Pr	59		N/A	1.00E+03	1.00E+03
Pt	78	2.00E+03	N/A		2.00E+03
Pu	94	1.00E+02	N/A	3.00E+02	3.00E+02
Ra	88	1.00E+02	N/A	1.00E+02	1.00E+02
Rb	37	1.70E+01	N/A	2.00E+02	2.00E+02
Re	75	5.95E+01	N/A		5.95E+01
Rh	45		N/A	1.00E+02	1.00E+02
Rn	86		N/A		
Ru	44	1.00E+03	N/A	1.00E+02	1.00E+02
S	16	4.40E-01	N/A	1.00E+00	1.00E+00
Sb	51	5.00E+00	N/A	1.00E+02	1.00E+02
Sc	21		N/A	3.00E+02	3.00E+02
Se	34	1.00E+03	N/A	5.00E+03	5.00E+03
Si	14	3.33E+01	N/A	5.00E+04	5.00E+04
Sm	62	1.00E+03	N/A	1.00E+03	1.00E+03
Sn	50	1.00E+03	N/A	5.00E+04	5.00E+04
Sr	38	2.00E+01	N/A	1.00E+00	1.00E+00
Ta	73	1.67E+04	N/A	3.00E+03	3.00E+03
Tb	65		N/A	1.00E+03	1.00E+03
Tc	43	5.00E+01	N/A	1.00E+01	1.00E+01
Te	52	1.00E+05	N/A	1.00E+03	1.00E+03
Th	90	2.00E+03	N/A	1.00E+03	1.00E+03
Ti	22	1.00E+03	N/A		1.00E+03
Tl	81		N/A	1.00E+03	1.00E+03
U	92	1.00E+01	N/A	1.00E+01	1.00E+01
V	23	5.00E+01	N/A		5.00E+01
W	74		N/A	1.00E+01	1.00E+01
Y	39	1.00E+03	N/A	1.00E+03	1.00E+03
Zn	30	5.00E+04	N/A	5.00E+04	5.00E+04
Zr	40	8.00E+01	N/A	5.00E+01	5.00E+01

**Table 7. 2010/2016 Vegetable Production as a Function of Distance and Sector**

Based on 2007 Weighted Vegetable Production Grid surrounding SRS increased 10 times for unreported (home use) production (Kg/yr)

<b>Sector</b>	<b>10-20 Mi</b>	<b>20-30 Mi</b>	<b>30-40 Mi</b>	<b>40-50 Mi</b>	<b>Total</b>
N	1.5E+04	2.5E+04	4.1E+04	2.2E+05	3.1E+05
NNE	1.4E+04	2.5E+04	2.5E+05	7.9E+05	1.1E+06
NE	4.2E+04	4.0E+04	1.3E+05	4.7E+05	6.8E+05
ENE	6.1E+04	1.5E+05	6.4E+04	4.5E+04	3.2E+05
E	6.8E+04	2.6E+05	4.4E+05	2.5E+05	1.0E+06
ESE	6.2E+04	1.6E+05	3.1E+05	2.3E+05	7.5E+05
SE	5.2E+04	8.7E+04	4.5E+04	1.8E+04	2.0E+05
SSE	4.1E+04	6.4E+04	6.7E+04	2.5E+04	2.0E+05
S	1.3E+04	2.9E+04	4.1E+04	7.7E+04	1.6E+05
SSW	9.8E+03	1.3E+04	1.4E+04	8.8E+04	1.2E+05
SW	1.0E+04	1.5E+04	1.0E+04	1.2E+04	4.7E+04
WSW	1.1E+04	1.7E+04	2.4E+04	4.0E+04	9.0E+04
W	9.3E+03	1.3E+04	2.3E+04	3.1E+04	7.6E+04
WNW	1.4E+04	1.1E+04	1.0E+04	1.1E+04	4.6E+04
NW	1.6E+04	2.2E+04	2.6E+04	1.9E+04	8.3E+04
NNW	1.6E+04	2.5E+04	3.9E+04	5.6E+04	1.3E+05
<b>Total</b>	<b>4.5E+05</b>	<b>9.5E+05</b>	<b>1.5E+06</b>	<b>2.4E+06</b>	<b>5.3E+06</b>

**Table 8. 2010/2016 Beef Production as a Function of Distance and Sector**

Based on 2007 Weighted Beef Production Grid surrounding SRS Increased 25% for unreported (home use) production (Kg/yr)

<b>Sector</b>	<b>10-20 Mi</b>	<b>20-30 Mi</b>	<b>30-40 Mi</b>	<b>40-50 Mi</b>	<b>Total</b>
N	4.9E+04	8.2E+04	1.3E+05	5.1E+05	7.8E+05
NNE	4.7E+04	8.2E+04	1.0E+05	1.0E+05	3.3E+05
NE	4.4E+04	7.9E+04	1.0E+05	1.0E+05	3.3E+05
ENE	4.6E+04	8.9E+04	1.1E+05	1.3E+05	3.8E+05
E	5.2E+04	1.0E+05	1.6E+05	1.5E+05	4.7E+05
ESE	4.8E+04	1.3E+05	1.4E+05	6.1E+04	3.8E+05
SE	9.2E+04	1.8E+05	8.5E+04	2.4E+04	3.8E+05
SSE	9.3E+04	1.5E+05	1.6E+05	6.2E+04	4.7E+05
S	8.9E+04	1.1E+05	1.5E+05	1.7E+05	5.2E+05
SSW	1.0E+05	1.3E+05	1.4E+05	1.2E+05	4.8E+05
SW	1.0E+05	1.7E+05	1.8E+05	1.5E+05	6.0E+05
WSW	1.1E+05	1.7E+05	2.4E+05	2.4E+05	7.7E+05
W	6.3E+04	1.0E+05	1.7E+05	1.7E+05	5.0E+05
WNW	4.8E+04	5.5E+04	8.8E+04	1.2E+05	3.1E+05
NW	5.2E+04	7.6E+04	1.1E+05	1.1E+05	3.5E+05
NNW	5.1E+04	8.2E+04	1.3E+05	2.5E+05	5.2E+05
<b>Total</b>	<b>1.1E+06</b>	<b>1.8E+06</b>	<b>2.2E+06</b>	<b>2.5E+06</b>	<b>7.6E+06</b>

**Table 9. 2010/2016 Milk Production as a Function of Distance and Sector**

Based on 2007 Weighted Milk Production Grid surrounding SRS Increased 25% for unreported (home use) production (L/yr)

<b>Sector</b>	<b>10-20 Mi</b>	<b>20-30 Mi</b>	<b>30-40 Mi</b>	<b>40-50 Mi</b>	<b>Total</b>
N	4.4E+03	4.4E+03	3.0E+05	3.2E+06	3.5E+06
NNE	4.4E+03	4.4E+03	4.4E+03	4.4E+03	1.8E+04
NE	4.4E+03	1.0E+06	2.0E+06	1.2E+06	4.2E+06
ENE	4.4E+03	1.6E+06	3.8E+06	4.5E+06	9.9E+06
E	4.4E+03	2.5E+06	5.3E+06	5.2E+06	1.3E+07
ESE	4.4E+03	9.6E+05	3.0E+06	7.3E+05	4.7E+06
SE	4.4E+03	4.4E+03	4.4E+03	4.4E+03	1.8E+04
SSE	1.6E+05	1.3E+05	1.9E+05	1.4E+05	6.2E+05
S	1.5E+06	3.8E+05	4.7E+05	5.5E+05	2.9E+06
SSW	2.1E+06	1.9E+06	1.3E+06	1.3E+06	6.6E+06
SW	2.1E+06	3.4E+06	3.1E+06	2.6E+06	1.1E+07
WSW	2.2E+06	3.5E+06	4.8E+06	3.8E+06	1.4E+07
W	8.0E+05	1.4E+06	2.6E+06	3.7E+06	8.5E+06
WNW	4.4E+03	8.9E+03	6.6E+03	1.5E+06	1.5E+06
NW	4.4E+03	7.0E+04	6.1E+05	4.4E+05	1.1E+06
NNW	4.4E+03	1.5E+04	9.0E+05	1.8E+06	2.7E+06
<b>Total</b>	<b>9.0E+06</b>	<b>1.7E+07</b>	<b>2.9E+07</b>	<b>3.1E+07</b>	<b>8.5E+07</b>

**Table 10. SRS Typical Person (previously Average Individual) Behavioral Parameters for Dose Calculations**

Parameter	Units	1977	1991	2008	2010	2016	% Difference 2010 Jannik/ 2016 Jannik
		NRC Default	Hamby	Lee and Coffield	Jannik et al.	Jannik et al.	
<b>Average Individual and Population Usage</b>							
Inhalation Rate	m <sup>3</sup> /yr	8,000	8,000	5,548	5,548	5,000	-9.88%
Drinking Water consumption rate	L/yr	370	370	337	337	300	-10.88%
Leafy Vegetable consumption rate	kg/yr	64	21	21	21	11	-47.62%
Other Produce consumption rate	kg/yr	190	163	163	163	89	-45.40%
Meat consumption rate	kg/yr	95	43	43	43	32	-25.58%
Milk consumption rate	L/yr	110	120	120	120	69	-42.50%
Fish consumption rate	kg/yr	6.9	9	9	9	3.7	-58.89%
Invertebrate consumption rate	kg/yr	1	2	N/A	2	1.5	-25.00%
Soil consumption rate	kg/yr	-	-	0.0365	0.0365	0.0365	0%
Shoreline Exposure Time	hr/yr	8.3	23.0	23.0	10.0	10.0	0%
Swimming Exposure Time	hr/yr	-	8.9	8.9	7.0	7.0	0%
Boating Exposure Time	hr/yr	-	21.0	21.0	22.0	22.0	0%
Population Shoreline Exposure Time	per.-hr	-	9.60E+05	N/A	8.22E+05	8.22E+05	0%
Population Swimming Exposure Time	per.-hr	-	1.60E+05	N/A	2.95E+05	2.95E+05	0%
Population Boating Exposure Time	per.-hr	-	1.10E+06	N/A	3.11E+06	3.11E+06	0%
Fraction of year working in garden	-	-	-	0.01	0.01	0.01	0%
Fraction of year residing in home	-	-	-	0.7	0.7	0.7	0%
Time taking a shower	min/d	-	-	10	10	10	0%
Population served - BJWSA (Chelsea)	persons	-	5.00E+04	N/A	7.70E+04	8.29E+04	7.01%
Population served - BJWSA (Purrysburg)	persons	-	N/A	N/A	5.80E+04	6.42E+04	10.69%
Population served - Savannah I&D	persons	-	1.50E+04	N/A	2.63E+04	3.50E+04	33.08%

**Table 11. SRS Reference Person (*previously Maximally Exposed Individual*) Behavioral Parameters for Dose Calculations**

Parameter	Units	1977	1991	2008	2010	2016	% Difference 2010 Jannik/ 2016 Jannik
		NRC Default	Hamby	Lee and Coffield	Jannik et al.	Jannik et al.	
<b>Maximally Exposed Individual Usage</b>							
Inhalation Rate	m <sup>3</sup> /yr	8,000	8,000	N/A	8,000	6,400	-20.00%
Drinking Water consumption rate	L/yr	730	730	N/A	730	800	9.59%
Leafy Vegetable consumption rate	kg/yr	64	43	N/A	43	31	-27.91
Other Produce consumption rate	kg/yr	520	276	N/A	276	289	4.71%
Meat consumption rate	kg/yr	110	81	N/A	81	81	0.00%
Milk consumption rate	L/yr	310	230	N/A	230	260	13.04%
Fish consumption rate	kg/yr	21	19	N/A	19	24	26.32%
Invertebrate consumption rate	kg/yr	5	8	N/A	8	9	12.50%
Soil consumption rate	kg/yr	-	-	N/A	0.0365	0.0365	0.00%
Shoreline Exposure Time	hr/yr	12	23.0	N/A	20.0	20	0.00%
Swimming Exposure Time	hr/yr	-	8.9	N/A	14.0	14	0.00%
Boating Exposure Time	hr/yr	-	21.0	N/A	44.0	44	0.00%

**Table 12. Average Recreational Usage Rates**

Survey Activity	2005	2005	1991	2010/2016
	Percentage Participating	Average Annual Frequency	Survey Hours per Occasion	per Capita Usage (hr/yr)
<b>Shoreline Usage</b>				
Fresh water fishing	38%	5.0	5	9.50
				<b>10</b>
<b>Swimming Usage</b>				
Lake/River Swimming	28%	4.0	3	3.36
Jet and Water Skiing	28%	4.0	3	3.36
				<b>7</b>
<b>Boating Usage</b>				
Canoeing, kayaking, rafting	11%	1.0	3	0.33
Boating/Sailing	55%	8.0	5	22.00
				<b>22</b>

SC 2005 Recreational Participation & Preference Study  
<http://www.scprt.com/our-partners/tourismstatistics/researchreports.aspx>

**Table 13. Weighted Usage Fractions**

Activity	State Usage Available Fraction	2000 Population Fraction*	Weighted Usage Fraction	Population Usage (person-hr/yr)
<b>Shoreline</b>				
SC, surf/bank fishing	0.041	0.6	0.0246	
GA, warmwater fishing	0.085	0.4	0.034	
			<b>0.059</b>	<b>8.22E+05</b>
<b>Swimming</b>				
SC, beach areas	0.032	0.6	0.0192	
GA, lake swimming	0.027	0.4	0.0108	
			<b>0.030</b>	<b>2.95E+05</b>
<b>Boating</b>				
SC, boat use average**	0.13	0.6	0.078	
GA, boating/sailing	0.057	0.4	0.0228	
			<b>0.101</b>	<b>3.11E+06</b>

\* Assumes 60% of population lives in SC and 40% of population lives in Georgia.

Based on Projected Census Data for Counties

\*\* Average of "other fishing" and "boat ramps" fractions

	Base Census 2000	Projected Census 2010
50 mile Counties SC Population	739,715	832,000
50 mile Counties GA Population	507,226	571,000
<b>Total</b>	<b>1,246,941</b>	<b>1,403,000</b>