

A Compendium of Transfer Factors for Agricultural and Animal Products

L. H. Staven K. Rhoads
B. A. Napier D. L. Streng

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Transfer factors are used in radiological risk assessments to estimate the amount of radioactivity that could be present in a food crop or organism based on the calculated concentration in the source medium (i.e., soil or animal feed). By calculating the concentration in the food, the total intake can be estimated and a dose calculated as a result of the annual intake. This report compiles transfer factors for radiological risk assessments, using common food products, including meats, eggs, and plants. Transfer factors used are most often selected from recommended values listed by national or international organizations for use in radiological food chain transport calculations. Several methods of estimation and extrapolation are used for radionuclides not listed in the primary information sources. Tables of transfer factors are listed by element and information source for leafy vegetables, fruit, root vegetables, grain, beef, poultry, milk, eggs, fresh and saltwater fish as well as crustaceans, mollusks, and aquatic plants.

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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, 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.

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1.0 Introduction

Transfer factors, also known as concentration ratios or bioaccumulation factors, are the ratio of the concentration of an element in an organism of interest, such as plants and food products, to the concentration in the source medium, such as soil (for plants), plant forage (for animals), or water (for fish, crustaceans, mollusks, and aquatic plants). Transfer factors are used in calculating radionuclide uptake by animals and humans via food pathways. Measurements show that similar concentrations of various radionuclides in soil or water do not produce the same concentrations once they are taken up into tissue. Transfer factors are used in radiological risk assessments to estimate the amount of radioactivity that could be present in a food crop or organism based on the calculated concentration in the source medium (i.e., soil or animal feed). By calculating the concentration in the food, the total intake can be estimated and a dose calculated as a result of the annual intake. This report compiles transfer factors for radiological risk assessments using common food products, including meats, eggs, and plants.

The transfer factor applies to long-term, chronic exposure of plants and animals and is ideally measured at equilibrium. For plant products, transfer factors relate the concentration of an element in soil to the element's concentration in the plant; for animals, the transfer factor relates concentration in animal feed to animal products; and for fish, the transfer factor relates the concentration in water to the concentration in fish muscle tissue. In terms of radionuclides, the transfer factor is used to calculate how many becquerel per kilogram (Bq per kg) of soil are transferred to the edible dry plant product. For vegetables, the units are kg soil/kg edible dry plants. For animal products, the transfer factor relates the daily intake to that of the animal product. Units for milk are Bq/L per Bq intake/d. For animal and fish meat products, transfer factors are measured in wet weight animal product: Bq/kg muscle per Bq/d intake for meat and Bq/kg muscle per Bq/L for fish. For water plants, the units are expressed in wet weight Bq/kg plant per Bq/L.

Numerous studies have been undertaken to quantify transfer factors for specific chemical elements as a function of food type. These studies have been compiled in several publications (see "Compilations of Data Sources," below).

1.1 Selection of Transfer Factors

Transfer factors compiled for this report are generally selected from recommended values listed by national or international organizations for use in radiological food chain transport calculations. (In some cases, where data are available, very recent references for specific values are preferred to compiled recommendations.) In general, the recommended values from more recent compilations are selected rather than those in older publications. The primary data sources are also cited where identified in the compilation document. In many cases, where neither a primary source of data nor a recommended value in a compilation is available, transfer factors for such elements are extrapolated from experimental data based on chemical similarities.

1.2 Compilations of Data Sources

A hierarchy of data sources was established to select recommended values for transfer factors. The most recent and comprehensive references are given priority. The first reference chosen is the International Atomic Energy Agency's (IAEA) 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. The second reference given consideration is NUREG/CR-5512, *Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent* (Kennedy and Streng 1992) because of its large set of data and traceable references. Three other references are also used to fill in data: NCRP Report #123 (1996), *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground*; the library from the GENII system of computer codes (Napier et al. 1988); and the series of documents by Coughtrey and Thorne, *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems, Vols. 1-6* (1983). NCRP Report #123 is chosen because it is a generally accepted reference for a generic model. The GENII values have been in use for a decade to model the semi-arid environment at the Hanford Site and are reasonably well documented. Although the methodology for the Coughtrey and Thorne values is somewhat different, resulting in high values for transfer factors, it is necessary to use their values to fill in data where no other information is available. When no referenceable documents are available, data are derived based on chemical groupings in the periodic table of the elements as described below.

1.3 Methods Used to Estimate Transfer Factors

Experimental data are not available for all elements for all food types. Therefore, several methods are employed to estimate transfer factors for elements and food types where data are lacking. In some cases, parameters from one vegetable type are applied to remaining vegetable types for the same element. In these cases, no adjustments are made for the wet/dry ratios for specific food types, due to the relatively large uncertainty inherent in applying the transfer factor from one food type to another. In other cases, chemical similarities among elements are the basis for estimating the transfer factor. If two or more transfer factors are available for elements in a chemical group, the geometric mean is calculated from the chemical group for the given food type (Figure 1.1). Where data are available for only one element in a chemical group, the transfer factor for that element is applied to other elements in the same chemical group. Specific cases are listed in the section below. For the actinides, many of the values from americium are applied to other elements for which parameters are not available. Cerium is the surrogate element for other lanthanides for which values are not known.

	IA																	Noble Gases		
	1 H	IIA										III A	IVA	VA	VIA	VIIA	2 He			
	3 Li	4 Be										5 B	6 C	7 N	8 O	9 F	10 Ne			
Period	11 Na	12 Mg	III	----- Periods IV - VII -----																
IV	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr		
V	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe		
VI	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn		
VII	87 Fr	88 Ra	89 Ac	104 Rf	105 Ha	106 Sg	107 Ns	108 Hs	109 Mt											

Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Figure 1.1. Chemical Periodic Table with Groups and Periods. A listing of the chemicals and their symbols is in Appendix A.

2.0 Food Types Evaluated

For this compendium of data, foods are grouped into the following types: beef, milk, poultry, eggs, fish, leafy vegetables, other (root) vegetables, fruit, and grain. Also included are transfer factors from the GENII code for saltwater fish, crustaceans, molluscs and water plants. When more than one food is listed for a given food type (e.g., spinach, cabbage, and lettuce are all listed as “leafy vegetables”), the transfer factor for each food is weighted by the U.S. Department of Agriculture annual per capita consumption rate (USDA 1983), and a weighted average of transfer factors is reported for that food type.

Plant transfer factors from the IAEA Handbook #364, NUREG/CR-5512, GENII, and Coughtrey and Thorne are based on dry weight data (Bq per kg dry crop edible product)/(Bq/kg dry soil in the upper 20 cm). When data are presented on a wet weight basis, they are converted to dry weight using conversion factors found in Table 2.1. A wilted plant from moist soil is likely to produce a much different transfer factor than a freshly harvested plant from drier soil. By analyzing dry weight plant-to-soil transfer factors only, the variability due to moisture content of plants and soil is eliminated.

Table 2.1. Dry-to-Wet Weight Conversion Factors for Food Products^(a)

Plant Type	Conversion Factor
Leafy vegetables	0.2
Other vegetables	0.25
Other/root vegetables	0.25
Fruit	0.18
Grain	0.91
Beef	
Forage	0.22
Stored hay	0.22
Stored grain	0.91
Poultry	
Forage	0.22
Stored hay	0.22
Stored grain	0.91
Dairy	
Forage	0.22
Stored hay	0.22
Stored grain	0.91
Eggs	
Forage	0.22
Stored hay	0.22
Stored grain	0.91
(a) From Kennedy and Strenge (1992), as adapted from Till and Meyer (1983) Table 5-16. Factors in Till & Meyer are expressed as fresh (wet) to dry and were expressed by Kennedy and Strenge (1992) and in this report, as inversions for the purposes of converting from wet to dry weight.	

All terrestrial plant transfer factors presented in this report are based on dry weight. Animal products and aquatic plants are presented on a wet weight or volume (milk) basis.

Tables 2.2 to 2.14 list a) the recommended transfer factors by food or crop type, b) the compilation from which the value is taken, and c) the original sources of data as cited in each compilation document. Some transfer factors, described below, are estimated for special cases without direct primary references.

2.1 Leafy Vegetables

The soil-to-leafy-vegetables transfer factors for N, Hf, Ta, and Au are calculated as the geometric means of the transfer factors in their respective periodic table groups. All the lanthanide elements are assigned the value for Ce. Actinium (Ac), Pa, and Cf are assigned the leafy vegetables transfer factor from Am.

2.2 Fruit

The soil-to-fruit transfer factors for N, Os, Au, and Hg are calculated based on the geometric mean of the transfer factors in their respective groups on the periodic table. Hafnium (Hf) and Ta are assigned values equal to those for Zr and Nb, respectively. All the lanthanide elements are assigned the value for Ce.

2.3 Root Vegetables

The soil-to-root transfer factors for N and Au are calculated as the geometric mean of the transfer factors in their respective periodic table groups. Hafnium (Hf) and Ta are based on a single established value in their respective chemical groups. The root transfer factors for Ac, Pa, and Cf are based on Am. All lanthanide elements are assigned the value for Ce.

2.4 Grain

The soil-to-grain transfer factors for Be, N, and Hg are calculated as the geometric mean of the transfer factors in their respective periodic table groups. Silver (Ag), Hf, Ta, and Au transfer factors for grain are based on the single known value in their respective chemical groups. All the lanthanide elements are assigned the value for Ce. The grain transfer factors for Ac, Pa, and Cf are based on Am.

2.5 Beef

The Ta transfer factor for feed-to-beef is set equal to the Nb value, and all lanthanides are based on Ce. Unknown actinides, Ac, Pa, and Cf values are set equal to Am values for their respective food types. All other values are based on the recommended values in a compilation document.

Table 2.2. Transfer Factors for Leafy Vegetables (Bq/kg leafy vegetables per Bq/kg soil)

Z and Element	Recommended Value (Dry Weight)	Compiled in	Primary Reference	Z and Element	Recommended Value (Dry Weight)	Compiled in	Primary Reference
04 Be	1.0E-2	KS92	Ba84	52 Te	2.5E-2	KS92	Ba84
06 C	7.0E-1	KS92		53 I	4.0E-2	Sn94	Sn94
07 N	5.5E-2	KS92	Ba84	55 Cs	4.6E-1	IAEA94	Fr82
09 F	6.0E-2	KS92	Ba84	56 Ba	1.5E-1	KS92	Ba84
11 Na	3.0E-1	IAEA94	Ng82b	57 La	5.2E-3	IAEA94	Fr89
12 Mg	1.0E+0	KS92	Ba84	58 Ce	2.0E-2	Ng82b	Ng82b
14 Si	3.5E-1	KS92	Ba84	59 Pr	2.0E-2	Based on Ce	Ng82b
15 P	3.5E+0	KS92	Ba84	60 Nd	2.0E-2	Based on Ce	Ng82b
16 S	1.5E+0	KS92	Ba84	61 Pm	2.0E-2	Based on Ce	Ng82b
17 Cl	7.0E+1	KS92	Ba84	62 Sm	2.0E-2	Based on Ce	Ng82b
19 K	1.0E+0	KS92	Ba84	63 Eu	2.0E-2	Based on Ce	Ng82b
20 Ca	3.5E+0	KS92	Ba84	64 Gd	2.0E-2	Based on Ce	Ng82b
21 Sc	6.0E-3	KS92	Ba84	65 Tb	2.0E-2	Based on Ce	Ng82b
24 Cr	7.5E-3	KS92	Ba84	66 Dy	2.0E-2	Based on Ce	Ng82b
25 Mn	7.0E-1	IAEA94	Fr89	67 Ho	2.0E-2	Based on Ce	Ng82b
26 Fe	5.0E-2	CT83	CT83	68 Er	2.0E-2	Based on Ce	Ng82b
27 Co	2.3E-1	IAEA94	Fr89	72 Hf	1.0E-3	Based on Zr	Ng82b
28 Ni	2.8E-1	KS92	IUR89	73 Ta	2.5E-2	Based on Nb	CT83
29 Cu	4.0E-1	KS92	Ba84	74 W	3.0E+0	Na88	NCRP86
30 Zn	1.3E+0	IAEA94	Fr89	75 Re	1.5E+0	KS92	Ba84
31 Ga	4.0E-3	Based on In	Ba84	76 Os	1.5E-2	KS92	Ba84
33 As	4.0E-2	KS92	Ba84	77 Ir	5.5E-2	KS92	Ba84
34 Se	2.5E-1	CT83	CT83	79 Au	1.0E-2	g.m.	g.m.
35 Br	1.5E+0	KS92	Fu78	80 Hg	8.5E-1	g.m.	g.m.
37 Rb	9.0E-1	IAEA94	Ng82b	81 Tl	4.0E-3	Based on In	Fu78
38 Sr	3.0E+0	IAEA94	Fr82	82 Pb	1.0E-2	IAEA94	Fr89
39 Y	1.0E-2	IAEA94	Ng82b	83 Bi	5.0E-1	IAEA94	IAEA82
40 Zr	1.0E-3	IAEA94	Ng82b	84 Po	1.2E-3	IAEA94	Ho91
41 Nb	2.5E-2	CT83	CT83	88 Ra	4.9E-2	IAEA94	Fr89
42 Mo	8.0E-1	IAEA94	Ng82b	89 Ac	4.7E-4	Based on Am	Fr82
43 Tc	2.1E+2	IAEA94	Fr89	90 Th	1.8E-3	IAEA94	Fr89
44 Ru	4.0E-2	IAEA94	Ng82b	91 Pa	4.7E-4	Based on Am	Fr82
45 Rh	1.5E-1	KS92	Ba84	92 U	8.3E-3	IAEA94	Fr89
46 Pd	1.5E-1	KS92	Ba84	93 Np	3.2E-2	IAEA94	Fr82
47 Ag	2.7E-4	IAEA94	Fr89	94 Pu	6.0E-5	IAEA94	Fr82
48 Cd	5.5E-1	KS92	Ba84	95 Am	4.7E-4	IAEA94	Fr82
49 In	4.0E-3	KS92	Fu78	96 Cm	7.7E-4	IAEA94	Fr82
50 Sn	3.0E-2	KS92	Fu78	98 Cf	4.7E-4	Based on Am	Fr82
51 Sb	1.3E-4	KS92	IUR89	98 Cf	2.5E-4	Based on Am	Ba84

g.m. = geometric mean.

Table 2.3. Transfer Factors for Fruit (Bq/kg fruit per Bq/kg soil)

Z and Element	Recommended Value (Dry Weight)	Compiled in	Primary Reference	Z and Element	Recommended Value (Dry Weight)	Compiled in	Primary Reference
04 Be	1.5E-3	KS92	Ba84	52 Te	4.0E-3	KS92	Ba84
06 C	7.0E-1	Na88	Na88	53 I	4.0E-2	Sn94	Sn94
07 N	3.0E-2	g.m.	g.m.	55 Cs	2.2E-1	IAEA94	Fr89
09 F	6.0E-3	KS92	Ba84	56 Ba	1.5E-2	KS92	Ba84
11 Na	3.0E-1	IAEA94	Ng82b	57 La	4.0E-3	KS92	Ba84
12 Mg	5.5E-1	KS92	Ba84	58 Ce	2.0E-2	Ng82b	Ng82b
14 Si	7.0E-2	KS92	Ba84	59 Pr	2.0E-2	Based on Ce	Ng82b
15 P	3.5E+0	KS92	Ba84	60 Nd	2.0E-2	Based on Ce	Ng82b
16 S	1.5E+0	KS92	Ba84	61 Pm	2.0E-2	Based on Ce	Ng82b
17 Cl	7.0E+1	KS92	Ba84	62 Sm	2.0E-2	Based on Ce	Ng82b
19 K	5.5E-1	KS92	Ba84	63 Eu	2.0E-2	Based on Ce	Ng82b
20 Ca	3.5E-1	KS92	Ba84	64 Gd	2.0E-2	Based on Ce	Ng82b
21 Sc	1.0E-3	KS92	Ba84	65 Tb	2.0E-2	Based on Ce	Ng82b
24 Cr	4.5E-3	KS92	Ba84	66 Dy	2.0E-2	Based on Ce	Ng82b
25 Mn	5.0E-2	KS92	Ba84	67 Ho	2.0E-2	Based on Ce	Ng82b
26 Fe	5.0E-2	CT83	CT83	68 Er	2.0E-2	Based on Ce	Ng82b
27 Co	7.0E-3	KS92	Ba84	72 Hf	1.0E-3	Based on Zr	Ng82b
28 Ni	6.0E-2	KS92	Ba84	73 Ta	2.5E-2	Based on Nb	CT83
29 Cu	2.5E-1	KS92	Ba84	74 W	3.0E+0	NCRP96	NCRP96
30 Zn	9.0E-1	KS92	Ba84	75 Re	3.5E-1	KS92	Ba84
31 Ga	4.0E-4	Based on In	Ba84	76 Os	4.5E-2	g.m.	g.m.
33 As	6.0E-3	KS92	Ba84	77 Ir	1.5E-2	KS92	Ba84
34 Se	5.0E-2	CT83	CT83	79 Au	1.4E-2	g.m.	g.m.
35 Br	1.5E+0	KS92	Fu78	80 Hg	3.7E-1	g.m.	g.m.
37 Rb	9.0E-1	IAEA94	Ng82b	81 Tl	4.0E-4	KS92	Ba84
38 Sr	2.0E-1	IAEA94	Fr82	82 Pb	1.0E-2	IAEA94	Fr89
39 Y	1.0E-2	IAEA94	Ng82b	83 Bi	5.0E-1	IAEA94	IAEA82
40 Zr	1.0E-3	IAEA94	Ng82b	84 Po	1.2E-3	IAEA94	Ho91
41 Nb	2.5E-2	CT83	CT83	88 Ra	6.1E-3	IAEA94	Fr89
42 Mo	5.0E-2	CT83	CT83	89 Ac	2.5E-4	Based on Am	Ba84
43 Tc	1.5E+0	KS92	Ba84	90 Th	2.5E-4	Based on Am	Ba84
44 Ru	4.0E-2	IAEA94	Ng82b	91 Pa	2.5E-4	Based on Am	Ba84
45 Rh	4.0E-2	KS92	Ba84	92 U	4.0E-3	KS92	Ba84
46 Pd	4.0E-2	KS92	Ba84	93 Np	1.0E-2	KS92	Ba84
47 Ag	8.0E-4	IAEA94	Fr89	94 Pu	4.5E-5	KS92	Ba84
48 Cd	1.5E-1	KS92	Ba84	95 Am	2.5E-4	KS92	Ba84
49 In	4.0E-4	KS92	Fu78	96 Cm	1.5E-5	KS92	Ba84
50 Sn	6.0E-3	KS92	Fu78	98 Cf	2.5E-4	Based on Am	Ba84
51 Sb	8.0E-5	KS92	IUR89				

g.m. = geometric mean.

Table 2.4. Transfer Factors for Root Vegetables (Bq/kg root vegetable per Bq/kg soil)

Z and Element	Recommended			Z and Element	Recommended		
	Value (Dry Weight)	Compiled in	Primary Reference		Value (Dry Weight)	Compiled in	Primary Reference
04 Be	1.5E-3	KS92	Ba84	52 Te	4.0E-3	KS92	Ba84
06 C	7.0E-1	Na88	Na88	53 I	4.0E-2	Sn94	Sn94
07 N	4.9E-2	KS92	Ba84	55 Cs	1.3E-1	IAEA94	Fr82
09 F	6.0E-3	KS92	Ba84	56 Ba	1.5E-2	KS92	Ba84
11 Na	3.0E-1	IAEA94	Ng82b	57 La	3.5E-4	IAEA94	Fr89
12 Mg	5.5E-1	KS92	Ba84	58 Ce	2.0E-2	Ng82b	Ng82b
14 Si	7.0E-2	KS92	Ba84	59 Pr	2.0E-2	Based on Ce	Ng82b
15 P	3.5E+0	KS92	Ba84	60 Nd	2.0E-2	Based on Ce	Ng82b
16 S	1.5E+0	KS92	Ba84	61 Pm	2.0E-2	Based on Ce	Ng82b
17 Cl	7.0E+1	KS92	Ba84	62 Sm	2.0E-2	Based on Ce	Ng82b
19 K	5.5E-1	KS92	Ba84	63 Eu	2.0E-2	Based on Ce	Ng82b
20 Ca	3.5E-1	KS92	Ba84	64 Gd	2.0E-2	Based on Ce	Ng82b
21 Sc	1.0E-3	KS92	Ba84	65 Tb	2.0E-2	Based on Ce	Ng82b
24 Cr	4.5E-3	KS92	Ba84	66 Dy	2.0E-2	Based on Ce	Ng82b
25 Mn	2.0E-1	IAEA94	Fr89	67 Ho	2.0E-2	Based on Ce	Ng82b
26 Fe	5.0E-2	CT83	CT83	68 Er	2.0E-2	Based on Ce	Ng82b
27 Co	6.7E-2	IAEA94	Fr89	72 Hf	1.0E-3	Based on Zr	Ng82b
28 Ni	6.0E-2	KS92	Ba84	73 Ta	2.5E-2	Based on Nb	CT83
29 Cu	2.5E-1	KS92	Ba84	74 W	3.0E+0	Na88	NCRP86
30 Zn	3.5E-1	IAEA94	Fr89	75 Re	3.5E-1	KS92	Ba84
31 Ga	4.0E-4	Based on In	Ba84	76 Os	3.5E-3	KS92	Ba84
33 As	6.0E-3	KS92	Ba84	77 Ir	1.5E-2	KS92	Ba84
34 Se	5.0E-2	CT83	CT83	79 Au	1.8E-2	g.m.	g.m.
35 Br	1.5E+0	KS92	Fu78	80 Hg	2.0E-1	KS92	Ba84
37 Rb	9.0E-1	IAEA94	Ng82b	81 Tl	4.0E-4	Based on In	Fu78
38 Sr	5.0E-1	IAEA94	Fr82	82 Pb	6.0E-3	IAEA94	Fr89
39 Y	1.0E-2	IAEA94	Ng82b	83 Bi	5.0E-1	IAEA94	IAEA82
40 Zr	1.0E-3	IAEA94	Ng82b	84 Po	7.0E-3	IAEA94	HW91
41 Nb	2.5E-2	CT83	CT83	88 Ra	2.0E-3	IAEA94	Fr89
42 Mo	8.0E-1	IAEA94	Ng82b	89 Ac	3.5E-4	Based on Am	Fr82
43 Tc	2.4E-1	IAEA94	Fr89	90 Th	3.3E-4	IAEA94	Fr89
44 Ru	4.0E-2	IAEA94	Ng82b	91 Pa	3.5E-4	Based on Am	Fr82
45 Rh	4.0E-2	KS92	Ba84	92 U	1.2E-2	IAEA94	Fr89
46 Pd	4.0E-2	KS92	Ba84	93 Np	1.3E-2	IAEA94	Fr82
47 Ag	1.3E-3	IAEA94	Fr89	94 Pu	1.1E-3	IAEA94	Fr82
48 Cd	1.5E-1	KS92	Ba84	95 Am	3.5E-4	IAEA94	Fr82
49 In	4.0E-4	KS92	Fu78	96 Cm	4.3E-4	IAEA94	Fr82
50 Sn	6.0E-3	KS92	Fu78	98 Cf	3.5E-4	Based on Am	Fr82
51 Sb	5.6E-4	IAEA94	Fr89				

g.m. = geometric mean.

Table 2.5. Transfer Factors for Grain (Bq/kg grain per Bq/kg soil)

Z and Element	Recommended Value (Dry Weight)	Compiled in	Primary Reference	Z and Element	Recommended Value (Dry Weight)	Compiled in	Primary Reference
04 Be	2.0E-3	g.m.	g.m.	52 Te	4.0E-3	KS92	Ba84
06 C	7.0E-1	Na88	Na88	53 I	4.0E-2	Sn94	Sn94
07 N	1.3E-1	g.m.	g.m.	55 Cs	2.6E-2	IAEA94	Fr82
09 F	6.0E-3	KS92	Ba84	56 Ba	1.5E-2	KS92	Ba84
11 Na	3.0E-1	IAEA94	Ng82b	57 La	4.0E-3	KS92	Ba84
12 Mg	5.5E-1	KS92	Ba84	58 Ce	2.0E-2	Ng82b	Ng82b
14 Si	7.0E-2	KS92	Ba84	59 Pr	2.0E-2	Based on Ce	Ng82b
15 P	3.5E+0	KS92	Ba84	60 Nd	2.0E-2	Based on Ce	Ng82b
16 S	1.5E+0	KS92	Ba84	61 Pm	2.0E-2	Based on Ce	Ng82b
17 Cl	7.0E+1	KS92	Ba84	62 Sm	2.0E-2	Based on Ce	Ng82b
19 K	5.5E-1	KS92	Ba84	63 Eu	2.0E-2	Based on Ce	Ng82b
20 Ca	3.5E-1	KS92	Ba84	64 Gd	2.0E-2	Based on Ce	Ng82b
21 Sc	1.0E-3	KS92	Ba84	65 Tb	2.0E-2	Based on Ce	Ng82b
24 Cr	4.5E-3	KS92	Ba84	66 Dy	2.0E-2	Based on Ce	Ng82b
25 Mn	3.0E-1	IAEA94	AEA94	67 Ho	2.0E-2	Based on Ce	Ng82b
26 Fe	5.0E-2	CT83	CT83	68 Er	2.0E-2	Based on Ce	Ng82b
27 Co	3.7E-3	IAEA94	Fr89	72 Hf	1.0E-3	Based on Zr	Ng82b
28 Ni	3.0E-2	IAEA94	Fr89	73 Ta	2.5E-2	Based on Nb	CT83
29 Cu	2.5E-1	KS92	Ba84	74 W	3.0E+0	NCRP96	NCRP96
30 Zn	1.6E+0	IAEA94	Fr89	75 Re	3.5E-1	KS92	Ba84
31 Ga	4.0E-4	Based on In	Ba84	76 Os	3.5E-3	KS92	Ba84
33 As	6.0E-3	KS92	Ba84	77 Ir	1.5E-2	KS92	Ba84
34 Se	2.5E-1	CT83	CT83	79 Au	2.5E-1	Based on Cu	Ba84
35 Br	1.5E+0	KS92	Fu78	80 Hg	4.9E-1	g.m.	g.m.
37 Rb	9.0E-1	IAEA94	Ng82b	81 Tl	4.0E-4	KS92	Ba84
38 Sr	2.1E-1	IAEA94	Fr82	82 Pb	4.7E-3	IAEA94	Fr89
39 Y	1.0E-2	IAEA94	Ng82b	83 Bi	5.0E-1	IAEA94	IAEA82
40 Zr	1.0E-3	IAEA94	Ng82b	84 Po	2.3E-3	IAEA94	HW91
41 Nb	2.5E-2	CT83	CT83	88 Ra	1.2E-3	IAEA94	Fr89
42 Mo	8.0E-1	IAEA94	Ng82b	89 Ac	2.2E-5	Based on Am	Fr82
43 Tc	7.3E-1	IAEA94	Fr89	90 Th	3.4E-5	KS92	IUR89
44 Ru	5.0E-3	IAEA94	Fr89	91 Pa	2.2E-5	Based on Am	Fr82
45 Rh	4.0E-2	KS92	Ba84	92 U	1.3E-3	IAEA94	Bi91
46 Pd	4.0E-2	KS92	Ba84	93 Np	2.7E-3	IAEA94	Fr82
47 Ag	2.5E-1	Based on Cu	Ba84	94 Pu	8.6E-6	IAEA94	Fr82
48 Cd	1.5E-1	KS92	Ba84	95 Am	2.2E-5	IAEA94	Fr82
49 In	4.0E-4	KS92	Fu78	96 Cm	2.1E-5	IAEA94	Fr82
50 Sn	6.0E-3	KS92	Fu78	98 Cf	2.2E-5	Based on Am	Fr82
51 Sb	3.0E-2	KS92	Fu78				

g.m. = geometric mean.

Table 2.6. Transfer Factors for Beef (Bq/kg muscle per Bq/d intake)

Z and Element	Recommended Value (Wet Weight)	Compiled in	Primary Reference	Z and Element	Recommended Value (Wet Weight)	Compiled in	Primary Reference
04 Be	1.0E-3	KS92	Ng68	52 Te	7.0E-3	IAEA94	Jo88
07 N	7.5E-2	KS92	Ng68	53 I	4.0E-2	IAEA94	Bi89
09 F	1.5E-1	KS92	Ng68	55 Cs	5.0E-2	IAEA94	Co90
11 Na	8.0E-2	IAEA94	Ng82a	56 Ba	2.0E-4	IAEA94	Jo88
12 Mg	2.0E-2	IAEA94	Ng82a	57 La	2.0E-3	NCRP96	NCRP96
14 Si	4.0E-5	KS92	Ng68	58 Ce	2.0E-5	IAEA94	CEC87
15 P	5.0E-2	IAEA94	Ng82a	59 Pr	2.0E-5	Based on Ce	CEC87
16 S	2.0E-1	Na88	IAEA87	60 Nd	2.0E-5	Based on Ce	CEC87
17 Cl	2.0E-2	IAEA94	Bi89	61 Pm	2.0E-5	Based on Ce	CEC87
19 K	2.0E-2	IAEA94	Ng82a	62 Sm	2.0E-5	Based on Ce	CEC87
20 Ca	2.0E-3	IAEA94	Ng82a	63 Eu	2.0E-5	Based on Ce	CEC87
21 Sc	1.5E-2	KS92	Ng68	64 Gd	2.0E-5	Based on Ce	CEC87
24 Cr	9.0E-3	IAEA94	Ng82a	65 Tb	2.0E-5	Based on Ce	CEC87
25 Mn	5.0E-4	IAEA94	Ng82a	66 Dy	2.0E-5	Based on Ce	CEC87
26 Fe	2.0E-2	IAEA94	Ng82a	67 Ho	2.0E-5	Based on Ce	CEC87
27 Co	1.0E-2	IAEA94	Ng82a	68 Er	2.0E-5	Based on Ce	CEC87
28 Ni	5.0E-3	IAEA94	Cr90	72 Hf	1.0E-3	KS92	Ng68
29 Cu	9.0E-3	IAEA94	Ng82a	73 Ta	3.0E-7	Based on Nb	Jo88
30 Zn	1.0E-1	IAEA94	Ng82a	74 W	4.0E-2	IAEA94	Ng82a
31 Ga	5.0E-4	KS92	Ba84	75 Re	8.0E-3	KS92	Ng68
33 As	2.0E-3	KS92	Ng68	76 Os	4.0E-1	KS92	Ng68
34 Se	1.5E-2	KS92	Ng68	77 Ir	1.5E-3	KS92	Ng68
35 Br	2.5E-2	KS92	Ng68	79 Au	5.0E-3	Na88	NCRP86
37 Rb	1.0E-2	IAEA94	Ng82a	80 Hg	2.5E-1	KS92	Ng68
38 Sr	8.0E-3	IAEA94	Co90	81 Tl	4.0E-2	KS92	Ng68
39 Y	1.0E-3	IAEA94	Ng82a	82 Pb	4.0E-4	IAEA94	Ng82a
40 Zr	1.0E-6	IAEA94	Jo88	83 Bi	4.0E-4	KS92	Ng68
41 Nb	3.0E-7	IAEA94	Jo88	84 Po	5.0E-3	IAEA94	Ng82a
42 Mo	1.0E-3	IAEA94	Jo88	88 Ra	9.0E-4	IAEA94	MB90
43 Tc	1.0E-4	IAEA94	Bi89	89 Ac	4.0E-4	Na88	LS85
44 Ru	5.0E-2	IAEA94	Co90	90 Th	4.0E-5	Based on Am	Co90
45 Rh	2.0E-3	KS92	Ng79	91 Pa	4.0E-5	Based on Am	Co90
46 Pd	4.0E-3	KS92	Ng68	92 U	3.0E-4	IAEA94	Cr90
47 Ag	3.0E-3	IAEA94	CEC87	93 Np	1.0E-3	IAEA94	Br79
48 Cd	4.0E-4	IAEA94	Ng82a	94 Pu	1.0E-5	IAEA94	Co90
49 In	8.0E-3	KS92	Ng68	95 Am	4.0E-5	IAEA94	Co90
50 Sn	8.0E-2	KS92	Ng68	96 Cm	4.0E-5	Based on Am	Co90
51 Sb	1.0E-3	Na88	IAEA87	98 Cf	4.0E-5	Based on Am	Co90

Table 2.7. Transfer Factors for Poultry (Bq/kg poultry muscle per Bq/d intake)

Z and Element	Recommended		Primary Reference	Z and Element	Recommended		Primary Reference
	Value (Wet Weight)	Compiled in			Value (Wet Weight)	Compiled in	
04 Be	4.0E-1	KS92	Na88	52 Te	6.0E-1	IAEA94	En88a
07 N	9.8E-2	g.m.	g.m.	53 I	5.0E-2	Sn94	Sn94
09 F	1.4E-2	g.m.	g.m.	55 Cs	3.0E+0	Vo93	Vo93
11 Na	1.0E-2	KS92	Na88	56 Ba	9.0E-3	IAEA94	En88a
12 Mg	3.0E-2	KS92	KS92	57 La	1.0E-1	IAEA94	Ng82a
14 Si	8.0E-1	Based on As	Na88	58 Ce	2.0E-3	IAEA94	Ng82a
15 P	1.9E-1	KS92	Na88	59 Pr	2.0E-3	Based on Ce	Ng82a
16 S	2.3E+0	g.m.	g.m.	60 Nd	2.0E-3	Based on Ce	Ng82a
17 Cl	3.0E-2	KS92	Na88	61 Pm	2.0E-3	Based on Ce	Ng82a
19 K	4.0E-1	KS92	KS92	62 Sm	2.0E-3	Based on Ce	Ng82a
20 Ca	4.0E-2	IAEA94	Ng82a	63 Eu	2.0E-3	Based on Ce	Ng82a
21 Sc	4.0E-3	KS92	Na88	64 Gd	2.0E-3	Based on Ce	Ng82a
24 Cr	2.0E-1	KS92	KS92	65 Tb	2.0E-3	Based on Ce	Ng82a
25 Mn	5.0E-2	IAEA94	Ng82a	66 Dy	2.0E-3	Based on Ce	Ng82a
26 Fe	1.0E+0	IAEA94	Ng82a	67 Ho	2.0E-3	Based on Ce	Ng82a
27 Co	2.0E+0	IAEA94	Ng82a	68 Er	2.0E-3	Based on Ce	Ng82a
28 Ni	1.0E-3	KS92	Na88	72 Hf	6.0E-5	based on Zr	En88a
29 Cu	5.0E-1	IAEA94	Ng82a	73 Ta	3.0E-4	Based on Nb	En88a
30 Zn	7.0E+0	IAEA94	Ng82a	74 W	2.0E-1	Based on Mo	IAEA94
31 Ga	8.0E-1	Based on As	Na88	75 Re	4.0E-2	KS92	Ba84
33 As	8.3E-1	KS92	Na88	76 Os	8.4E-2	g.m.	g.m.
34 Se	9.0E+0	IAEA94	Ng82a	77 Ir	2.0E+0	Based on Co	Ng82a
35 Br	4.0E-3	KS92	Na88	79 Au	1.0E+0	g.m.	g.m.
37 Rb	2.0E+0	KS92	Na88	80 Hg	3.0E-2	IAEA94	Ng82a
38 Sr	8.0E-2	IAEA94	Co90	81 Tl	8.0E-1	Based on In	Na88
39 Y	1.0E-2	IAEA94	Ng82a	82 Pb	8.0E-1	Based on As	Na88
40 Zr	6.0E-5	IAEA94	En88a	83 Bi	9.8E-2	g.m.	g.m.
41 Nb	3.0E-4	IAEA94	En88a	84 Po	2.3E+0	g.m.	g.m.
42 Mo	1.8E-1	En88a	En88a	88 Ra	3.0E-2	KS92	KS92
43 Tc	3.0E-2	IAEA94	En88b	89 Ac	6.0E-3	Based on Am	Co90
44 Ru	7.0E-3	Na88	Ng82a	90 Th	6.0E-3	Based on Am	Co90
45 Rh	2.0E+0	Based on Co	Ng82a	91 Pa	6.0E-3	Based on Am	Co90
46 Pd	3.0E-4	KS92	Na88	92 U	1.0E+0	IAEA94	Ng82a
47 Ag	2.0E+0	IAEA94	CEC87	93 Np	6.0E-3	Based on Am	Co90
48 Cd	8.0E-1	IAEA94	Ng82a	94 Pu	3.0E-3	IAEA94	Co90
49 In	8.0E-1	Based on As	Na88	95 Am	6.0E-3	IAEA94	Co90
50 Sn	8.0E-1	Based on As	Na88	96 Cm	6.0E-3	Based on Am	Co90
51 Sb	6.0E-3	Na88	Na88	98 Cf	6.0E-3	Based on Am	Co90

g.m. = geometric mean.

Table 2.8. Transfer Factors for Milk (Bq/L milk per Bq/d intake)

Z and Element	Recommended			Z and Element	Recommended		
	Value (Wet Weight)	Compiled in	Primary Reference		Value (Wet Weight)	Compiled in	Primary Reference
01 H	1.5E-2	IAEA94	Va83	51 Sb	2.5E-5	IAEA94	Va82
04 Be	9.0E-7	KS92	Ng77	52 Te	4.5E-4	IAEA94	Jo88
06 C	ND			53 I	9.0E-3	Sn94	Sn94
07 N	2.5E-2	KS92	Ng77	55 Cs	7.9E-3	IAEA94	Co90
09 F	1.0E-3	KS92	Ng77	56 Ba	4.8E-4	IAEA94	Jo88
11 Na	1.6E-2	IAEA94	IAEA94	57 La	2.0E-5	KS92	Ng77
12 Mg	3.9E-3	IAEA94	Ng82a	58 Ce	3.0E-5	IAEA94	CEC87
14 Si	2.0E-5	KS92	Ng77	59 Pr	3.0E-5	Based on Ce	CEC87
15 P	1.6E-2	IAEA94	Ng82a	60 Nd	3.0E-5	Based on Ce	CEC87
16 S	1.6E-2	IAEA94	Ng82a	61 Pm	3.0E-5	Based on Ce	CEC87
17 Cl	1.7E-2	IAEA94	Bi89	62 Sm	3.0E-5	Based on Ce	CEC87
19 K	7.2E-3	IAEA94	Ng82a	63 Eu	3.0E-5	Based on Ce	CEC87
20 Ca	3.0E-3	IAEA94	CT83	64 Gd	3.0E-5	Based on Ce	CEC87
21 Sc	5.0E-6	KS92	Ng77	65 Tb	3.0E-5	Based on Ce	CEC87
24 Cr	1.0E-5	IAEA94	Va84	66 Dy	3.0E-5	Based on Ce	CEC87
25 Mn	3.0E-5	IAEA94	Va84	67 Ho	3.0E-5	Based on Ce	CEC87
26 Fe	3.0E-5	IAEA94	Va84	68 Er	3.0E-5	Based on Ce	CEC87
27 Co	3.0E-4	IAEA94	Ba84	72 Hf	5.5E-7	Based on Zr	Jo88
28 Ni	1.6E-2	IAEA94	Cr90	73 Ta	4.1E-7	Based on Nb	Jo88
29 Cu	2.0E-3	Na88	IAEA87	74 W	3.0E-4	KS92	Ng77
30 Zn	1.0E-2	KS92	Ng77	75 Re	1.5E-3	KS92	Ng77
31 Ga	5.0E-5	KS92	Ng77	76 Os	5.0E-3	KS92	Ng77
33 As	6.0E-5	KS92	Ng77	77 Ir	2.0E-6	KS92	Ng77
34 Se	4.0E-3	KS92	Ng77	79 Au	5.5E-6	KS92	Ng77
35 Br	2.0E-2	KS92	Ng77	80 Hg	4.7E-4	IAEA94	Ng82a
37 Rb	1.2E-2	IAEA94	Ng82a	81 Tl	2.0E-3	Na88	Na88
38 Sr	2.8E-3	IAEA94	Co90	82 Pb	2.6E-4	KS92	Ng77
39 Y	2.0E-5	KS92	Ng77	83 Bi	5.0E-4	KS92	Ng77
40 Zr	5.5E-7	IAEA94	Jo88	84 Po	3.4E-4	IAEA94	Ng82a
41 Nb	4.1E-7	IAEA94	Jo88	88 Ra	1.3E-3	IAEA94	MB90
42 Mo	1.7E-3	IAEA94	Jo88	89 Ac	2.0E-5	KS92	Ng77
43 Tc	1.4E-4	IAEA94	Jo88	90 Th	5.0E-6	KS92	Ng77
44 Ru	3.3E-6	IAEA94	Co90	91 Pa	5.0E-6	KS92	Ng77
45 Rh	1.0E-2	KS92	Ng77	92 U	4.0E-4	IAEA94	MB90
46 Pd	1.0E-2	KS92	Ng77	93 Np	5.0E-6	IAEA94	Ng82a
47 Ag	5.0E-5	IAEA94	CEC87	94 Pu	1.1E-6	IAEA94	Co90
48 Cd	1.0E-3	KS92	Ng77	95 Am	1.5E-6	IAEA94	Co90
49 In	2.0E-4	Na88	NCRP86	96 Cm	2.0E-5	KS92	Ng77
50 Sn	1.0E-3	Na88	NCRP86	98 Cf	1.5E-6	Based on Am	Co90

ND = Not defined. Specific activity model implemented.

Table 2.9. Transfer Factors for Eggs (Bq/kg egg per Bq/d intake)

Z and Element	Recommended Value (Wet Weight)	Compiled in	Primary Reference	Z and Element	Recommended Value (Wet Weight)	Compiled in	Primary Reference
04 Be	2.0E-2	KS92	Na88	52 Te	5.0E+0	IAEA94	En88a
07 N	2.6E-1	g.m.	g.m.	53 I	4.4E+0	Sn94	Sn94
09 F	2.7E+0	g.m.	g.m.	55 Cs	4.0E-1	IAEA94	Co90
11 Na	6.0E+0	IAEA94	Ng82a	56 Ba	9.0E-1	IAEA94	En88a
12 Mg	2.0E+0	IAEA94	Ng82a	57 La	9.0E-3	IAEA94	Ng82a
14 Si	1.0E+0	Based on P	Na88	58 Ce	4.0E-5	IAEA94	CEC87
15 P	1.0E+0	KS92	Na88	59 Pr	4.0E-5	Based on Ce	CEC87
16 S	7.0E+0	g.m.	g.m.	60 Nd	4.0E-5	Based on Ce	CEC87
17 Cl	2.7E+0	g.m.	g.m.	61 Pm	4.0E-5	Based on Ce	CEC87
19 K	1.0E+0	IAEA94	Ng82a	62 Sm	4.0E-5	Based on Ce	CEC87
20 Ca	4.0E-1	IAEA94	Ng82a	63 Eu	4.0E-5	Based on Ce	CEC87
21 Sc	4.2E-3	g.m.	g.m.	64 Gd	4.0E-5	Based on Ce	CEC87
24 Cr	9.0E-1	Based on Mo	En88a	65 Tb	4.0E-5	Based on Ce	CEC87
25 Mn	6.0E-2	IAEA94	Ng82a	66 Dy	4.0E-5	Based on Ce	CEC87
26 Fe	1.0E+0	IAEA94	Ng82a	67 Ho	4.0E-5	Based on Ce	CEC87
27 Co	1.0E-1	IAEA94	Ng82a	68 Er	4.0E-5	Based on Ce	CEC87
28 Ni	1.0E-1	KS92	Na88	72 Hf	2.0E-4	Based on Zr	Jo88
29 Cu	5.0E-1	IAEA94	Ng82a	73 Ta	1.0E-3	Based on Nb	En88a
30 Zn	3.0E+0	IAEA94	Ng82a	74 W	9.0E-1	Based on Mo	En88a
31 Ga	1.0E+0	Based on P	Na88	75 Re	4.2E-1	g.m.	g.m.
33 As	2.6E-1	g.m.	g.m.	76 Os	7.1E-2	g.m.	g.m.
34 Se	9.0E+0	IAEA94	Ng82a	77 Ir	1.0E-1	Based on Co	Ng82a
35 Br	1.6E+0	KS92	Na88	79 Au	5.0E-1	Based on Cu	Ng82a
37 Rb	3.0E+0	KS92	Na88	80 Hg	5.0E-1	g.m.	g.m.
38 Sr	2.0E-1	IAEA94	Co90	81 Tl	1.0E+0	Based on P	Na88
39 Y	2.0E-3	IAEA94	Ng82a	82 Pb	1.0E+0	Based on P	Na88
40 Zr	2.0E-4	IAEA94	En88a	83 Bi	2.6E-1	g.m.	g.m.
41 Nb	1.0E-3	IAEA94	En88a	84 Po	7.0E+0	g.m.	g.m.
42 Mo	9.0E-1	IAEA94	En88a	88 Ra	3.1E-1	g.m.	g.m.
43 Tc	3.0E+0	IAEA94	En88a	89 Ac	4.0E-3	Based on Am	Ng82a
44 Ru	5.0E-3	IAEA94	Co90	90 Th	4.0E-3	Based on Am	Ng82a
45 Rh	1.0E-1	Based on Co	Ng82a	91 Pa	4.0E-3	Based on Am	Ng82a
46 Pd	4.0E-3	KS92	Na88	92 U	1.0E+0	IAEA94	Ng82a
47 Ag	5.0E-1	Based on Cu	Ng82a	93 Np	4.0E-3	Based on Am	Ng82a
48 Cd	1.0E-1	IAEA94	Ng82a	94 Pu	5.0E-4	IAEA94	Ng82a
49 In	1.0E+0	Based on P	Na88	95 Am	4.0E-3	IAEA94	Ng82a
50 Sn	1.0E+0	Based on P	Na88	96 Cm	4.0E-3	Based on Am	Ng82a
51 Sb	7.0E-2	KS92	Na88	98 Cf	4.0E-3	Based on Am	Ng82a

g.m. = geometric mean.

Table 2.10. Concentration Ratios for Freshwater Fish (Bq/kg muscle per Bq/L)

Z and Element	Recommended Value (Wet Weight)	Compiled in	Primary Reference	Z and Element	Recommended Value (Wet Weight)	Compiled in	Primary Reference
02 He	1.0E+0	IAEA94	IAEA94	51 Sb	1.0E+2	IAEA94	IAEA82
04 Be	1.0E+2	IAEA94	IAEA94	52 Te	4.0E+2	IAEA94	IAEA82
06 C	5.0E+4	IAEA94	IAEA94	53 I	4.0E+1	IAEA94	IAEA82
07 N	2.0E+5	IAEA94	IAEA94	55 Cs	2.0E+3	IAEA94	IAEA82
08 O	1.0E+0	IAEA94	IAEA94	56 Ba	4.0E+0	IAEA94	IAEA82
09 F	1.0E+1	KS92	St86	57 La	3.0E+1	IAEA94	IAEA82
11 Na	2.0E+1	IAEA94	IAEA82	58 Ce	3.0E+1	IAEA94	IAEA82
12 Mg	5.0E+1	NCRP96	NCRP96	59 Pr	3.0E+1	Based on Ce	IAEA82
14 Si	2.0E+1	NCRP96	NCRP96	60 Nd	3.0E+1	Based on Ce	IAEA82
15 P	5.0E+4	IAEA94	IAEA82	61 Pm	3.0E+1	Based on Ce	IAEA82
16 S	8.0E+2	IAEA94	IAEA82	62 Sm	3.0E+1	Based on Ce	IAEA82
17 Cl	5.0E+1	KS92	St86	63 Eu	3.0E+1	Based on Ce	IAEA82
19 K	1.0E+3	KS92	St86	64 Gd	3.0E+1	Based on Ce	IAEA82
20 Ca	4.0E+1	KS92	St86	65 Tb	3.0E+1	Based on Ce	IAEA82
21 Sc	1.0E+2	IAEA94	IAEA94	66 Dy	3.0E+1	Based on Ce	IAEA82
24 Cr	4.0E+0	Sn94	Th94	67 Ho	3.0E+1	Based on Ce	IAEA82
25 Mn	4.0E+2	IAEA94	IAEA82	68 Er	3.0E+1	Based on Ce	IAEA82
26 Fe	2.0E+2	IAEA94	IAEA82	72 Hf	3.0E+2	Based on Zr	IAEA82
27 Co	3.0E+2	IAEA94	IAEA82	73 Ta	3.0E+2	Based on Nb	IAEA94
28 Ni	1.0E+2	IAEA94	IAEA82	74 W	1.0E+1	Based on Mo	IAEA94
29 Cu	2.0E+2	IAEA94	IAEA94	75 Re	1.2E+2	KS92	St86
30 Zn	3.5E+2	Sn94	Th94	76 Os	1.0E+1	KS92	St86
31 Ga	4.0E+2	NCRP96	NCRP96	77 Ir	1.0E+1	KS92	St86
33 As	1.7E+3	Sn94	Th94	79 Au	3.3E+1	KS92	St86
34 Se	1.7E+2	KS92	St86	80 Hg	1.0E+3	KS92	St86
35 Br	4.0E+2	IAEA94	IAEA94	81 Tl	1.0E+4	NCRP96	NCRP96
37 Rb	2.0E+3	IAEA94	IAEA94	82 Pb	3.0E+2	IAEA94	IAEA82
38 Sr	6.0E+1	IAEA94	IAEA82	83 Bi	1.5E+1	KS92	St86
39 Y	3.0E+1	IAEA94	IAEA82	84 Po	5.0E+1	IAEA94	IAEA82
40 Zr	3.0E+2	IAEA94	IAEA82	88 Ra	5.0E+1	IAEA94	IAEA82
41 Nb	3.0E+2	IAEA94	IAEA82	89 Ac	2.5E+1	KS92	St86
42 Mo	1.0E+1	IAEA94	IAEA94	90 Th	1.0E+2	KS92	Na88
43 Tc	2.0E+1	IAEA94	IAEA82	91 Pa	1.0E+1	NCRP96	NCRP96
44 Ru	1.0E+2	KS92	Na88	92 U	1.0E+1	IAEA94	IAEA82
45 Rh	1.0E+1	IAEA94	IAEA94	93 Np	2.1E+1	Sn94	Th94
46 Pd	1.0E+1	KS92	St86	94 Pu	3.0E+1	IAEA94	IAEA82
47 Ag	5.0E+0	IAEA94	IAEA82	95 Am	3.0E+1	IAEA94	IAEA82
48 Cd	2.0E+2	KS92	St86	96 Cm	3.0E+1	IAEA94	IAEA82
49 In	1.0E+4	NCRP96	NCRP96	98 Cf	2.5E+1	KS92	St86
50 Sn	3.0E+3	KS92	St86				

Table 2.11. Concentration Ratios for Saltwater Fish, as Compiled in GENII (Na88)^(a) (Bq/kg per Bq/L)

Z and Element	Recommended Value (Wet Weight)	Z and Element	Recommended Value (Wet Weight)
02 He	1.0E+0	51 Sb	1.0E+3
04 Be	1.0E+3	52 Te	1.0E+3
06 C	2.0E+4	53 I	1.0E+1
07 N	1.0E+0	55 Cs	1.0E+2
09 F	4.0E+0	56 Ba	1.0E+1
11 Na	1.0E+0	57 La	3.0E+1
14 Si	5.0E+4	58 Ce	1.0E+2
15 P	2.8E+4	59 Pr	1.0E+2
16 S	2.0E+0	60 Nd	1.0E+2
17 Cl	1.0E+0	61 Pm	5.0E+2
20 Ca	2.0E+0	62 Sm	5.0E+2
21 Sc	7.5E+2	63 Eu	3.0E+2
24 Cr	6.0E+2	64 Gd	5.0E+2
25 Mn	4.0E+2	65 Tb	6.0E+1
26 Fe	3.0E+3	66 Dy	5.0E+2
27 Co	1.0E+2	67 Ho	3.0E+2
28 Ni	1.0E+2	68 Er	1.0E+2
29 Cu	1.0E+3	72 Hf	4.0E+1
30 Zn	1.0E+3	73 Ta	6.0E+1
31 Ga	1.0E+3	74 W	1.0E+1
33 As	3.0E+2	77 Ir	2.0E+1
34 Se	6.0E+3	80 Hg	2.0E+4
35 Br	1.0E+1	81 Tl	5.0E+3
37 Rb	5.0E+2	82 Pb	2.0E+2
38 Sr	4.0E+0	83 Bi	1.5E+1
39 Y	2.0E+1	84 Po	2.0E+3
40 Zr	5.0E+1	88 Ra	9.5E+2
41 Nb	1.0E+2	89 Ac	3.0E+1
42 Mo	4.0E+1	90 Th	6.0E+2
43 Tc	3.0E+1	91 Pa	3.0E+2
44 Ru	1.0E+1	92 U	5.0E+1
45 Rh	1.0E+1	93 Np	2.5E+3
46 Pd	5.0E+1	94 Pu	1.0E+3
47 Ag	3.0E+2	95 Am	2.5E+3
48 Cd	2.0E+3	96 Cm	2.5E+3
49 In	1.0E+3	98 Cf	5.0E+1
50 Sn	5.0E+4		

(a) Concentration ratios for the following elements are not included in the GENII documentation and are not included above: O, Mg, K, Re, Os, and Au.

Table 2.12. Concentration Ratios for Saltwater and Freshwater Crustaceans, as Compiled in GENII (Na88)^(a) (Bq/kg muscle per Bq/L [wet])

Z and Element	Saltwater	Freshwater	Z and Element	Saltwater	Freshwater
02 He	1.0E+0	1.0E+0	51 Sb	1.0E+2	1.0E+2
04 Be	1.0E+4	5.0E+1	52 Te	1.0E+3	6.1E+3
06 C	2.0E+4	9.0E+3	53 I	5.0E+1	1.0E+2
07 N	1.0E+0	1.0E+0	55 Cs	3.0E+1	5.0E+2
09 F	4.0E+0	1.0E+2	56 Ba	1.0E+0	2.0E+2
11 Na	1.0E-0	1.0E+2	57 La	1.0E+2	1.0E+3
14 Si	5.0E+4	1.0E+4	58 Ce	5.0E+2	1.0E+3
15 P	3.8E+4	1.0E+5	59 Pr	1.0E+3	1.0E+3
16 S	1.0E+0	1.0E+2	61 Pm	1.0E+3	3.0E+3
17 Cl	1.0E+0	5.0E+1	62 Sm	1.0E+3	3.0E+3
20 Ca	5.0E+0	2.0E+3	63 Eu	1.0E+3	3.0E+3
21 Sc	3.0E+2	1.0E+3	64 Gd	2.0E+3	2.0E+3
24 Cr	5.0E+2	2.0E+3	65 Tb	1.0E+3	1.0E+3
25 Mn	8.0E+2	1.0E+5	66 Dy	1.0E+3	1.0E+3
26 Fe	5.0E+3	1.0E+2	67 Ho	1.0E+3	3.0E+3
27 Co	2.0E+3	2.0E+3	68 Er	5.0E+2	1.0E+3
28 Ni	5.0E+2	5.0E+2	72 Hf	1.0E+3	1.0E+3
29 Cu	5.0E+3	4.0E+2	73 Ta	3.0E+3	3.0E+3
30 Zn	5.0E+4	1.0E+4	74 W	1.0E+1	1.0E+1
31 Ga	1.0E+4	1.0E+4	77 Ir	1.0E+2	2.0E+2
33 As	3.0E+2	3.0E+2	80 Hg	2.0E+4	2.0E+4
34 Se	5.0E+3	2.0E+3	81 Tl	1.0E+3	1.0E+3
35 Br	1.0E+1	3.3E+2	82 Pb	1.0E+3	5.0E+2
37 Rb	2.0E+2	1.0E+3	83 Bi	1.0E+3	1.0E+5
38 Sr	1.0E+0	1.0E+2	84 Po	5.0E+4	2.0E+4
39 Y	1.0E+3	1.0E+3	88 Ra	1.0E+2	1.0E+3
40 Zr	5.0E+1	5.0E+1	89 Ac	1.0E+3	1.0E+3
41 Nb	5.0E+1	5.0E+1	90 Th	1.0E+3	1.0E+2
42 Mo	2.0E+1	1.0E+2	91 Pa	1.0E+1	3.0E+1
43 Tc	1.0E+1	1.0E+2	92 U	1.0E+1	1.0E+2
44 Ru	1.0E+2	3.0E+2	93 Np	1.0E+1	3.0E+1
45 Rh	1.0E+2	3.0E+2	94 Pu	3.0E+2	1.0E+2
46 Pd	3.0E+2	2.0E+3	95 Am	3.6E+2	1.0E+2
47 Ag	3.5E+2	2.0E+2	96 Cm	4.6E+2	1.0E+3
48 Cd	5.0E+3	1.0E+4	98 Cf	5.0E+2	1.0E+3
49 In	1.0E+4	1.0E+4			
50 Sn	5.0E+4	1.0E+4			

(a) Concentration ratios for the following elements are not included in the GENII documentation and are not included above: O, Mg, K, Nd, Re, Os, and Au.

Table 2.13. Concentration Ratios for Molluscs, as Compiled in GENII (Na88)^(a) (Bq/kg per Bq/L)

Z and Element	Saltwater	Freshwater	Z and Element	Saltwater	Freshwater
02 He	1.0E+0	1.0E+0	51 Sb	1.2E+3	1.0E+2
04 Be	1.0E+4	5.0E+1	52 Te	1.0E+3	6.1E+3
06 C	2.0E+4	9.0E+3	53 I	5.0E+1	1.0E+2
07 N	1.0E+0	1.0E+0	55 Cs	3.0E+1	5.0E+2
09 F	4.0E+0	1.0E+2	56 Ba	2.0E+1	2.0E+2
11 Na	3.0E-0	1.0E+2	57 La	1.0E+2	1.0E+3
14 Si	5.0E+4	1.0E+4	58 Ce	5.0E+2	1.0E+3
15 P	4.5E+4	1.0E+5	59 Pr	1.0E+3	1.0E+3
16 S	4.0E+0	1.0E+2	61 Pm	5.0E+3	3.0E+3
17 Cl	1.0E+0	5.0E+1	62 Sm	5.0E+3	3.0E+3
20 Ca	1.0E+0	2.0E+3	63 Eu	7.0E+3	3.0E+3
21 Sc	1.0E+2	1.0E+3	64 Gd	5.0E+3	5.0E+3
24 Cr	1.1E+3	2.0E+3	65 Tb	3.0E+3	1.0E+3
25 Mn	6.0E+3	1.0E+5	66 Dy	5.0E+3	5.0E+3
26 Fe	3.0E+4	1.0E+2	67 Ho	1.0E+3	3.0E+3
27 Co	3.0E+3	2.0E+3	68 Er	5.0E+2	1.0E+3
28 Ni	5.0E+2	5.0E+2	72 Hf	3.0E+3	3.0E+3
29 Cu	5.0E+3	4.0E+2	73 Ta	3.0E+3	3.0E+3
30 Zn	3.0E+4	1.0E+4	74 W	1.0E+2	1.0E+1
31 Ga	1.0E+4	1.0E+4	77 Ir	1.0E+2	2.0E+2
33 As	3.0E+2	3.0E+2	80 Hg	1.0E+4	2.0E+4
34 Se	6.0E+3	2.0E+3	81 Tl	5.0E+3	5.0E+3
35 Br	1.0E+1	3.3E+2	82 Pb	1.0E+3	5.0E+2
37 Rb	2.0E+2	1.0E+3	83 Bi	1.0E+3	1.0E+5
38 Sr	4.0E+1	1.0E+2	84 Po	1.0E+4	2.0E+4
39 Y	1.0E+3	1.0E+3	88 Ra	1.0E+2	1.0E+3
40 Zr	5.0E+1	5.0E+1	89 Ac	1.0E+3	1.0E+3
41 Nb	5.0E+1	5.0E+1	90 Th	1.0E+3	1.0E+2
42 Mo	2.0E+1	1.0E+2	91 Pa	1.0E+1	3.0E+1
43 Tc	2.0E+1	1.0E+2	92 U	3.0E+1	1.0E+2
44 Ru	2.0E+3	3.0E+2	93 Np	1.5E+2	3.0E+1
45 Rh	1.0E+2	3.0E+2	94 Pu	3.0E+3	1.0E+2
46 Pd	3.0E+2	2.0E+3	95 Am	2.9E+2	1.0E+2
47 Ag	5.8E+2	2.0E+2	96 Cm	4.6E+2	1.0E+3
48 Cd	1.0E+4	1.0E+4	98 Cf	2.0E+3	1.0E+3
49 In	1.0E+4	1.0E+4			
50 Sn	5.0E+4	1.0E+4			

(a) Concentration ratios for the following elements are not included in the GENII documentation and are not included above: O, Mg, K, Nd, Re, Os, and Au.

Table 2.14. Concentration Ratios for Water Plants, as Compiled in GENII (Na88)^(a) (Bq/kg per Bq/L)

Z and Element	Saltwater	Freshwater	Z and Element	Saltwater	Freshwater
02 He	1.0E+0	1.0E+0	51 Sb	1.0E+2	1.0E+3
04 Be	1.0E+4	2.0E+2	52 Te	4.0E+2	1.0E+2
06 C	1.8E+3	4.5E+3	53 I	1.5E+3	3.0E+2
07 N	1.0E+0	1.0E+0	55 Cs	7.0E+2	1.0E+3
09 F	1.0E+0	2.0E+0	56 Ba	1.0E+2	5.0E+2
11 Na	1.0E+0	1.0E+2	57 La	3.0E+2	5.0E+3
14 Si	5.0E+4	5.0E+4	58 Ce	5.0E+3	4.0E+3
15 P	1.0E+5	5.0E+5	59 Pr	1.0E+3	5.0E+3
16 S	5.0E+0	1.0E+0	61 Pm	3.0E+3	5.0E+3
17 Cl	1.0E+0	5.0E+1	62 Sm	5.0E+3	5.0E+3
20 Ca	5.0E+1	1.0E+3	63 Eu	5.0E+3	5.0E+3
21 Sc	1.0E+3	1.0E+4	64 Gd	1.0E+0	1.0E+0
24 Cr	4.0E+4	4.0E+4	65 Tb	1.0E+3	5.0E+3
25 Mn	1.0E+4	1.0E+4	66 Dy	1.0E+0	1.0E+0
26 Fe	5.0E+4	1.0E+3	67 Ho	5.0E+3	5.0E+3
27 Co	4.0E+2	1.0E+3	68 Er	5.0E+3	4.0E+3
28 Ni	3.0E+3	5.0E+2	72 Hf	1.0E+0	1.0E+0
29 Cu	1.0E+3	2.0E+3	73 Ta	1.0E+0	1.0E+0
30 Zn	5.0E+4	2.0E+4	74 W	1.0E+2	1.2E+3
31 Ga	1.0E+0	1.0E+0	77 Ir	1.0E+2	2.0E+2
33 As	3.0E+2	3.0E+2	80 Hg	3.4E+4	3.4E+4
34 Se	1.0E+3	1.0E+2	81 Tl	1.0E+0	1.0E+0
35 Br	1.0E+1	5.0E+1	82 Pb	5.0E+4	2.0E+3
37 Rb	1.0E+3	1.0E+3	83 Bi	1.0E+4	1.5E+3
38 Sr	3.0E+2	3.0E+3	84 Po	1.0E+3	2.0E+3
39 Y	3.0E+2	5.0E+3	88 Ra	1.0E+3	3.0E+4
40 Zr	5.0E+3	5.0E+3	89 Ac	1.0E+3	1.0E+4
41 Nb	5.0E+2	5.0E+2	90 Th	2.0E+3	3.0E+3
42 Mo	1.0E+2	1.0E+3	91 Pa	5.0E+1	3.0E+2
43 Tc	5.0E+3	5.0E+3	92 U	1.0E+3	9.0E+2
44 Ru	1.0E+3	2.0E+3	93 Np	6.0E+0	3.0E+2
45 Rh	1.0E+2	2.0E+2	94 Pu	3.6E+3	8.9E+2
46 Pd	2.0E+4	2.0E+3	95 Am	2.9E+3	3.0E+3
47 Ag	1.0E+3	1.0E+3	96 Cm	4.3E+4	1.0E+4
48 Cd	1.0E+3	5.0E+2	98 Cf	5.0E+3	5.0E+3
49 In	1.0E+0	1.0E+0			
50 Sn	5.0E+4	5.0E+4			

(a) Concentration ratios for the following elements are not included in the GENII documentation and are not included above: O, Mg, K, Nd, Re, Os, and Au.

2.6 Poultry

The N, F, S, K, Re, Os, Au, Bi, and Po transfer factors for feed-to-poultry are derived from the geometric mean of the other available transfer factors in their respective groups. The Cr, Rh, Ta, W, and Ir poultry transfer factors are set equal to a single established value in their respective chemical groups. The transfer factors for Ga, In, Tl, Si, Sn, and Pb are based on the greatest value (most conservative) of the next periodic table group (VA) of elements. For poultry, this resulted in a value of 0.8 being assigned to the missing values. All the lanthanide elements are assigned the value for Ce. Those actinides without a value are assigned the value for Am.

2.7 Milk

The Ta, Hf, and Cf transfer factors for feed-to-milk are set equal to the values from Nb, Zr, and Am, respectively. All the lanthanides are based on Ce values. All other values are based on the recommended values in a compilation document.

2.8 Egg

The N, F, S, Cl, Sc, As, Re, Os, Hg, Bi, Po, and Ra transfer factors for feed-to-eggs are calculated as the geometric mean of the established transfer factors in their respective chemical groups. The Cr, Rh, Ag, Hf, Ta, W, Ir, and Au transfer factors for eggs are based on a single established value in their respective groups. The transfer factors for Ga, In, Tl, Si, Sn, and Pb are based on the greatest value (most conservative) for the next group (VA) of elements. For eggs, this results in a value of 1.0 being assigned to the missing values. All the lanthanide elements are assigned the value for Ce. Those actinides without a value are assigned the value for Am.

2.9 Freshwater Fish

Most of the water-to-fish transfer factors are available from one of the compilations. However, values for all lanthanides are based on Ce.

2.10 Saltwater Fish, Crustaceans, Molluscs, and Water Plants

Four additional types of transfer factors are all derived from GENII 1.485 (Na88) without current updating. These are the transfer factors for saltwater fish, fresh and saltwater crustaceans, fresh and saltwater molluscs, and fresh and saltwater plants. All transfer factors in these tables come from the GENII 1.485 data files. For marine species, the GENII 1.485 values in Napier et al. (1988) are largely traceable back to *A Model for the Approximate Calculation of Safe Rates of Discharge of Radioactive Wastes into Marine Environments* (Fr67). Specifically for freshwater environments, the parameters are ultimately traceable to *Concentration Factors of Chemical Elements in Edible Aquatic Organisms* (Th72), which in turn is primarily derived from Ng's (Ng68) *Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere*.

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Appendix A

List of the Elements

List of Elements

Atomic Number	Symbol	Name	Atomic Number	Symbol	Name	Atomic Number	Symbol	Name
1	H	hydrogen	38	Sr	strontium	75	Re	rhenium
2	He	helium	39	Y	yttrium	76	Os	osmium
3	Li	lithium	40	Zr	zirconium	77	Ir	iridium
4	Be	beryllium	41	Nb	niobium	78	Pt	platinum
5	B	boron	42	Mo	molybdenum	79	Au	gold
6	C	carbon	43	Tc	technetium	80	Hg	mercury
7	N	nitrogen	44	Ru	ruthenium	81	Tl	thallium
8	O	oxygen	45	Rh	rhodium	82	Pb	lead
9	F	fluorine	46	Pd	palladium	83	Bi	bismuth
10	Ne	neon	47	Ag	silver	84	Po	polonium
11	Na	sodium	48	Cd	cadmium	85	At	astatine
12	Mg	magnesium	49	In	indium	86	Rn	radon
13	Al	aluminum	50	Sn	tin	87	Fr	francium
14	Si	silicon	51	Sb	antimony	88	Ra	radium
15	P	phosphorus	52	Te	tellurium	89	Ac	actinium
16	S	sulfur	53	I	iodine	90	Th	thorium
17	Cl	chlorine	54	Xe	xenon	91	Pa	protactinium
18	Ar	argon	55	Cs	cesium	92	U	uranium
19	K	potassium	56	Ba	barium	93	Np	neptunium
20	Ca	calcium	57	La	lanthanum	94	Pu	plutonium
21	Sc	scandium	58	Ce	cerium	95	Am	americium
22	Ti	titanium	59	Pr	praseodymium	96	Cm	curium
23	V	vanadium	60	Nd	neodymium	97	Bk	berkelium
24	Cr	chromium	61	Pm	promethium	98	Cf	californium
25	Mn	manganese	62	Sm	samarium	99	Es	einsteinium
26	Fe	iron	63	Eu	europium	100	Fm	fermium
27	Co	cobalt	64	Gd	gadolinium	101	Md	mendelevium
28	Ni	nickel	65	Tb	terbium	102	No	nobelium
29	Cu	copper	66	Dy	dysprosium	103	Lr	lawrencium
30	Zn	zinc	67	Ho	holmium	104	Rf	rutherfordium
31	Ga	gallium	68	Er	erbium	105	Ha	hafnium
32	Ge	germanium	69	Tm	thulium	106	Sg	seaborgium
33	As	arsenic	70	Yb	ytterbium	107	Ns	nielsbohrium
34	Se	selenium	71	Lu	lutetium	108	Hs	hassium
35	Br	bromine	72	Hf	hafnium	109	Mt	meitnerium
36	Kr	krypton	73	Ta	tantalum			
37	Rb	rubidium	74	W	tungsten			

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