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DOE STANDARD

DERIVED CONCENTRATION TECHNICAL STANDARD

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EXECUTIVE SUMMARY

Derived Concentration Standards (DCS) are quantities used in the design and conduct of radiological environmental protection programs at Department of Energy (DOE) facilities and sites. These quantities represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving 1 millisievert (mSv) (100 millirem (mrem)) effective dose following continuous exposure for one year for each of the following pathways: ingestion of water, submersion in air, and inhalation. DCSs were last published by DOE in 1993 in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. Since that publication, the radiation protection framework on which DCSs are based has evolved with more sophisticated biokinetic and dosimetric information provided by the International Commission on Radiological Protection (ICRP), thus enabling consideration of age and gender. The purpose of this standard is to establish DCS values reflecting the current state of knowledge and practice in radiation protection. These DCSs are based on age-specific effective dose coefficients, revised gender-specific physiological parameters for the Reference Man (ICRP 2002), and the latest information on the energies and intensities of radiations emitted by radionuclides (ICRP 2008). This standard addresses some nuclides encountered at accelerator facilities that were not addressed in previous DOE directives and guidance.

1. INTRODUCTION

This standard supports the implementation of Department of Energy (DOE) Order 458.1, *Radiation Protection of the Public and the Environment*. Derived Concentration Standards (DCS) are radiological quantities used in the design and conduct of radiological environmental protection programs at DOE facilities and sites. These quantities provide reference values to control effluent releases from DOE facilities and may be used in implementing the as low as reasonably achievable (ALARA) process for environmental programs.

This standard establishes the numerical values of DCSs in a manner reflecting the current state of knowledge and practice in radiation protection. DCSs were last published by DOE in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993). Since that 1993 publication, radiation protection, as reflected in publications of the International Commission on Radiological Protection (ICRP), has evolved to include more sophisticated biokinetic and dosimetric models which account for the dependence of radiation effects on age and gender. The DCSs of this standard are based on age-specific effective dose coefficients computed in the manner of ICRP Publication 72 (ICRP 1996) and Federal Guidance Report 13 (EPA 1999), using revised gender-specific physiological parameters for members of the public set forth in ICRP Publication 89 (ICRP 2002), and the nuclear decay data of ICRP Publication 107 (ICRP 2008). This standard also addresses radionuclides encountered at accelerator facilities.

The previously labeled derived concentration guides were based on dose coefficients and physiological parameters for the adult worker, which represented the best available information in the early 1990s. In this standard, DCSs are derived using age-specific effective dose coefficients for Reference Persons of the public and age- and gender- dependent intake rates for ingestion of water and inhalation of air. The members of the public are represented by six age subgroups (Newborn, 1-year, 5-year, 10-year, 15-year, and Adult). The analysis weights the effective dose coefficients for each subgroup by their fractional representation in the U.S. population and their intake of the radionuclide through inhalation, ingestion, or air submersion. This procedure is described in greater detail in Chapter 2. The single-value nature of the resultant DCSs — with respect to each pathway and radionuclide — enables them to be effectively and consistently applied in radiological environmental protection programs at DOE facilities and sites. These DCS values are all based on the same annual effective dose [i.e., 1 mSv (100 mrem)].

The DCSs presented in this standard account for three discrete exposure pathways — ingested water or inhaled air or air submersion — and do not include other potentially significant pathways that might be present in the environs of a specific facility. A complete pathway analysis, such as described by Yu *et al.* (2001), is required for calculating public radiation doses.

Consistent with DOE Policy 441.1, *Department of Energy Radiological Health and Safety Policy*, this

1.1. DOSE QUANTITIES

The dosimetric system of the ICRP Publication 60 (1991) involves three dosimetric quantities, which are briefly described below.

a. Absorbed dose. Absorbed dose, D, is the basic physical dose quantity defined as the quotient of mean energy imparted to a volume by the mass of the volume. The volume can be differential and thus the quantity can be defined at a point (see glossary). The quantity is applicable to all types of ionizing radiations and to any material. The SI unit is the gray (Gy)(J kg^{-1}). The conventional unit of absorbed dose is the rad (1 rad = 0.01 Gy).

b. Equivalent dose. Equivalent dose, H_T, is a radiation protection quantity specific to an organ or tissue of the body. Equivalent dose is based on the mean absorbed dose in the volume of an organ or tissue, T, due to radiation of type, R, modified by a radiation weighting factor for that radiation, w_R. The w_R-modified absorbed dose due to each radiation type is then summed (see glossary) and the resultant sum is called equivalent dose. The w_R-weighting attempts to put the various radiations, R, on a common scale without consideration of the particular organ or tissue being irradiated. The radiation weighting factors used in this standard are those of ICRP Publication 60 (ICRP 1991) and are given in Table 1. The SI unit of equivalent dose is the sievert (Sv)(J kg^{-1}). The conventional unit of equivalent dose is the rem (1 rem = 0.01 Sv).

Table 1: Radiation Weighting Factors, w_R (ICRP 1991)

Radiation type and energy	w_R
Photons, all energies	1
Electrons, all energies	1
Neutrons, energy < 10 keV	5
10 to 100 keV	10
100 keV to 2 MeV	20
2 MeV to 20 MeV	10
> 20 MeV	5
Alpha particles, fission fragments	20

c. Effective dose. The effective dose, E, introduced in ICRP Publication 60 (ICRP 1991), is the primary radiation protection quantity and is a weighted sum of the equivalent doses in the various organs and tissues of the body. The tissue weighting factors, w_T, reflect the relative radiosensitivities of the various organs and tissues of the body from stochastic effects (cancer and

Table 2: Tissue Weighting Factors, w_T (ICRP 1991)

Organ/Tissue	
Gonads	w_T
Colon[a], lungs, red marrow, stomach	0.20
Bladder, breast, liver, esophagus, thyroid, remainder[b])	0.12
Bone surface, skin	0.05
a) Defined as the upper and lower large intestine.	0.01
b) The remainder includes adrenals, brain, extrathoric airways (added to list of remainder tissue in ICRP Publication 68) (ICRP 1994b), small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. The dose to the remainder is computed as the mass weighted average dose to its members. If a member receives the highest dose then the dose to the remainder is computed as the arithmetic average of the dose to the highly irradiated tissue and the mass weighted average dose to the other members of the remainder.	

The tissue weighting factors are based on nominal risk coefficients for radiation-induced cancer and genetic effects with consideration of life lost, lethality, and loss of quality of life. The factors are gender-averaged and are used for assessment of effective dose for workers and members of the public. Thus, the effective dose is not specific to any particular individual, but applies to a Reference Person.

1.2. REFERENCE INDIVIDUAL AND REFERENCE PERSON

The radiation protection quantities equivalent dose and effective dose are not measurable quantities, and their values must be derived by applying dosimetric coefficients to measured or predicted concentrations of radionuclides in the workplace or the environment. Such coefficients are established for Reference Individuals (e.g., Reference Male and Reference Female), based on detailed anatomical and physiological information. ICRP first tabulated such information for Standard Man in ICRP Publication 2 (ICRP 1960), extended that information to include children and both genders in the Reference Man concept of ICRP Publication 23 (ICRP 1975), and more recently updated and further expanded the information in ICRP Publication 89 (ICRP 2002). These ICRP publications detail, for radiation protection purposes, the

2. METHODOLOGY

2.1. DERIVED CONCENTRATION STANDARDS FOR AIR AND WATER

The DCSs set forth in this standard for the public are derived using age-specific effective dose coefficients coupled with information on the age and gender structure of the U.S. population and age and gender specific intake of air and water. The age and gender structure of the U.S. population is based on the U.S. Census 2000. This information, along with age- and gender-dependent daily air intakes reported in ICRP Publication 89 (ICRP 2002), and the daily total intake of water (Roseberry and Burnmaster 1992) are listed in Table 3. The first column of Table 3 lists the reference age subgroups for which dose coefficients have been developed, and the second column defines by age range the population subgroup to which these coefficients apply (ICRP 1996). The third and fourth columns note the fraction of the U.S. population in each subgroup; the remaining columns list by age and gender the daily intakes of air and water.

The water intake data of Table 3 are based on the data of Roseberry and Burnmaster (1992) which have been interpreted[1] to correspond to the age ranges of column 2. These values are the total daily water intake (median value) and represent water drunk as a beverage, water added in preparation of food and beverage, and water intrinsic in food. The gender dependence in the intake introduced at ages 12 and higher assumes that the female intake is 75 percent of the male intake (ICRP 2002).

Table 3: U.S. Population and Usage Data

Reference Age Groups	Age x, (y)	Population fraction		Daily Intake			
				Air (m^3)		Water (L)	
		Male	Female	Male	Female	Male	Female
Newborn	0 ≤ x < 1	0.00693	0.00660	4.15	4.15	1.07	1.07
1-y	1 ≤ x < 3	0.01383	0.01321	5.89	5.89	1.12	1.12
5-y	3 ≤ x < 7	0.02864	0.02731	9.00	9.08	1.27	1.27
10-y	7 ≤ x < 12	0.03814	0.03632	15.2	15.0	1.50	1.50
15-y	12 ≤ x < 17	0.03672	0.03482	20.0	15.8	2.02	1.52
Adult	x ≥ 17	0.36630	0.39118	22.2	17.7	2.29	1.71

Age-specific effective dose coefficients were calculated using the DCAL System (Eckerman *et al*. 2006) , the nuclear decay data of ICRP Publication 107 (ICRP 2008), and the dosimetric and biokinetic models of the ICRP with the exceptions[2] noted in Federal Guidance Report 13 (EPA 1999). The effective dose coefficients for each age subgroup of the U.S. population are tabulated in Tables A-1, A-2, and A-3 of Appendix A. The DCAL System was used in the preparation of Federal Guidance Report 13 (EPA 1999)

2.2. CALCULATION OF DCS FOR WATER INGESTION

The DCS for water ingestion, DCS_{ing}, is computed as

$$DCS_{ing} = \frac{E}{t \sum_{i=1,6} (f_i^M U_{ing,i}^M + f_i^F U_{ing,i}^F) EC_{ing,i}} \quad (1)$$

where E is the constraint on the annual effective dose (0.001 Sv), $EC_{ing,\,i}$ is the effective dose coefficient for ingestion intakes of the radionuclide by Reference Person of subgroup i (Sv Bq^{-1} ingested activity), f_i^M and f_i^F are the fractions of the U.S. population in age subgroup i for males and female, respectively, and $U_{ing,i}^M$ and $U_{ing,i}^F$ are the daily intakes of water (L) by age subgroup i for males and females, respectively. The duration of the intake, t, is 365 days. The fractions of the U.S. population and daily water intakes in each subgroup are given in Table 3. The age-specific effective dose coefficients used in the calculation are given in Table A-1 of Appendix A.

The DCS_{ing} values are given in Table 5 for each chemical form, represented by the f_1 value, considered in Federal Guidance Report 13 (EPA 1999). The f_1 values shown in Table 5 apply to infants and may differ from values for other age groups. For radionuclides with multiple f_1 values, the chemical forms associated with the f_1 values are listed following the data for the radioisotopes of the element. If specific information on the chemical form (applicable f_1) is lacking, then the most restrictive DCS should be used.

2.3. CALCULATION OF DCS FOR INHALATION

The DCS for air inhalation, DCS_{inh}, is computed as

$$DCS_{inh} = \frac{E}{t \sum_{i=1,6} (f_i^M U_{inh,i}^M + f_i^F U_{inh,i}^F) EC_{inh,i}} \quad (2)$$

where E is the constraint on the annual effective dose (0.001 Sv), $EC_{inh,\,i}$ is the effective dose coefficient for inhalation intakes of the radionuclide by Reference Person of subgroup i (Sv Bq^{-1} inhaled activity), f_i^M and f_i^F are the fractions of the U.S. population in age subgroup i for males and female, respectively, and $U_{inh,i}^M$ and $U_{inh,i}^F$ are the daily intakes of air (m^3) by age subgroup i for males and females, respectively. The duration of the intake, t, is 365 days. The fractions of the U.S. population and daily air intakes in each subgroup are given in Table 3. The age-specific effective dose coefficients used in the calculation are given in Table A-2 of Appendix A.

The DCS_{inh} values are given in Table 5 for all absorption types (F, M, or S) defined by the ICRP (ICRP 1994a). Table 4 lists the classification of absorption types for particulate aerosols. For some radionuclides,

2.4. CALCULATION OF DCS FOR AIR SUBMERSION

The air submersion DCS, DCS_{sub}, for a given radionuclide is calculated as

$$DCS_{sub} = \frac{E}{t\ ERC} \tag{3}$$

where E is the constraint on the annual effective dose (0.001 Sv), ERC is the effective dose rate coefficient for a Reference Person (Sv m^3 Bq^{-1} s^{-1}), and the duration of the exposure, t, is 1 year or 3.16×10^7 seconds. The calculation assumes continuous, nonshielded exposure via submersion in a semi-infinite atmospheric cloud containing the radionuclide. The effective dose rate coefficients used to calculate the DCSs for air submersion were calculated in the manner of Federal Guidance Report 12 (EPA 1993) using the information in ICRP Publication 107 (ICRP 2008) on the energies and intensities of the radiations emitted by nuclides. The effective dose rate coefficients used in the calculation can be found in Table A-3 of Appendix A. The effective dose rate coefficients of Table A-3 are those for the adult in unshielded exposure geometry, and little variation (up to 20 percent) is expected with age (Yamaguchi 1994).

The DCS_{sub} values are given in Table 6. The radionuclides of Table 6 represent the following three classes:

- The first class of radionuclides includes noble gases and short-lived activation products that occur in gaseous form. For these radionuclides, inhalation doses are negligible compared to the external dose from submersion in an atmospheric cloud.

- The second class includes those radionuclides for which the DCS_{inh} has been calculated, but the DCS_{sub} for external exposure in the contaminated atmosphere is more restrictive than DCS_{inh} (i.e., $DCS_{sub} < DCS_{inh}$). These radionuclides generally have half-lives of a few hours or less, or are eliminated from the body following inhalation sufficiently rapidly to limit the inhalation dose.

- The third class includes radionuclides with half-lives less than 10 minutes; thus, their intake by inhalation is not considered. These radionuclides typically undergo energetic decay emitting high-energy photons.

A few noble gas radionuclides do not emit radiations of sufficient energy to penetrate the dead layer of the skin and thus their effective dose rate coefficient is determined by assuming the air within the lungs has equilibrated with the atmospheric concentration of the radionuclide. Further details regarding this calculation are given in Table A-3.

Table 4: Classification of Absorption Types for Particulates

Element	Lung absorption Type(s)[a]	Element	Lung absorption Type(s)[a]	Element	Lung absorption Type(s)[a]
Hydrogen	F, M[b], S	Zirconium	F, M[b], S	Lutetium[c]	F[d], M, S
Beryllium[c]	F[d], M, S	Niobium	F, M[b], S	Hafnium[c]	F, M, S[d]
Carbon	F, M[b], S	Molybdenum	F, M[b], S	Tantalum[c]	F[d], M, S
Fluorine[c]	F, M, S	Technetium	F, M[b], S	Tungsten[c]	F, M[d], S[d]
Sodium[c]	F, M[d], S[d]	Ruthenium	F, M[b], S	Rhenium[c]	F, M, S[d]
Magnesium[c]	F, M, S[d]	Rhodium[c]	F, M, S	Osmium[c]	F, M, S
Aluminum[c]	F, M. S[d]	Palladium[c]	F, M, S	Iridium[c]	F, M, S
Silicon[c]	F, M, S	Silver	F, M[b], S	Platinum[c]	F, M[d], S[d]
Phosphorus[c]	F, M, S[d]	Cadmium[c]	F, M, S	Gold[c]	F, M, S
Sulfur	F, M[b], S	Indium[c]	F, M, S[d]	Mercury[c]	F, M, S
Chlorine[c]	F, M, S[d]	Tin[c]	F, M, S[d]	Thallium[c]	F, M[d], S[d]
Potassium[c]	F, M[d], S[d]	Antimony	F, M[b], S	Lead	F, M[b], S
Calcium	F, M[b], S	Tellurium	F, M[b], S	Bismuth[c]	F, M, S[d]
Scandium[c]	F[d], M[d], S	Iodine	F[b], M, S	Polonium	F, M[b], S
Titanium[c]	F, M, S	Cesium	F[b], M, S	Astatine[c]	F, M, S[d]
Vanadium[c]	F, M, S[d]	Barium	F, M[b], S	Francium[c]	F, M[d], S[d]
Chromium[c]	F, M, S	Lanthanum[c]	F, M, S[d]	Radium	F, M[b], S
Manganese[c]	F, M, S[d]	Cerium	F, M[b], S	Actinium[c]	F, M, S
Iron	F, M[b], S	Praseodymium[c]	F[d], M, S	Thorium	F, M, S[b]
Cobalt	F, M[b], S	Neodymium[c]	F[d], M, S	Protactinium[c]	F[d], M, S
Nickel	F, M[b], S	Promethium[c]	F, M, S	Uranium	F, M[b], S
Copper[c]	F, M, S	Samarium[c]	F[d], M, S[d]	Neptunium	F, M[b], S
Zinc	F, M[b], S	Europium[c]	F[d], M, S[d]	Plutonium	F, M[b], S
Gallium[c]	F, M, S[d]	Gadolinium[c]	F, M, S[d]	Americium	F, M[b], S
Germanium[c]	F, M, S[d]	Terbium[c]	F[d], M, S[d]	Curium	F, M[b], S
Arsenic[c]	F[d], M, S[d]	Dysprosium[c]	F[d], M, S[d]	Berkelium[c]	F[d], M, S[d]
Selenium	F[b], M, S	Holmium[c]	F[d], M, S[d]	Californium[c]	F[d], M, S[d]
Bromine[c]	F, M, S[d]	Erbium[c]	F[d], M, S[d]	Einsteinium[c]	F[d], M, S[d]
Rubidium[c]	F, M[d], S[d]	Thulium[c]	F[d], M, S[d]	Fermium[c]	F[d], M, S[d]
Strontium	F, M[b], S	Ytterbium[c]	F[d], M, S		

3. RESULTS

DCSs for water and air are presented in Table 5 and those for air submersion in Table 6. The DCSs are based on an annual effective dose of 1 mSv (100 mrem). Inhalation DCSs are tabulated for particulate aerosols classified in terms of absorption types F, M, and S (ICRP 1994a). Radionuclides associated with particulate matter of Type F undergo fast dissolution with a high level of absorption to blood; Type M represent an intermediate rate of dissolution and an intermediate level of absorption to blood; and Type S represent slow dissolution and a low level of absorption to blood. Ideally, the applicable DCS_{inh} would be based on information on the chemical form or absorption type of the material expected to be released to the environment. Guidance provided in ICRP Publication 72 (ICRP 1996) regarding a suitable default absorption type is provided in Table 4.

The DCS entries in Table 5 for water include a measure of the fractional absorption from the gut, the f_1 value. For radionuclides with multiple f_1 values, information on the chemical forms to be associated with the f_1 values is presented following the listing of all radioisotopes of the element. In instances of multiple f_1 values, ideally the applicable DCS would be based on the chemical form expected to be released to the environment. If such information is not available then the most restrictive DCS_{ing} for the radionuclide should be assumed.

The air submersion DCSs of Table 6 are based on an effective dose of 1 mSv (100 mrem) from an annual exposure. In addition to noble gases and short-lived particulate radionuclides, this table includes some radionuclides for which the submersion DCS was more limiting than the inhalation DCS for its most restrictive chemical form or absorption type.

Inhalation DCS are established only for radionuclides of half-life greater than 10 minutes and the DCS includes the contribution to dose of any decay product(s) formed within the body without regard to the physical half-life of the decay product(s). The numerical values of the DCSs in the tabulations are given to two significant figures. This level of precision is provided only to minimize numerical errors as the tabulated values are converted to different units or used in further calculations. The result of any numerical calculations involving DCSs should be rounded, at the end of the computations, to a single significant figure following conventional numerical rounding procedures.

Changes in the DCSs between this 2009 evaluation and the 1993 evaluation can be attributed to three modifications made in the methodology: incorporating age and gender dependence into the dose coefficients and physiological parameters; incorporating more sophisticated biokinetic and dosimetric models of the ICRP; and incorporating the latest publication of nuclear decay data also from the ICRP.

As expected, the introduction of the latest nuclear decay data had a minimal effect on the DCSs. However, the updated data did enable consideration of a larger number of radionuclides, particularly

While the introduction of age and gender dependence into the dose coefficients and physiological parameters allowed for a much better representation of the members of the public, it did not have a substantial effect on the DCSs. The reason for this is twofold; the higher dose coefficients at the younger ages are tempered by their lower daily intakes and the U.S. population distribution for which 74 percent of the population falls into the adult subgroup.

The most significant change in the DCSs resulted from the incorporation of the more sophisticated biokinetic and dosimetric models of the ICRP. For example, the latest biokinetic model for bone-surface-seeking radionuclides, such as the actinides, considers a movement of the radionuclide into the volume of the bone mineral not included in the previous biokinetic model, which leads to a decrease in the dose coefficient (Leggett and Eckerman 2003). Therefore, DCSs for the actinides have increased substantially. There was little change in DCSs for air submersion; however, many additional radionuclides were added to the tabulations due to the inclusion of radionuclides of half-lives between 1 and 10 minutes in ICRP Publication 107 (ICRP 2008). Some of these radionuclides are specific to accelerators at DOE facilities.

4. DISCUSSION

4.1. INTENDED USES OF DCSs

The DCSs are intended to provide guidance for the design and conduct of radiological environmental protection programs at DOE facilities and sites. A use of the DCSs for water, DCS_{ing}, is directed in DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011), in establishing criteria for use of best available technology (BAT) for liquid effluent streams. The DCSs for inhalation of air, $\mathrm{DCS}_{\mathrm{inh}}$, and air submersion, DCS_{sub}, while not directed by the Order, are presented here for completeness and general guidance in ALARA considerations. The limitations of the DCSs are discussed in the next section. In summary, the intended applications are as follows:

- Defining criteria for applying BAT at point of discharge for liquid effluent streams (DOE Order 458.1);
- Relative ranking of the importance of radionuclides within a waste stream; and
- Relative ranking of multiple effluent streams to air or water.

4.2. APPLICATION TO MIXTURES OF RADIONUCLIDES

DCSs are given for individual radionuclides. For known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding DCS must not exceed 1.0. Note that the result of the mixture calculation should be rounded to two significant figures.

4.3. LIMITATIONS

The DCSs are developed with consideration of only three exposure modes (ingestion of water, inhalation of air, and air submersion). While they provide relative guidance for the ranking of potential radionuclides in effluent streams released from facilities, they are not intended to be used to infer the dose to members of the public nor to demonstrate compliance with DOE radiation protection dose limits. The DCSs are derived at the point of discharge and do not account for attenuation along the pathway before reaching the receptor. Typically, more complex environmental pathways are involved; thus, a complete pathway analysis is required for calculating public radiation doses resulting from DOE activities. Often such pathway analysis, such as described by Yu *et al*. (2001), is required by the legally applicable rules and regulations of other Federal, State, and local agencies for which DOE activities also must demonstrate compliance.

5. CONCLUSIONS

This standard provides DCSs based on current radiation protection practices as guidelines for controlling exposure to members of the public. The guidelines are based on the effective dose used currently in radiation protection and defined for Reference Persons in the population. This approach enabled consideration of age and gender attributes for the population subgroups while still resulting in a single-valued quantity suitable for DOE's regulatory framework. This single-valued DCS quantity — with respect to each pathway and radionuclide — can be effectively and consistently applied to design and implementation of radiological environmental protection programs for DOE radiological activities throughout the DOE Complex.

Table 5: Derived Concentration Standards for Members of the Public from Ingested Water and Inhaled Air

	Ingested water, DCS			Inhaled air, DCS					
				Type F		Type M		Type S	
	f_1	(Bq/L)	(µCi/mL)	(Bq/m^3)	(µCi/mL)	(Bq/m^3)	(µCi/mL)	(Bq/m^3)	(µCi/mL)
Hydrogen									
H-3	1.0E+00 [(a)]	7.0E+04	1.9E-03	2.3E+04	6.1E-07	2.8E+03	7.6E-08	5.2E+02	1.4E-08
	1.0E+00 [(b)]	3.2E+04	8.6E-04				Water Vapor	7.8E+03	2.1E-07
	(a) Tritiated Water						Elemental	7.8E+07	2.1E-03
	(b) Organic Bound Tritium						Organic	3.4E+03	9.3E-08
Beryllium									
Be-7	2.0E-02	4.2E+04	1.1E-03	3.4E+03	9.3E-08	2.6E+03	7.1E-08	2.4E+03	6.4E-08
Be-10	2.0E-02	9.4E+02	2.5E-05	2.0E+01	5.5E-10	1.4E+01	3.9E-10	4.1E+00	1.1E-10
Carbon									
C-11	1.0E+00	4.7E+04	1.3E-03	1.2E+04	3.1E-07	7.2E+03	1.9E-07	6.9E+03	1.9E-07
							Monoxide	1.1E+05	2.9E-06
							Dioxide	5.9E+04	1.6E-06
C-14	1.0E+00	2.3E+03	6.2E-05	6.9E+02	1.9E-08	6.8E+01	1.8E-09	2.5E+01	6.6E-10
							Monoxide	1.5E+05	4.1E-06
							Dioxide	2.2E+04	6.1E-07
Fluorine									
F-18	1.0E+00	2.3E+04	6.3E-04	4.6E+03	1.2E-07	2.4E+03	6.5E-08	2.3E+03	6.1E-08
Sodium									
Na-22	1.0E+00	3.8E+02	1.0E-05	1.0E+02	2.7E-09	1.4E+01	3.7E-10	4.8E+00	1.3E-10
Na-24	1.0E+00	2.7E+03	7.2E-05	4.4E+02	1.2E-08	2.7E+02	7.3E-09	2.6E+02	7.0E-09
Magnesium									
Mg-28	1.0E+00	5.2E+02	1.4E-05	2.0E+02	5.4E-09	1.1E+02	2.9E-09	1.0E+02	2.7E-09
Aluminum									
Al-26	2.0E-02	3.2E+02	8.6E-06	1.1E+01	3.1E-10	7.0E+00	1.9E-10	1.3E+00	3.6E-11

Table 5: Derived Concentration Standards for Members of the Public from Ingested Water and Inhaled Air (cont'd)

				Inhaled air, DCS					
	Ingested water, DCS			Type F		Type M		Type S	
	f_1	(Bq/L)	(μCi/mL)	(Bq/m^3)	(μCi/mL)	(Bq/m^3)	(μCi/mL)	(Bq/m^3)	(μCi/mL)
Silicon									
Si-31	2.0E-02	6.9E+03	1.9E-04	4.4E+03	1.2E-07	1.7E+03	4.7E-08	1.6E+03	4.4E-08
Si-32	2.0E-02	1.8E+03	4.9E-05	3.9E+01	1.0E-09	8.2E+00	2.2E-10	1.3E+00	3.5E-11
Phosphorus									
P-32	1.0E+00	4.3E+02	1.2E-05	1.5E+02	4.0E-09	3.9E+01	1.1E-09	3.4E+01	9.3E-10
P-33	1.0E+00	4.3E+03	1.2E-04	1.3E+03	3.5E-08	9.2E+01	2.5E-09	7.7E+01	2.1E-09
Sulfur									
S-35	1.0E+00 (c)	8.4E+03	2.3E-04	2.4E+03	6.4E-08	9.6E+01	2.6E-09	7.4E+01	2.0E-09
	1.0E+00 (d)	1.4E+03	3.8E-05				Dioxide	1.2E+03	3.1E-08
							Carbon Disulfide	1.8E+02	4.7E-09
S-38	1.0E+00 (c)	3.4E+03	9.1E-05	9.2E+02	2.5E-08	4.5E+02	1.2E-08	4.3E+02	1.2E-08
	1.0E+00 (d)	4.2E+03	1.1E-04				Dioxide	6.7E+02	1.8E-08
	(c) Inorganic Sulfur						Carbon Disulfide	7.1E+02	1.9E-08
	(d) Organic Sulfur								
Chlorine									
Cl-34m	1.0E+00	1.1E+04	2.9E-04	4.6E+03	1.2E-07	2.9E+03	7.7E-08	2.7E+03	7.4E-08
Cl-36	1.0E+00	1.2E+03	3.2E-05	3.7E+02	9.9E-09	1.9E+01	5.1E-10	3.8E+00	1.0E-10
Cl-38	1.0E+00	9.4E+03	2.5E-04	4.8E+03	1.3E-07	2.8E+03	7.5E-08	2.6E+03	7.1E-08
Cl-39	1.0E+00	1.3E+04	3.5E-04	4.8E+03	1.3E-07	2.7E+03	7.4E-08	2.6E+03	7.0E-08
Potassium									
K-40	1.0E+00	1.8E+02	4.8E-06	5.8E+01	1.6E-09	9.7E+00	2.6E-10	1.7E+00	4.6E-11
K-42	1.0E+00	2.5E+03	6.7E-05	9.6E+02	2.6E-08	3.9E+02	1.1E-08	3.7E+02	1.0E-08
K-43	1.0E+00	4.6E+03	1.2E-04	8.8E+02	2.4E-08	3.7E+02	1.0E-08	3.5E+02	9.4E-09
K-44	1.0E+00	1.3E+04	3.6E-04	6.1E+03	1.6E-07	3.9E+03	1.1E-07	3.8E+03	1.0E-07
K-45	1.0E+00	2.3E+04	6.1E-04	9.1E+03	2.5E-07	6.0E+03	1.6E-07	5.7E+03	1.5E-07

Table 5: Derived Concentration Standards for Members of the Public from Ingested Water and Inhaled Air (cont'd)

	Ingested water, DCS			Inhaled air, DCS					
				Type F		Type M		Type S	
	f_1	(Bq/L)	(µCi/mL)	(Bq/m^3)	(µCi/mL)	(Bq/m^3)	(µCi/mL)	(Bq/m^3)	(µCi/mL)
Calcium									
Ca-41	6.0E-01	4.9E+03	1.3E-04	6.6E+02	1.8E-08	1.2E+03	3.2E-08	6.5E+02	1.8E-08
Ca-45	6.0E-01	1.4E+03	3.8E-05	2.6E+02	7.0E-09	5.0E+01	1.4E-09	3.8E+01	1.0E-09
Ca-47	6.0E-01	7.1E+02	1.9E-05	2.3E+02	6.1E-09	7.0E+01	1.9E-09	6.3E+01	1.7E-09
Scandium									
Sc-43	1.0E-03	5.0E+03	1.4E-04	2.1E+03	5.6E-08	1.1E+03	2.9E-08	1.0E+03	2.7E-08
Sc-44	1.0E-03	3.1E+03	8.4E-05	1.2E+03	3.3E-08	7.1E+02	1.9E-08	6.8E+02	1.8E-08
Sc-44m	1.0E-03	4.5E+02	1.2E-05	1.7E+02	4.6E-09	8.9E+01	2.4E-09	9.1E+01	2.5E-09
Sc-46	1.0E-03	7.8E+02	2.1E-05	2.0E+01	5.4E-10	2.3E+01	6.2E-10	2.0E+01	5.5E-10
Sc-47	1.0E-03	2.0E+03	5.3E-05	7.6E+02	2.1E-08	2.0E+02	5.5E-09	1.9E+02	5.0E-09
Sc-48	1.0E-03	6.9E+02	1.9E-05	2.0E+02	5.5E-09	1.2E+02	3.3E-09	1.2E+02	3.1E-09
Sc-49	1.0E-03	1.3E+04	3.6E-04	7.3E+03	2.0E-07	3.4E+03	9.2E-08	3.2E+03	8.7E-08
Titanium									
Ti-44	2.0E-02	2.0E+02	5.3E-06	2.2E+00	5.9E-11	3.2E+00	8.7E-11	1.1E+00	3.1E-11
Ti-45	2.0E-02	7.3E+03	2.0E-04	2.9E+03	7.8E-08	1.4E+03	3.9E-08	1.4E+03	3.7E-08
Vanadium									
V-47	2.0E-02	1.7E+04	4.7E-04	7.1E+03	1.9E-07	4.3E+03	1.2E-07	4.1E+03	1.1E-07
V-48	2.0E-02	5.8E+02	1.6E-05	1.3E+02	3.5E-09	5.5E+01	1.5E-09	4.9E+01	1.3E-09
V-49	2.0E-02	5.8E+04	1.6E-03	5.8E+03	1.6E-07	3.8E+03	1.0E-07	1.9E+03	5.1E-08
V-50	2.0E-02	3.9E+02	1.1E-05	2.3E+00	6.1E-11	5.1E+00	1.4E-10	5.4E+00	1.5E-10
Chromium									
Cr-48	2.0E-01	5.9E+03	1.6E-04	1.3E+03	3.6E-08	6.8E+02	1.8E-08	6.2E+02	1.7E-08
Cr-49	2.0E-01	1.8E+04	4.9E-04	6.6E+03	1.8E-07	3.8E+03	1.0E-07	3.6E+03	9.8E-08
Cr-51	2.0E-01	2.9E+04	7.9E-04	6.2E+03	1.7E-07	3.9E+03	1.1E-07	3.5E+03	9.4E-08

Table 5: Derived Concentration Standards for Members of the Public from Ingested Water and Inhaled Air (cont'd)

	Ingested water, DCS			Inhaled air, DCS Type F		Inhaled air, DCS Type M		Inhaled air, DCS Type S	
	f_1	(Bq/L)	(μCi/mL)	(Bq/m^3)	(μCi/mL)	(Bq/m^3)	(μCi/mL)	(Bq/m^3)	(μCi/mL)
Manganese									
Mn-51	2.0E-01	1.2E+04	3.2E-04	5.4E+03	1.5E-07	3.1E+03	8.3E-08	2.9E+03	7.9E-08
Mn-52	2.0E-01	6.5E+02	1.8E-05	1.3E+02	3.6E-09	9.5E+01	2.6E-09	9.1E+01	2.5E-09
Mn-52m	2.0E-01	1.6E+04	4.3E-04	6.6E+03	1.8E-07	4.4E+03	1.2E-07	4.2E+03	1.1E-07
Mn-53	2.0E-01	3.5E+04	9.5E-04	4.3E+03	1.2E-07	2.3E+03	6.3E-08	4.1E+02	1.1E-08
Mn-54	2.0E-01	1.6E+03	4.4E-05	1.5E+02	4.1E-09	8.5E+01	2.3E-09	4.2E+01	1.1E-09
Mn-56	2.0E-01	4.3E+03	1.2E-04	1.9E+03	5.1E-08	1.0E+03	2.8E-08	9.8E+02	2.6E-08
Iron									
Fe-52	6.0E-01	8.0E+02	2.2E-05	3.0E+02	8.1E-09	2.1E+02	5.6E-09	2.0E+02	5.3E-09
Fe-55	6.0E-01	2.7E+03	7.2E-05	1.7E+02	4.5E-09	3.4E+02	9.3E-09	7.2E+02	2.0E-08
Fe-59	6.0E-01	5.3E+02	1.4E-05	5.6E+01	1.5E-09	3.7E+01	9.9E-10	3.4E+01	9.2E-10
Fe-60	6.0E-01	9.9E+00	2.7E-07	5.1E-01	1.4E-11	1.0E+00	2.8E-11	2.8E+00	7.7E-11
Cobalt									
Co-55	6.0E-01	1.2E+03	3.1E-05	4.6E+02	1.3E-08	2.5E+02	6.8E-09	2.3E+02	6.3E-09
Co-56	6.0E-01	4.2E+02	1.1E-05	6.8E+01	1.8E-09	2.8E+01	7.5E-10	2.0E+01	5.5E-10
Co-57	6.0E-01	4.7E+03	1.3E-04	6.7E+02	1.8E-08	2.4E+02	6.6E-09	1.3E+02	3.6E-09
Co-58	6.0E-01	1.4E+03	3.9E-05	2.4E+02	6.4E-09	8.5E+01	2.3E-09	6.4E+01	1.7E-09
Co-58m	6.0E-01	4.7E+04	1.3E-03	2.4E+04	6.5E-07	9.6E+03	2.6E-07	7.8E+03	2.1E-07
Co-60	6.0E-01	2.7E+02	7.2E-06	2.5E+01	6.8E-10	1.3E+01	3.6E-10	4.6E+00	1.2E-10
Co-60m	6.0E-01	6.5E+05	1.7E-02	2.0E+05	5.4E-06	1.1E+05	3.0E-06	1.0E+05	2.7E-06
Co-61	6.0E-01	1.5E+04	3.9E-04	6.4E+03	1.7E-07	2.7E+03	7.3E-08	2.5E+03	6.8E-08
Co-62m	6.0E-01	2.3E+04	6.1E-04	8.8E+03	2.4E-07	6.2E+03	1.7E-07	6.0E+03	1.6E-07
Nickel									
Ni-56	1.0E-01	1.4E+03	3.7E-05	2.6E+02	7.0E-09	1.5E+02	4.0E-09	1.3E+02	3.4E-09
							Vapor	6.7E+02	1.8E-08