CLM-R299

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Dosimetric Data for FISPACT

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ABSTRACT

A complete set of dosimetric data has been compiled for all the radionuclides included in the data libraries associated with the fusion activation code FISPACT. Data contained in the existing literature have been used wherever possible. However, for some radionuclides it was necessary to estimate the appropriate values. The methodology adopted for estimation is also presented.

April 1990

1 Introduction

The neutrons produced from reactions within a fusion reactor will lead to the activation of elements within the component materials. As the presence of these radioactive materials poses a potential radiological hazard it is important to be able to predict the quantities produced. Because of the complex nature of such calculations and the large quantities of data required it is necessary to use large computer codes and data libraries to generate the desired information. FISPACT is the fusion activation code currently employed in the UK (1), UKACT1 is the associated cross-section library (2) and UKDECAY3 the associated decay and spectral data library.

The actual radiological impact of the activation products is obviously dependent upon the exposure routes which occur. It is possible, however, to generate values of parameters which are indicative of the potential radiological implications of the material considered. These are of particular significance when comparing materials. The parameters determined by FISPACT which fall into this category are: specific activities, surface dose rates, and radiological hazard potentials, RHP, associated with intake of the material by ingestion or inhalation. The latter, in Sv/kg, are defined as follows

$$(RHP)_{ing} = \sum_i A_i (CEDE_{ing})_i$$

$$(RHI)_{inh} = \sum_i A_i (CEDE_{inh})_i$$

where A_i is the specific activity of the radionuclide i in the material (Bq/kg), $CEDE_{ing}$ is the committed effective dose equivalent received by an adult following ingestion of unit activity of radionuclide i (Sv/Bq), and $CEDE_{inh}$ is the committed effective dose equivalent received by an adult following inhalation of unit activity of radionuclide i (Sv/Bq). The sum is taken over the radionuclides present. A detailed definition of the committed effective dose equivalent to an adult is given in reference 3.

With previous versions of the FISPACT data libraries it was not always possible to generate accurate values of RHP as values of $CEDE_{ing}$ and $CEDE_{inh}$ were not available for many of the radionuclides. To rectify this situation a complete set of dosimetric data has been compiled for all the radionuclides represented in the decay data library UKDECAY3.

2 Dosimetric data

For many of the radionuclides included in the data library UKDECAY3, values for $CEDE_{ing}$ and $CEDE_{inh}$ are to be found in reference 4. The data in reference 4 were generated using the basic dosimetry and metabolic models devised by the International Commission on Radiological Protection (ICRP), which are described in detail in the same reference. The method consists of the following steps. The

quantities of a radionuclide within each of the body organs through which it passes following intake, the 'source organs', and thus the number of radioactive decays occurring within each organ, are determined as a function of time using compartmental metabolic models. The compartments represent a body organ, a group of organs or part of an organ. The compartments through which the radionuclide passes, the rate of movement of activity between compartments and the rate of excretion from the body are determined by considering the metabolic characteristics of the element and basic decay data for the radionuclide. The effective dose rate received by each body organ ('target organ') irradiated by emissions from a source organ or organs, is then calculated, as a function of time, by considering such factors as the distance between the organs, the type and energy of emissions and attenuation by intervening organs. These effective dose rates are integrated over 50 years to yield the committed effective dose to each organ. These are then summed using the appropriate weighting factors (2) to determine the committed effective dose equivalent.

Additional dosimetric data are to be found in a publication of the National Radiological Protection Board (NRPB), reference 5. The data in reference 5 were also derived using the methodology described in reference 4, with a few minor alterations (6). For some additional radionuclides, dosimetric data were provided by the NRPB (7); these were derived in the same manner as those in reference 4.

The metabolic behaviour of an element following intake into the body is dependent upon the chemical form in which it exists. In references 4 and 5, to reflect this chemical variation, values of $CEDE$ for intake of radionuclides in various different chemical forms are given. In this work, for the majority of the radionuclides, the highest $CEDE$ values are quoted, ie. those determined assuming the worst chemical state. The only exceptions to this are Nickel and Cobalt. It is assumed that Nickel is not inhaled in the form of the vapour nickel carbonyl, and that Cobalt is not in the form of cyancobalamin on ingestion or inhalation.

Of the radionuclides for which dosimetric data could not be found, the majority had short half lives (less than 3 days) and, as such, would generally have little radiological impact. In the present work approximate values of $CEDE_{ing}$ and $CEDE_{inh}$ have been derived for each of these radionuclides by considering the dosimetric data for other radionuclides of the same element, or a chemically similar element, and scaling these values according to half lives and decay energies. The method is described in more detail in Appendix A.

A simple method was also derived for estimating dosimetric data for some very long lived alpha emitting radionuclides (half lives exceeding 10^{10} years), such as Sm-148, and this is also described in Appendix A.

Dosimetric data were also required for the noble gases. Values of $CEDE$ for noble gases have not previously been determined and presented in the literature. One reason for this is that for most radioactive noble gases it is considered that external doses arising from immersion in a cloud of the gas would be far greater than those from inhaling the gas, also it is not possible to produce a $(CEDE)_{ing}$ value for

direct ingestion of a gas. In fusion reactor materials, however, the noble gas atoms will be contained within a solid matrix. It is therefore possible to envisage scenarios in which ingestion and inhalation of noble gases contained in dust particles from the fusion materials occurs. Additionally, following disposal of fusion wastes in a repository, the processes of degradation of waste by groundwater may result in small quantities of noble gas dissolving in the water. This groundwater may be released into streams and rivers in the biosphere, and exposures arising from consumption of this water may need to be determined. To generate $CEDE$ values for the radioactive noble gases it was therefore assumed that they existed as solids. The method used for determining dosimetric data for the noble gases is described in more detail in Appendix A.

The dosimetric data for all the radionuclides included in UKDECAY3 are contained in Table 1. The values of $CEDE_{ing}$ and $CEDE_{inh}$ estimated using the methods described in Appendix A will usually be higher than would be the case if they had been generated using the more accurate methods (4,5). In general, if x is the value predicted using the approximate method, and z is the value predicted using the more exact method, then for the large majority of radionuclides x will lie somewhere in the range $0.1z$ to $100z$.

If in any future assessment of the radiological impact of fusion one of the radionuclides for which dosimetric data has been estimated seems to dominate the values of RHP predicted, then it is recommended that the values of $CEDE_{ing}$ and $CEDE_{inh}$ used be reviewed and if appropriate recalculated using a more rigorous approach.

3 REFERENCES

1. R A Forrest and D A J Endacott, FISPACT - User Manual, AERE-M-3654,1988.

2. R A Forrest, M G Sowerby, B H Patrick and D A J Endacott, The data library UKACT1 and the inventory code FISPACT, Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, Japan, 30 May - 3 June 1988, p1061.

3. International Commission on Radiological Protection, A compilation of the major concepts and quantities in use by ICRP, ICRP Publication 42 (1984), Pergamon Press, Oxford.

4. International Commission on Radiological Protection, Limits for Intakes of Radionuclides by Workers, ICRP Publication 30, Parts 1-3 (1979-1981) and Supplements to Parts 1-3 (1979-1982), Pergamon Press, Oxford.

5. G M Kendall, B W Kennedy, J R Greenhalgh, N Adams and T P Fell, Committed dose equivalent to selected organs and committed effective dose equivalent from intakes of radionuclides, NRPB-GS7(1987) (HMSO, London).

6. J R Greenhalgh, T P Fell and N Adams, Doses from intakes of radionuclides by adults and young people, NRPB-R162(1985) (HMSO, London).

7. G M Kendall, personal communication, National Radiological Protection Board, 1989.

Table 1: Dosimetric Data

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
H 3	1.23E1 y	1.7E-11	1.7E-11	4,5
He 6	8.08E2 ms	3.3E-14	1.5E-14	this work
Li 8	8.42E2 ms	1.1E-14	7.8E-15	this work
Li 9	1.78E2 ms	2.6E-15	1.8E-15	this work
Be 8	6.7E-14 ms	4.4E-31	4.5E-31	this work
Be 10	1.6E6 y	1.1E-9	9.3E-8	4,5
Be 11	1.38E1 s	3.3E-13	3.4E-13	this work
B 12	2.02E1 ms	3.5E-15	7.9E-15	this work
B 13	1.74E1 ms	3.1E-15	6.9E-15	this work
C 14	5.73E3 y	5.6E-10	5.6E-10	5
C 15	2.45 s	1.1E-13	1.1E-13	this work
N 13	9.97 m	6.3E-12	6.3E-12	this work
N 16	7.12 s	3.6E-13	3.6E-13	this work
N 17	4.17 s	5.1E-14	5.1E-14	this work
N 18	6.30E2 ms	4.1E-14	4.1E-14	this work
O 19	2.69E1 s	5.1E-13	5.1E-13	this work
F 18	1.83 h	2.8E-11	1.9E-11	4,5
F 20	1.10E1 s	1.5E-13	1.0E-13	this work
F 21	4.32 s	4.2E-14	2.8E-14	this work
F 22	4.23 s	1.1E-13	7.4E-14	this work
Ne 23	3.72E1 s	2.0E-12	9.4E-13	this work
Ne 24	3.38 m	7.2E-11	3.4E-11	this work
Ne 25	6.02E2 ms	9.1E-14	4.2E-14	this work
Na 21	2.25E1 s	1.0E-13	7.1E-14	this work
Na 22	2.60 y	3.1E-9	2.1E-9	5
Na 24	1.50E1 h	3.7E-10	2.6E-10	5
Na 24m	2.02E1 ms	2.3E-16	1.5E-16	this work
Na 25	5.96E1 s	2.5E-13	1.7E-13	this work
Na 26	1.08 s	1.3E-14	8.7E-15	this work
Na 27	3.04E2 ms	3.5E-15	2.4E-15	this work
Na 28	3.05E1 ms	7.2E-16	4.9E-16	this work
Mg 27	9.46 m	5.8E-12	2.9E-12	this work
Mg 28	2.09E1 h	2.0E-9	1.1E-9	4,5
Mg 29	1.09 s	4.8E-14	2.4E-14	this work
Al 25	7.18 s	4.8E-13	1.1E-12	this work
Al 26	7.20E5 y	3.4E-9	2.1E-8	4
Al 26m	6.35 s	4.2E-13	9.3E-13	this work
Al 28	2.24 m	1.1E-11	2.4E-11	this work
Al 29	6.56 m	2.5E-11	5.5E-11	this work
Al 30	3.65 s	5.7E-13	1.3E-12	this work
Al 31	6.44E2 ms	1.0E-13	2.2E-13	this work
Al 32	3.50E1 ms	6.0E-15	1.3E-14	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Si 31	2.62 h	1.5E-10	5.3E-11	4,5
Si 32	3.30E2 y	4.6E-10	2.7E-7	4
Si 33	6.11 s	6.3E-13	2.2E-13	this work
P 30	2.50 m	6.7E-12	6.4E-12	this work
P 32	1.43E1 d	2.1E-9	3.6E-9	4,5
P 33	2.54E1 d	2.4E-10	5.1E-10	4
P 34	1.24E1 s	5.9E-13	5.7E-13	this work
P 35	4.73E1 s	2.2E-12	2.1E-12	this work
P 36	5.9 s	7.7E-13	7.4E-13	this work
S 35	8.75E1 d	6.9E-10	6.1E-10	4,5
S 37	4.99 m	8.9E-11	3.4E-11	this work
S 38	2.84 h	4.3E-9	1.6E-9	this work
S 39	1.15E1 s	5.8E-12	2.2E-12	this work
Cl 34	1.53 s	3.8E-14	2.3E-14	this work
Cl 34m	3.21E1 m	6.1E-11	3.7E-11	this work
Cl 36	3.02E5 y	8.2E-10	5.5E-9	4,5
Cl 38	3.72E1 m	5.4E-11	3.3E-11	5
Cl 38m	7.70E2 ms	2.3E-14	1.4E-14	this work
Cl 39	5.56E1 m	3.7E-11	2.6E-11	4
Cl 40	1.35 m	3.6E-12	2.2E-12	this work
Cl 41	3.4E1 s	1.5E-12	9.2E-13	this work
Cl 42	6.8 s	3.6E-13	2.2E-13	this work
Ar 37	3.50E1 d	1.2E-11	9.9E-11	this work
Ar 39	2.69E2 y	2.4E-9	8.0E-8	this work
Ar 41	1.83 h	3.0E-10	1.4E-10	this work
Ar 42	3.3E1 y	2.1E-8	7.0E-7	this work
Ar 43	5.37 m	3.4E-11	1.6E-11	this work
Ar 44	1.19E1 m	1.2E-10	5.4E-11	this work
Ar 45	2.15E1 s	4.2E-12	2.0E-12	this work
Ar 46	8.3 s	2.0E-12	9.2E-13	this work
K 38	7.61 m	1.6E-11	8.1E-12	this work
K 38m	9.24E2 ms	2.5E-14	1.2E-14	this work
K 40	1.28E9 y	5.1E-9	3.4E-9	4
K 42	1.24E1 h	2.9E-10	2.9E-10	5
K 43	2.22E1 h	2.1E-10	1.5E-10	4,5
K 44	2.21E1 m	4.0E-11	2.0E-11	4
K 45	1.78E1 m	2.5E-11	1.2E-11	4
K 46	1.92 m	2.2E-12	1.1E-12	this work
K 47	1.75E1 s	7.1E-13	3.8E-13	this work
K 48	6.8 s	5.3E-13	2.6E-13	this work
Ca 41	1.03E5 y	3.8E-10	4.0E-10	5
Ca 45	1.63E2 d	8.1E-10	1.6E-9	5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Ca 47	4.54 d	1.6E-9	1.5E-9	4,5
Ca 49	8.72 m	1.4E-10	1.2E-10	4
Sc 42	6.81E2 ms	5.6E-14	2.1E-14	this work
Sc 42m	1.03 m	7.9E-12	3.0E-12	this work
Sc 43	3.89 h	1.9E-10	5.9E-11	4
Sc 44	3.93 h	3.6E-10	1.1E-10	4
Sc 44m	2.44 d	2.7E-9	1.9E-9	4
Sc 45m	3.16E2 ms	4.1E-17	1.5E-17	this work
Sc 46	8.38E1 d	1.5E-9	5.5E-9	4,5
Sc 46m	1.87E1 s	8.5E-14	4.3E-14	this work
Sc 47	3.4 d	5.2E-10	4.6E-10	5
Sc 48	1.82 d	1.7E-9	9.9E-10	4,5
Sc 49	5.72E1 m	6.6E-11	2.5E-11	4
Sc 50	1.71 m	5.3E-12	2.0E-12	this work
Sc 50m	3.5E2 ms	2.0E-14	7.5E-15	this work
Ti 44	4.73E1 y	5.7E-9	2.4E-7	5
Ti 45	3.08 h	1.6E-10	5.3E-11	4
Ti 51	5.76 m	4.9E-12	1.6E-12	this work
Ti 52	1.7 m	4.0E-12	1.3E-12	this work
V 47	3.26E1 m	4.3E-11	1.7E-11	4
V 48	1.6E1 d	2.1E-9	2.2E-9	5
V 49	3.3E2 d	1.5E-11	7.6E-11	4
V 52	3.75 m	1.0E-11	2.3E-11	this work
V 53	1.61 m	3.6E-12	7.8E-12	this work
V 54	4.98E1 s	5.1E-12	1.1E-11	this work
Cr 49	4.19E1 m	4.6E-11	1.6E-11	4
Cr 51	2.77E1 d	3.9E-11	7.3E-11	5
Cr 55	3.55 m	2.6E-12	1.2E-12	this work
Cr 56	5.94 m	1.3E-11	6.0E-12	this work
Cr 57	2.11E1 s	8.4E-13	3.9E-13	this work
Mn 51	4.62E1 m	6.7E-11	2.7E-11	4
Mn 52	5.59 d	1.9E-9	1.5E-9	4,5
Mn 52m	2.11E1 m	4.0E-11	1.5E-11	4,5
Mn 53	3.7E6 y	2.6E-11	1.1E-10	4
Mn 54	3.13E2 d	7.2E-10	1.7E-9	5
Mn 56	2.58 h	2.5E-10	8.8E-11	4,5
Mn 57	1.61 m	1.4E-12	5.7E-13	this work
Mn 58	1.09 m	3.3E-12	1.3E-12	this work
Mn 58m	3.0 s	1.0E-13	4.2E-14	this work
Mn 59	4.6 s	2.0E-13	8.3E-14	this work
Mn 60	1.79 s	1.2E-13	4.8E-14	this work
Fe 52	8.28 h	1.4E-9	5.4E-10	5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Fe 52m	4.59E1 s	8.6E-12	3.2E-12	this work
Fe 53	8.51 m	2.6E-11	8.6E-12	this work
Fe 53m	2.5 m	1.8E-11	6.0E-12	this work
Fe 55	2.7 y	1.6E-10	7.1E-10	5
Fe 59	4.51E1 d	1.8E-9	4.0E-9	4,5
Fe 60	3.0E5 y	4.2E-8	2.1E-7	4
Fe 61	5.98 m	2.5E-11	8.3E-12	this work
Fe 62	1.13 m	7.7E-12	2.6E-12	this work
Fe 63	4.9 s	7.0E-13	2.3E-13	this work
Co 54	1.93E2 ms	2.0E-14	2.9E-14	this work
Co 54m	1.46 m	1.2E-11	1.8E-11	this work
Co 55	1.75E1 h	1.1E-9	5.2E-10	4
Co 56	7.88E1 d	3.3E-9	7.1E-9	5
Co 57	2.71E2 d	3.1E-10	2.0E-9	4,5
Co 58	7.08E1 d	9.4E-10	1.9E-9	4,5
Co 58m	9.15 h	2.4E-11	2.1E-11	4,5
Co 60	5.27 y	7.0E-9	4.1E-8	4,5
Co 60m	1.05E1 m	9.4E-13	5.0E-13	4
Co 61	1.65 h	6.9E-11	2.4E-11	4
Co 62	1.5 m	6.8E-12	9.7E-12	this work
Co 62m	1.39E1 m	2.5E-11	8.6E-12	4
Co 63	2.74E1 s	1.1E-12	1.6E-12	this work
Co 64	3.0E2 ms	2.5E-14	3.5E-14	this work
Co 65	1.0 s	1.2E-13	1.7E-13	this work
Co 66	1.0 s	1.1E-13	1.7E-13	this work
Ni 56	6.1 d	9.7E-10	1.0E-9	4
Ni 57	1.5 d	9.0E-10	4.5E-10	4
Ni 59	7.495E4 y	5.6E-11	3.6E-10	5
Ni 63	1.0E2 y	1.5E-10	8.4E-10	5
Ni 65	2.52 h	1.6E-10	5.7E-11	5
Ni 66	2.28 d	3.0E-9	2.1E-9	4
Ni 67	1.8E1 s	3.4E-12	1.6E-12	this work
Ni 68	1.0 s	1.4E-13	6.5E-14	this work
Ni 69	1.0 s	1.2E-13	5.5E-14	this work
Cu 62	9.74 m	1.2E-11	7.6E-12	this work
Cu 64	1.27E1 h	1.2E-10	6.3E-11	5
Cu 66	5.1 m	3.1E-12	2.0E-12	this work
Cu 67	2.58 d	2.9E-10	2.9E-10	4,5
Cu 68	3.1E1 s	6.9E-13	4.5E-13	this work
Cu 68m	3.75 m	7.4E-12	4.8E-12	this work
Cu 69	3.0 m	2.4E-12	1.6E-12	this work
Cu 70	4.5 s	1.1E-13	7.1E-14	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Cu 70m	4.6E1 s	1.9E-12	1.2E-12	this work
Cu 71	1.95E1 s	6.9E-13	4.5E-13	this work
Cu 72	6.6 s	3.8E-13	2.8E-13	this work
Zn 63	3.81E1 m	5.3E-11	2.0E-11	4
Zn 65	2.44E2 d	3.9E-9	5.1E-9	5
Zn 69	5.7E1 m	2.3E-11	9.6E-12	4,5
Zn 69m	1.38E1 h	3.3E-10	1.9E-10	4,5
Zn 71	2.45 m	7.4E-12	4.2E-12	this work
Zn 71m	3.94 h	2.2E-10	7.9E-11	4
Zn 72	1.94 d	1.3E-9	1.1E-9	4
Zn 73	2.35E1 s	2.4E-12	1.3E-12	this work
Zn 74	1.583 m	1.7E-11	9.7E-12	this work
Ga 66	9.49 h	1.3E-9	4.7E-10	4
Ga 67	3.26 d	1.9E-10	1.3E-10	4,5
Ga 68	1.14 h	8.9E-11	3.3E-11	5
Ga 70	2.12E1 m	1.9E-11	7.8E-12	4
Ga 72	1.41E1 h	1.2E-9	4.6E-10	5
Ga 73	4.87 h	2.8E-10	9.1E-11	4
Ga 74	8.1 m	4.4E-11	1.8E-11	this work
Ga 74m	9.5 s	8.8E-13	3.6E-13	this work
Ga 75	2.17 m	5.8E-12	2.3E-12	this work
Ga 76	2.71E1 s	3.1E-12	1.2E-12	this work
Ga 77	1.32E1 s	1.4E-12	5.7E-13	this work
Ge 67	1.87E1 m	3.1E-11	1.5E-11	4
Ge 68	2.71E2 d	2.9E-10	1.3E-8	4,5
Ge 69	1.63 d	9.9E-11	1.7E-10	4
Ge 71	1.12E1 d	2.6E-12	3.2E-11	4,5
Ge 73m	5.0E2 ms	3.4E-16	6.2E-16	this work
Ge 75	1.38 h	2.0E-11	1.7E-11	4
Ge 75m	4.77E1 s	2.9E-13	5.2E-13	this work
Ge 77	1.13E1 h	1.5E-10	2.4E-10	4,5
Ge 77m	5.4E1 s	7.4E-13	1.4E-12	this work
Ge 78	1.45 h	5.6E-11	6.6E-11	4
Ge 79	3.9E1 s	7.1E-13	1.3E-12	this work
Ge 79m	3.9E1 s	1.6E-12	2.8E-12	this work
As 70	5.26E1 m	1.0E-10	2.7E-11	4
As 71	2.7 d	3.6E-10	2.9E-10	4
As 72	1.08 d	1.5E-9	9.3E-10	4
As 73	8.03E1 d	1.7E-10	8.3E-10	4,5
As 74	1.78E1 d	9.1E-10	1.8E-9	4,5
As 76	1.1 d	1.3E-9	9.1E-10	4,5
As 77	1.62 d	3.0E-10	2.6E-10	4,5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
As 78	1.51 h	1.7E-11	6.1E-11	4
As 79	9.01 m	6.0E-12	1.3E-11	this work
As 80	1.65E1 s	6.0E-13	1.3E-12	this work
As 81	3.3E1 s	9.8E-13	2.1E-12	this work
As 82	2.1E1 s	9.6E-13	2.1E-12	this work
As 82m	1.3E1 s	8.2E-13	1.7E-12	this work
Se 71	4.74 m	3.3E-11	1.3E-11	this work
Se 72	8.4 d	5.0E-9	4.3E-9	7
Se 73	7.15 h	4.2E-10	1.0E-10	4
Se 73m	3.98E1 m	4.0E-11	9.3E-12	4
Se 75	1.2E2 d	2.5E-9	2.2E-9	5
Se 77m	1.75E1 s	9.8E-14	3.7E-14	this work
Se 79	6.5E4 y	2.3E-9	2.4E-9	4,5
Se 79m	3.91 m	7.7E-13	3.0E-13	this work
Se 81	1.85E1 m	1.6E-11	6.4E-12	4
Se 81m	5.73E1 m	5.5E-11	1.9E-11	4
Se 83	2.25E1 m	4.0E-11	1.2E-11	4
Se 83m	1.17 m	6.0E-12	2.3E-12	this work
Se 84	3.25 m	2.7E-11	1.0E-11	this work
Br 75	1.617 h	3.6E-11	2.8E-11	4
Br 76	1.62E1 h	3.7E-10	3.1E-10	4
Br 76m	1.31 s	7.9E-14	3.6E-14	this work
Br 77	2.38 d	8.2E-11	6.8E-11	5
Br 77m	4.28 m	1.4E-12	8.0E-13	this work
Br 78	6.46 m	1.4E-11	6.2E-12	this work
Br 79m	4.86 s	1.8E-14	7.9E-15	this work
Br 80	1.74E1 m	1.5E-11	6.4E-12	4
Br 80m	4.42 h	6.2E-11	9.3E-11	4
Br 82	1.47 d	4.6E-10	3.4E-10	5
Br 82m	6.1 m	1.4E-11	7.9E-12	this work
Br 83	2.39 h	2.0E-11	2.2E-11	4
Br 84	3.18E1 m	4.1E-11	2.3E-11	4
Br 84m	6.0 m	2.4E-11	1.0E-11	this work
Br 85	2.87 m	3.4E-12	1.5E-12	this work
Br 86	5.5E1 s	5.1E-12	2.2E-12	this work
Kr 77	1.24 h	2.5E-10	1.3E-10	this work
Kr 79	1.46 d	7.1E-10	4.3E-10	this work
Kr 79m	5.0E1 s	4.5E-13	2.5E-13	this work
Kr 81	2.1E5 y	1.7E-10	6.1E-9	this work
Kr 81m	1.3E1 s	6.5E-14	3.0E-14	this work
Kr 83m	1.83 h	7.2E-12	3.3E-12	this work
Kr 85	1.07E1 y	2.8E-9	8.8E-8	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Kr 85m	4.48 h	1.8E-10	8.5E-11	this work
Kr 87	1.27 h	2.6E-10	1.2E-10	this work
Kr 88	2.84 h	1.3E-9	6.2E-10	this work
Rb 80	3.4E1 s	2.4E-12	8.0E-13	this work
Rb 81	4.58 h	3.5E-11	2.7E-11	4,5
Rb 81m	3.06E1 m	5.0E-12	4.1E-12	4
Rb 82	1.27 m	4.1E-12	1.4E-12	this work
Rb 82m	6.47 h	1.2E-10	7.6E-11	4
Rb 83	8.62E1 d	2.1E-9	1.3E-9	4
Rb 84	3.29E1 d	2.7E-9	1.8E-9	4
Rb 84m	2.03E1 m	1.2E-11	4.6E-12	this work
Rb 86	1.87E1 d	2.5E-9	1.8E-9	5
Rb 86m	1.02 m	8.4E-13	3.2E-13	this work
Rb 87	4.80E10 y	1.3E-9	8.7E-10	5
Rb 88	1.78E1 m	4.4E-11	2.1E-11	5
Rb 89	1.52E1 m	2.2E-11	9.9E-12	5
Rb 90	2.55 m	1.3E-11	4.5E-12	this work
Rb 90m	4.3 m	2.5E-11	8.4E-12	this work
Sr 81	2.22E1 m	6.0E-11	1.8E-11	4
Sr 82	2.56E1 d	5.8E-9	1.5E-8	7
Sr 83	1.35 d	6.1E-10	3.8E-10	4
Sr 83m	4.95 s	1.1E-13	2.5E-13	this work
Sr 85	6.48E1 d	5.3E-10	8.5E-10	5
Sr 85m	1.13 h	6.3E-12	2.1E-12	5
Sr 87m	2.81 h	3.3E-11	1.0E-11	4,5
Sr 89	5.05E1 d	2.3E-9	1.0E-8	4,5
Sr 90	2.91E1 y	3.3E-8	3.4E-7	5
Sr 91	9.52 h	8.1E-10	3.9E-10	5
Sr 92	2.71 h	5.1E-10	2.0E-10	5
Sr 93	7.32 m	3.8E-11	7.3E-11	this work
Sr 94	1.27 m	8.0E-12	1.5E-11	this work
Y 85	2.681 h	4.5E-10	8.6E-10	this work
Y 85m	4.861 h	8.9E-10	1.7E-9	this work
Y 86	1.47E1 h	1.1E-9	4.3E-10	4
Y 86m	4.8E1 m	6.4E-11	2.5E-11	4
Y 87	3.35 d	6.0E-10	4.3E-10	4,5
Y 87m	1.29E1 h	9.4E-10	2.4E-9	this work
Y 88	1.07E2 d	1.4E-9	5.7E-9	4
Y 89m	1.61E1 s	3.8E-13	7.2E-13	this work
Y 90	2.67 d	2.7E-9	2.2E-9	4,5
Y 90m	3.19 h	1.8E-10	1.2E-10	4
Y 91	5.85E1 D	2.4E-9	1.2E-8	4,5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Y 91m	4.97E1 m	1.0E-11	8.4E-12	4,5
Y 92	3.54 h	5.1E-10	1.7E-10	4,5
Y 93	1.01E1 h	1.2E-9	5.6E-10	4,5
Y 93m	8.2E2 ms	4.3E-14	8.2E-14	this work
Y 94	1.91E1 m	4.8E-11	1.8E-11	4
Y 95	1.03E1 m	2.6E-11	9.6E-12	4
Y 96	6.0 s	5.1E-13	9.6E-13	this work
Y 96m	1.0E1 s	1.5E-12	2.8E-12	this work
Y 96n	2.3 m	1.7E-11	3.3E-11	this work
Y 97	3.7 s	6.4E-13	1.2E-12	this work
Y 97m	1.21 s	2.2E-13	4.2E-13	this work
Zr 87	1.73 h	2.0E-10	3.4E-10	this work
Zr 87m	1.4E1 s	5.5E-13	9.0E-13	this work
Zr 88	8.34E1 d	3.6E-10	6.1E-9	4
Zr 89	3.27 d	8.3E-10	5.7E-10	4
Zr 89m	4.18 m	8.5E-12	1.8E-11	this work
Zr 90m	8.3E2 ms	3.6E-14	5.4E-14	this work
Zr 93	1.53E6 y	4.2E-10	8.7E-8	5
Zr 95	6.4E1 d	9.2E-10	5.1E-9	5
Zr 97	1.69E1 h	2.2E-9	1.1E-9	4,5
Zr 98	3.07E1 s	1.7E-12	2.5E-12	this work
Nb 89	1.1 h	1.2E-10	3.6E-11	4
Nb 89m	2.03 h	2.7E-10	8.7E-11	4
Nb 90	1.46E1 h	1.3E-9	5.8E-10	4
Nb 90m	1.88E1 s	1.2E-12	6.8E-13	this work
Nb 91	6.8E2 y	4.7E-11	3.9E-9	7
Nb 91m	6.2E1 d	3.8E-10	2.0E-9	7
Nb 92	3.5E7 y	1.1E-9	3.8E-8	7
Nb 92m	1.02E1 d	5.6E-10	5.5E-10	7
Nb 93m	1.64E1 y	1.2E-10	7.7E-9	4,5
Nb 94	2.03E4 y	1.7E-9	8.9E-8	5
Nb 94m	6.26 m	2.5E-13	1.3E-13	this work
Nb 95	3.52E1 d	6.0E-10	1.2E-9	5
Nb 95m	3.61 d	5.5E-10	6.0E-10	4
Nb 96	2.34E1 h	1.2E-9	5.5E-10	4
Nb 97	1.20 h	6.1E-11	1.9E-11	5
Nb 97m	1.0 m	1.6E-12	8.7E-13	this work
Nb 98	2.8 s	8.3E-14	4.5E-14	this work
Nb 98m	5.15E1 m	9.3E-11	2.8E-11	4
Nb 99	1.43E1 s	4.2E-13	2.4E-13	this work
Nb 99m	2.6 m	5.5E-12	3.1E-12	this work
Nb 100	3.1 s	1.8E-13	9.9E-14	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Nb 100m	1.5 s	7.7E-14	4.1E-14	this work
Mo 91	1.55E1 m	4.0E-11	2.1E-11	this work
Mo 91m	1.09 m	5.0E-12	2.6E-12	this work
Mo 93	3.5E3 y	3.0E-10	7.5E-9	5
Mo 93m	6.85 h	3.1E-10	9.6E-11	4
Mo 99	2.75 d	1.2E-9	9.9E-10	4,5
Mo 101	1.46E1 m	2.5E-11	9.7E-12	4,5
Mo 102	1.12E1 m	2.8E-11	1.5E-11	this work
Mo 103	1.13 m	4.4E-12	2.4E-12	this work
Mo 104	1.0 m	4.8E-12	2.5E-12	this work
Tc 94	4.88 h	1.6E-10	7.3E-11	4
Tc 94m	5.2E1 m	6.8E-11	3.2E-11	4
Tc 95	2.0E1 h	1.2E-10	6.7E-11	4
Tc 95m	6.1E1 d	3.8E-10	6.8E-10	7
Tc 96	4.28 d	7.3E-10	6.3E-10	5
Tc 96m	5.15E1 m	8.5E-12	5.6E-12	5
Tc 97	2.6E6 y	4.0E-11	2.3E-10	5
Tc 97m	8.9E1 d	2.9E-10	1.1E-9	4,5
Tc 98	4.2E6 y	1.3E-9	4.5E-9	4
Tc 99	2.13E5 y	3.5E-10	2.0E-9	5
Tc 99m	6.02 h	1.6E-11	8.7E-12	4,5
Tc 100	1.58E1 s	3.7E-13	6.2E-13	this work
Tc 101	1.42E1 m	1.0E-11	4.2E-12	4
Tc 102	5.28 s	1.8E-13	3.0E-13	this work
Tc 102m	4.35 m	1.5E-11	2.4E-11	this work
Tc 103	5.0E1 s	9.4E-13	1.6E-12	this work
Tc 104	1.82E1 m	4.5E-11	1.8E-11	4
Tc 105	7.6 m	2.4E-11	4.0E-11	this work
Tc 106	3.6E1 s	2.6E-12	4.4E-12	this work
Ru 95	1.64 h	1.6E-10	1.1E-10	this work
Ru 97	2.9 d	1.7E-10	1.1E-10	4,5
Ru 103	3.94E1 d	7.4E-10	2.1E-9	5
Ru 105	4.44 h	2.8E-10	1.1E-10	4,5
Ru 106	1.01 y	5.8E-9	1.2E-7	4,5
Ru 107	3.75 m	6.3E-12	4.4E-12	this work
Ru 108	4.5 m	9.9E-12	6.9E-12	this work
Ru 109	3.45E1 s	1.9E-12	1.3E-12	this work
Ru 109m	1.29E1 s	1.1E-12	7.9E-13	this work
Ru 110	1.26E1 s	5.2E-13	3.6E-13	this work
Rh 98	8.7 m	3.7E-11	6.9E-11	this work
Rh 98m	3.5 m	1.6E-11	2.9E-11	this work
Rh 99	1.6E1 d	5.5E-10	7.0E-10	4

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Rh 99m	4.7 h	7.4E-11	2.3E-11	4
Rh 100	2.08E1 h	8.4E-10	3.7E-10	4
Rh 100m	4.7 m	1.8E-11	3.7E-11	this work
Rh 101	3.3 y	6.1E-10	8.6E-9	4
Rh 101m	4.34 d	2.4E-10	1.8E-10	4
Rh 102	2.9 y	2.3E-9	2.3E-8	4
Rh 102m	2.07E2 d	9.5E-10	1.1E-8	4
Rh 103m	5.61E1 m	3.1E-12	1.2E-12	5
Rh 104	4.23E1 s	9.8E-13	1.8E-12	this work
Rh 104m	4.34 m	6.8E-12	1.3E-11	this work
Rh 105	1.47 d	3.7E-10	2.4E-10	5
Rh 105m	4.5E1 s	3.2E-13	6.9E-13	this work
Rh 106	2.98E1 s	1.1E-12	2.1E-12	this work
Rh 106m	2.17 h	1.6E-10	5.3E-11	4
Rh 107	2.17E1 m	1.4E-11	5.7E-12	4
Rh 108	1.68E1 s	9.1E-13	1.7E-12	this work
Rh 108m	5.9 m	2.6E-11	4.9E-11	this work
Rh 109	1.33 m	3.0E-12	5.7E-12	this work
Rh 110	3.0 s	1.7E-13	3.1E-13	this work
Rh 110m	2.85E1 s	2.3E-12	4.3E-12	this work
Rh 111	1.1E1 s	7.7E-13	1.5E-12	this work
Rh 112	8.0E2 ms	1.2E-13	2.4E-13	this work
Pd 99	2.14E1 m	6.7E-11	4.3E-11	this work
Pd 100	3.63 d	1.0E-9	1.0E-9	4
Pd 101	8.47 h	1.0E-10	4.5E-11	4
Pd 103	1.7E1 d	1.9E-10	3.8E-10	5
Pd 107	6.5E6 y	3.8E-11	3.4E-9	5
Pd 107m	2.13E1 s	1.3E-13	7.9E-14	this work
Pd 109	1.34E1 h	5.9E-10	2.9E-10	5
Pd 109m	4.69 m	4.9E-12	3.1E-12	this work
Pd 111	2.34E1 m	4.0E-11	2.7E-11	this work
Pd 111m	5.5 h	8.6E-10	5.6E-10	this work
Pd 112	2.11E1 h	4.2E-9	2.9E-9	this work
Pd 113	1.66 m	6.6E-12	4.1E-12	this work
Pd 113m	1.48 m	1.1E-11	7.1E-12	this work
Pd 114	2.45 m	1.1E-11	7.0E-12	this work
Ag 103	1.1 h	3.7E-11	1.4E-11	4
Ag 103m	5.7 s	1.4E-13	9.3E-14	this work
Ag 104	1.15 h	6.1E-11	1.9E-11	4
Ag 104m	3.35E1 m	4.1E-11	1.4E-11	4
Ag 105	4.13E1 d	5.2E-10	1.2E-9	5
Ag 105m	7.23 m	5.0E-13	5.3E-13	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Ag 106	2.4E1 m	2.1E-11	7.5E-12	4
Ag 106m	8.46 d	1.7E-9	2.0E-9	4
Ag 107m	4.43E1 s	8.4E-14	5.7E-14	this work
Ag 108	2.37 m	1.8E-12	1.2E-12	this work
Ag 108m	1.27E2 y	2.0E-9	5.4E-8	5
Ag 109m	3.96E1 s	7.1E-14	4.8E-14	this work
Ag 110	2.46E1 s	6.0E-13	4.1E-13	this work
Ag 110m	2.5E2 d	2.9E-9	1.4E-8	4,5
Ag 111	7.45 d	1.2E-9	1.6E-9	5
Ag 111m	1.08 m	2.0E-13	2.2E-13	this work
Ag 112	3.14 h	4.3E-10	1.7E-10	4
Ag 113	5.37 h	3.3E-10	2.2E-10	this work
Ag 113m	1.15 m	1.5E-12	1.0E-12	this work
Ag 114	4.6 s	2.0E-13	1.4E-13	this work
Ag 114m	2.0 m	1.1E-11	7.2E-12	this work
Ag 115	2.0E1 m	4.2E-11	1.7E-11	4
Ag 115m	1.8E1 s	9.1E-13	6.8E-13	this work
Ag 116	2.64 m	1.2E-11	8.1E-12	this work
Ag 116m	1.05E1 s	6.5E-13	4.4E-13	this work
Cd 105	5.55E1 m	2.0E-10	3.8E-10	this work
Cd 107	6.5 h	6.7E-11	2.7E-11	4
Cd 109	1.27 y	3.2E-9	2.8E-8	4,5
Cd 111m	4.86E1 m	4.4E-11	8.4E-11	this work
Cd 113	9.3E15 y	4.3E-8	4.2E-7	4
Cd 113m	1.41E1 y	4.0E-8	3.8E-7	5
Cd 115	2.23 d	1.3E-9	1.0E-9	4,5
Cd 115m	4.46E1 d	4.2E-9	1.8E-8	4,5
Cd 117	2.49 h	2.9E-10	1.2E-10	4
Cd 117m	3.36 h	3.0E-10	1.1E-10	4
Cd 118	5.03E1 m	2.6E-10	5.0E-10	this work
Cd 119	2.69 m	2.2E-11	4.1E-11	this work
Cd 119m	2.2 m	2.1E-11	4.0E-11	this work
Cd 120	5.08E1 s	8.9E-12	1.7E-11	this work
Cd 121	1.25E1 s	2.4E-12	4.6E-12	this work
Cd 121m	8.3 s	1.7E-12	3.2E-12	this work
Cd 122	5.78 s	9.5E-13	1.8E-12	this work
Cd 123	3.8 s	8.9E-13	1.7E-12	this work
In 110	1.15 h	8.9E-11	3.0E-11	4
In 110m	4.9 h	2.7E-10	8.1E-11	4
In 111	2.83 d	3.3E-10	2.1E-10	4,5
In 111m	7.7 m	1.1E-11	2.9E-11	this work
In 112	1.44E1 m	5.8E-12	2.2E-12	4

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
In 112m	2.09E1 m	4.5E-11	9.7E-11	this work
In 113m	1.66 h	2.7E-11	9.2E-12	4,5
In 114	1.2 m	1.3E-12	2.9E-12	this work
In 114m	4.95E1 d	4.0E-9	2.1E-8	5
In 115	5.1E14 y	3.8E-8	9.3E-7	4
In 115m	4.49 h	9.1E-11	3.2E-11	4,5
In 116	1.41E1 s	4.7E-13	1.0E-12	this work
In 116m	5.42E1 m	5.6E-11	1.7E-11	4
In 116n	2.16 s	1.5E-13	3.3E-13	this work
In 117	4.38E1 m	2.4E-11	8.0E-12	4
In 117m	1.94 h	1.1E-10	4.0E-11	4
In 118	5.0 s	2.5E-13	5.3E-13	this work
In 118m	4.45 m	2.1E-11	4.6E-11	this work
In 118n	8.5 s	7.1E-13	1.5E-12	this work
In 119	2.4 m	4.8E-12	1.0E-11	this work
In 119m	1.8E1 m	2.7E-11	1.1E-11	4
In 120	4.44E1 s	4.2E-12	9.0E-12	this work
In 120m	3.08 s	2.0E-13	4.3E-13	this work
In 121	2.31E1 s	1.1E-12	2.4E-12	this work
In 121m	3.88 m	9.4E-12	2.1E-11	this work
In 122	1.5 s	1.1E-13	2.3E-13	this work
In 122m	1.0E1 s	1.1E-12	2.4E-12	this work
In 122n	1.08E1 s	9.5E-13	2.1E-12	this work
In 123	5.97 s	3.5E-13	7.7E-13	this work
In 123m	4.78E1 s	2.4E-12	5.2E-12	this work
In 124	3.2 s	3.7E-13	8.0E-13	this work
In 124m	2.4 s	3.2E-13	6.8E-13	this work
In 125	2.33 s	1.8E-13	4.2E-13	this work
In 125m	1.22E1 s	8.2E-13	1.9E-12	this work
In 126	1.5 s	1.9E-13	4.1E-13	this work
In 126m	1.45 s	2.2E-13	4.7E-13	this work
Sn 111	3.53E1 m	1.9E-11	6.0E-12	4
Sn 113	1.15E2 d	7.4E-10	2.4E-9	4,5
Sn 113m	2.0E1 m	4.3E-13	1.6E-12	this work
Sn 117m	1.4E1 d	7.1E-10	9.3E-10	4
Sn 119m	2.93E2 d	3.3E-10	1.4E-9	5
Sn 121	1.13 d	2.3E-10	1.3E-10	4
Sn 121m	5.0E1 y	3.7E-10	2.4E-9	5
Sn 123	1.29E2 d	2.1E-9	8.1E-9	4,5
Sn 123m	4.01E1 m	2.9E-11	1.1E-11	4
Sn 125	9.64 d	3.0E-9	3.9E-9	4,5
Sn 125m	9.52 m	1.6E-11	2.5E-11	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Sn 126	1.0E5 y	4.7E-9	2.3E-8	4,5
Sn 127	2.1 h	2.0E-10	7.3E-11	4
Sn 127m	4.13 m	1.3E-11	2.3E-11	this work
Sn 128	5.91E1 m	1.4E-10	5.0E-11	4
Sn 128m	6.5 s	1.5E-12	2.4E-12	this work
Sn 129	2.4 m	1.8E-11	2.7E-11	this work
Sn 129m	6.9 m	5.6E-11	8.7E-11	this work
Sn 130	3.72 m	2.9E-11	4.6E-11	this work
Sn 130m	1.7 m	1.5E-11	2.3E-11	this work
Sb 116	1.58E1 m	1.5E-11	5.0E-12	4
Sb 116m	1.0 h	6.6E-11	2.0E-11	4
Sb 117	2.8 h	2.0E-11	6.2E-12	4
Sb 118	3.6 m	7.1E-12	3.0E-12	this work
Sb 118m	5.0 h	2.5E-10	6.9E-11	4
Sb 119	1.59 d	9.2E-11	5.1E-11	4
Sb 120	1.59E1 m	8.2E-12	3.1E-12	4
Sb 120m	5.76 d	1.4E-10	1.0E-9	4
Sb 122	2.7 d	1.7E-9	1.3E-9	4,5
Sb 122m	4.2 m	3.4E-12	2.1E-12	this work
Sb 124	6.02E1 d	2.6E-9	5.6E-9	5
Sb 124m	1.55 m	9.3E-13	4.7E-13	this work
Sb 124n	2.02E1 m	5.4E-12	2.3E-12	4
Sb 125	2.73 y	7.0E-10	2.6E-9	4,5
Sb 126	1.24E1 d	2.7E-9	2.7E-9	4
Sb 126m	1.9E1 m	2.0E-11	7.4E-12	4
Sb 126n	1.1E1 s	4.7E-13	2.0E-13	this work
Sb 127	3.85 d	1.8E-9	1.5E-9	4,5
Sb 128	9.01 h	8.5E-10	2.8E-10	5
Sb 128m	1.04E1 m	1.4E-11	3.7E-12	4
Sb 129	4.32 h	4.7E-10	1.5E-10	5
Sb 129m	1.77E1 m	4.9E-11	2.1E-11	this work
Sb 130	6.3 m	2.6E-11	1.1E-11	this work
Sb 130m	4.0E1 m	6.9E-11	2.2E-11	4,5
Sb 131	2.3E1 m	6.9E-11	3.4E-11	5
Sb 131m	1.67E1 m	1.1E-10	4.7E-11	this work
Sb 132	2.8 m	1.7E-11	8.6E-11	this work
Sb 132m	4.2 m	2.5E-11	1.3E-11	this work
Te 117	1.03 h	9.7E-10	1.0E-9	this work
Te 117m	1.03E2 ms	3.1E-14	3.2E-14	this work
Te 118	6.0 d	3.5E-8	6.9E-8	this work
Te 119	1.61E1 h	6.1E-9	6.7E-9	this work
Te 119m	4.69 d	7.9E-10	5.7E-10	7

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Te 121	1.68E1 d	4.1E-10	4.4E-10	4
Te 121m	1.54E2 d	1.8E-9	3.5E-9	4
Te 123	1.0E13 y	1.1E-9	2.8E-9	4
Te 123m	1.2E2 d	1.4E-9	2.5E-9	4,5
Te 125m	5.8E1 d	9.2E-10	1.9E-9	5
Te 127	9.35 h	1.8E-10	7.8E-11	4,5
Te 127m	1.09E2 d	2.2E-9	5.3E-9	5
Te 129	1.16 h	5.2E-11	2.1E-11	5
Te 129m	3.36E1 d	2.7E-9	5.5E-9	4,5
Te 131	2.5E1 m	5.1E-11	2.7E-11	5
Te 131m	1.25 d	1.5E-9	1.2E-9	5
Te 132	3.26 d	2.0E-9	1.9E-9	5
Te 133	1.25E1 m	4.1E-11	2.1E-11	5
Te 133m	5.54E1 m	1.8E-10	9.3E-11	5
I 122	3.62 m	3.9E-10	1.1E-10	this work
I 123	1.32E1 h	1.2E-10	6.8E-11	5
I 124	4.18 d	8.4E-9	5.1E-9	4
I 125	6.01E1 d	9.2E-9	5.8E-9	5
I 126	1.30E1 d	1.7E-8	1.1E-8	5
I 128	2.5E1 m	2.3E-11	1.2E-11	4
I 129	1.57E7 y	6.6E-8	4.2E-8	5
I 130	1.24E1 h	1.2E-9	6.7E-10	4
I 130m	9.0 m	1.3E-9	3.6E-10	this work
I 131	8.04 d	1.3E-8	8.0E-9	5
I 132	2.3 h	1.4E-10	8.5E-11	5
I 132m	1.39 h	1.3E-10	7.0E-11	4
I 133	2.08E1 h	2.5E-9	1.3E-9	5
I 133m	9.0 s	2.1E-11	6.1E-12	this work
I 134	5.26E1 m	5.0E-11	2.9E-11	5
I 134m	3.7 m	6.9E-10	1.9E-10	this work
I 135	6.61 h	4.8E-10	2.8E-10	5
I 136	1.4 m	3.2E-10	9.0E-11	this work
I 136m	4.5E1 s	1.7E-10	4.7E-11	this work
Xe 123	2.08 h	2.0E-10	9.5E-11	this work
Xe 125	1.7E1 h	4.6E-10	2.7E-10	this work
Xe 125m	5.7E1 s	8.1E-13	4.2E-13	this work
Xe 127	3.64E1 d	1.4E-9	1.2E-8	this work
Xe 127m	1.17 m	5.4E-13	5.0E-13	this work
Xe 129m	8.89 d	1.0E-9	2.2E-9	this work
Xe 131m	1.19E1 d	7.0E-10	2.0E-9	this work
Xe 133	5.25 d	7.1E-10	1.0E-9	this work
Xe 133m	2.19 d	8.9E-10	9.5E-10	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Xe 134m	2.9E2 ms	1.5E-14	6.9E-15	this work
Xe 135	9.09 h	4.8E-10	2.3E-10	this work
Xe 135m	1.57E1 m	2.7E-11	1.3E-11	this work
Xe 137	3.83 m	1.2E-11	5.6E-12	this work
Xe 138	1.42E1 m	1.2E-10	5.6E-11	this work
Cs 126	1.64 m	3.2E-12	1.5E-12	this work
Cs 127	6.25 h	2.1E-11	1.4E-11	4
Cs 128	3.62 m	5.0E-12	2.4E-12	this work
Cs 129	1.34 d	5.5E-11	4.0E-11	5
Cs 130	2.92E1 m	1.3E-11	7.2E-12	4
Cs 131	9.69 d	5.9E-11	4.1E-11	5
Cs 132	6.48 d	4.7E-10	3.0E-10	5
Cs 134	2.06 y	1.7E-8	1.1E-8	5
Cs 134m	2.9 h	1.1E-11	9.6E-12	5
Cs 135	2.3E6 y	1.7E-9	1.1E-9	5
Cs 135m	5.3E1 m	1.4E-11	6.8E-12	4
Cs 136	1.32E1 d	2.8E-9	1.8E-9	5
Cs 136m	1.9E1 s	1.6E-13	1.5E-13	this work
Cs 137	3.0E1 y	1.2E-8	7.7E-9	5
Cs 138	3.22E1 m	4.2E-11	2.4E-11	4,5
Cs 138m	2.9 m	9.9E-12	4.7E-12	this work
Cs 139	9.4 m	2.2E-11	1.0E-11	this work
Cs 140	1.06 m	3.5E-12	1.9E-12	this work
Ba 127	1.27E1 m	3.7E-11	1.5E-11	this work
Ba 128	2.43 d	2.7E-9	7.6E-10	4
Ba 129	2.23 h	1.8E-10	7.5E-11	this work
Ba 129m	2.17 h	1.7E-10	7.3E-11	this work
Ba 131	1.18E1 d	4.4E-10	1.8E-10	4,5
Ba 131m	1.46E1 m	2.7E-12	1.0E-12	4
Ba 133	1.07E1 y	8.5E-10	1.9E-9	5
Ba 133m	1.62 d	5.3E-10	1.5E-10	4,5
Ba 135m	1.2 d	4.2E-10	1.2E-10	4
Ba 136m	3.08E2 ms	1.5E-14	5.9E-15	this work
Ba 137m	2.55 m	2.4E-12	9.6E-13	this work
Ba 139	1.38 h	1.1E-10	4.4E-11	5
Ba 140	1.27E1 d	2.3E-9	9.6E-10	5
Ba 141	1.83E1 m	5.5E-11	2.0E-11	4
Ba 142	1.06E1 m	2.8E-11	9.6E-12	4
La 132	4.806 h	4.1E-10	1.4E-10	4
La 132m	2.43E1 m	1.1E-10	4.6E-11	this work
La 133	3.911 h	7.0E-11	2.8E-11	this work
La 134	6.45 m	1.5E-11	5.9E-12	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
La 135	1.95E1 h	3.6E-11	1.4E-11	4
La 136	9.87 m	1.1E-11	4.4E-12	this work
La 136m	1.14E2 ms	2.6E-15	1.0E-15	this work
La 137	6.0E4 y	1.2E-10	1.9E-8	4
La 138	1.35E11 y	1.6E-9	3.8E-7	4
La 140	1.68 d	2.1E-9	1.2E-9	4,5
La 141	3.93 h	3.7E-10	1.5E-10	5
La 142	1.54 h	1.7E-10	6.0E-11	4,5
La 143	1.42E1 m	3.8E-11	1.5E-11	4
La 144	4.1E1 s	3.6E-12	1.4E-12	this work
Ce 133	5.4 h	5.1E-10	3.9E-9	this work
Ce 133m	1.617 h	1.4E-10	1.1E-9	this work
Ce 134	3.16 d	2.4E-9	2.0E-9	4
Ce 135	1.78E1 h	8.8E-10	3.9E-10	4
Ce 135m	2.0E1 s	4.5E-13	3.6E-12	this work
Ce 137	9.0 h	2.7E-11	1.0E-11	4
Ce 137m	1.43 d	5.5E-10	3.4E-10	4
Ce 139	1.38E2 d	2.8E-10	2.0E-9	4,5
Ce 139m	5.64E1 s	9.6E-13	7.3E-12	this work
Ce 141	3.25E1 d	7.0E-10	2.3E-9	4,5
Ce 142	5.0E16 y	2.7E-8	1.1E-5	this work
Ce 143	1.38 d	1.1E-9	8.5E-10	4,5
Ce 144	2.84E2 d	5.4E-9	9.5E-8	5
Ce 145	2.98 m	8.7E-12	6.6E-11	this work
Ce 146	1.42E1 m	5.7E-11	4.4E-10	this work
Ce 147	5.5E1 s	3.7E-12	2.9E-11	this work
Ce 148	4.8E1 s	3.7E-12	2.8E-11	this work
Pr 137	1.28 h	3.6E-11	9.7E-12	4
Pr 138	1.45 m	4.8E-12	3.1E-12	this work
Pr 138m	2.1 h	1.3E-10	3.2E-11	4
Pr 139	4.41 h	3.4E-11	1.3E-11	4
Pr 140	3.39 m	6.2E-12	4.0E-12	this work
Pr 142	1.91E1 h	1.4E-9	7.3E-10	5
Pr 142m	1.46E1 m	1.7E-11	9.7E-12	4
Pr 143	1.36E1 d	1.2E-9	2.0E-9	4,5
Pr 144	1.73E1 m	3.0E-11	1.1E-11	5
Pr 144m	7.2 m	1.6E-11	1.0E-11	this work
Pr 145	5.98 h	4.2E-10	1.7E-10	5
Pr 146	2.42E1 m	1.0E-10	6.7E-11	this work
Pr 147	1.36E1 m	1.8E-11	7.4E-12	4
Pr 148	2.27 m	9.4E-12	6.1E-12	this work
Pr 148m	2.0 m	8.9E-12	5.7E-12	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Pr 149	2.3 m	9.3E-12	6.3E-12	this work
Pr 150	6.1 s	6.1E-13	3.9E-13	this work
Nd 138	5.04 h	6.8E-10	2.6E-10	4
Nd 139	2.97E1 m	1.5E-11	4.6E-12	4
Nd 139m	5.5 h	2.8E-10	9.3E-11	4
Nd 140	3.37 d	1.7E-9	1.5E-9	7
Nd 141	2.49 h	8.6E-12	2.2E-12	4
Nd 141m	1.04 m	9.7E-13	2.3E-12	this work
Nd 144	2.1E15 y	3.9E-8	1.6E-5	this work
Nd 147	1.1E1 d	1.1E-9	1.8E-9	5
Nd 149	1.73 h	1.2E-10	5.5E-11	4,5
Nd 151	1.24E1 m	2.0E-11	6.7E-11	4
Nd 152	1.14E1 m	2.6E-11	6.1E-11	this work
Pm 141	2.09E1 m	2.3E-11	7.8E-12	4
Pm 142	4.05E1 s	2.1E-12	1.7E-12	this work
Pm 143	2.65E2 d	2.6E-10	2.3E-9	4
Pm 144	3.63E2 d	1.1E-9	1.2E-8	4
Pm 145	1.77E1 y	1.2E-10	7.2E-9	4
Pm 146	5.53 y	8.8E-10	3.1E-8	4
Pm 147	2.62 y	2.6E-10	9.3E-9	5
Pm 148	5.37 d	2.6E-9	2.8E-9	5
Pm 148m	4.13E1 d	1.9E-9	4.7E-9	4,5
Pm 149	2.21 d	9.9E-10	7.6E-10	4,5
Pm 150	2.68 h	2.6E-10	7.8E-11	4
Pm 151	1.18 d	7.7E-10	4.4E-10	5
Pm 152	4.1 m	8.8E-12	7.0E-12	this work
Pm 152m	7.5 m	2.5E-11	2.0E-11	this work
Pm 152n	1.5E1 m	7.5E-11	5.9E-11	this work
Pm 153	5.4 m	7.2E-12	6.2E-12	this work
Pm 154	1.7 m	6.3E-12	5.0E-12	this work
Pm 154m	2.7 m	1.0E-11	8.1E-12	this work
Pm 155	4.8E1 s	2.3E-12	1.8E-12	this work
Sm 142	1.21 h	1.6E-10	5.0E-11	4
Sm 143	8.83 m	1.1E-11	3.9E-11	this work
Sm 143m	1.1 m	2.3E-12	8.3E-12	this work
Sm 145	3.4E2 d	2.2E-10	2.7E-9	4
Sm 146	7.4E7 y	5.3E-8	2.1E-5	4,5
Sm 147	1.06E11 y	4.8E-8	1.9E-5	4,5
Sm 148	8.0E15 y	4.2E-8	1.7E-5	this work
Sm 149	4.0E14 y	3.9E-8	1.5E-5	this work
Sm 151	9.0E1 y	9.2E-11	7.7E-9	5
Sm 153	1.95 d	7.2E-10	4.8E-10	5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Sm 155	2.21E1 m	1.8E-11	6.4E-12	4
Sm 156	9.4 h	2.7E-10	1.5E-10	4
Sm 157	8.0 m	1.7E-11	6.3E-11	this work
Eu 144	1.02E1 s	6.5E-13	4.8E-13	this work
Eu 145	5.93 d	8.6E-10	6.9E-10	4
Eu 146	4.59 d	1.4E-9	1.0E-9	4
Eu 147	2.4E1 d	4.8E-10	8.2E-10	4
Eu 148	5.45E1 d	1.4E-9	3.8E-9	4
Eu 149	9.31E1 d	1.1E-10	4.4E-10	4
Eu 150	1.26E1 h	4.0E-10	1.6E-10	4
Eu 150m	3.42E1 y	1.7E-9	7.3E-8	4
Eu 152	1.33E1 y	1.6E-9	5.8E-8	5
Eu 152m	9.32 h	5.1E-10	2.1E-10	5
Eu 152n	1.6 h	1.1E-10	8.1E-11	this work
Eu 154	8.6 y	2.5E-9	6.9E-8	5
Eu 154m	4.63E1 m	8.8E-12	6.6E-12	this work
Eu 155	4.96 y	3.7E-10	1.1E-8	4,5
Eu 156	1.52E1 d	2.4E-9	3.0E-9	4
Eu 157	1.52E1 h	6.3E-10	2.7E-10	4
Eu 158	4.59E1 m	7.0E-11	2.3E-11	4
Eu 159	1.87E1 m	3.4E-11	2.5E-11	this work
Eu 160	5.28E1 s	3.4E-12	2.5E-12	this work
Gd 145	2.34E1 m	2.9E-11	8.8E-12	4
Gd 145m	1.42 m	5.5E-12	2.4E-11	this work
Gd 146	4.83E1 d	1.0E-9	1.0E-8	4
Gd 147	1.59 d	6.9E-10	3.9E-10	4
Gd 148	7.5E1 y	5.6E-8	8.9E-5	4
Gd 149	9.25 d	5.0E-10	6.1E-10	4
Gd 150	1.2E5 y	5.2E-8	8.3E-5	7
Gd 151	1.2E2 d	2.1E-10	2.2E-9	4
Gd 152	1.08E14 y	4.2E-8	6.6E-5	4
Gd 153	2.42E2 d	2.9E-10	5.6E-9	5
Gd 159	1.86E1 h	5.1E-10	2.4E-10	4,5
Gd 161	3.7 m	5.2E-12	2.3E-11	this work
Gd 162	9.0 m	2.9E-11	1.2E-10	this work
Gd 163	1.13 m	4.2E-12	1.8E-11	this work
Gd 164	1.0 s	9.1E-14	3.8E-13	this work
Tb 150	3.472 h	2.6E-10	6.4E-11	4
Tb 150m	5.8 m	1.7E-11	1.0E-11	this work
Tb 151	1.76E1 h	3.8E-10	1.5E-10	4
Tb 151m	2.5E1 s	8.2E-13	7.9E-13	this work
Tb 152	1.75E1 h	1.8E-9	1.2E-9	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Tb 152m	4.3 m	1.2E-11	7.7E-12	this work
Tb 153	2.34 d	2.6E-10	1.9E-10	4
Tb 154	2.14E1 h	7.8E-10	3.2E-10	4
Tb 154m	9.0 h	1.2E-9	7.5E-10	this work
Tb 154n	2.26E1 h	3.5E-9	2.4E-9	this work
Tb 155	5.32 d	2.2E-10	1.8E-10	4
Tb 156	5.34 d	1.3E-9	9.9E-10	4
Tb 156m	5.0 h	8.8E-11	5.0E-11	4
Tb 156n	1.02 d	1.9E-10	1.8E-10	4
Tb 157	1.5E2 y	2.8E-11	2.4E-9	4
Tb 158	1.5E2 y	1.1E-9	6.8E-8	4
Tb 158m	1.05E1 s	2.2E-14	1.4E-14	this work
Tb 160	7.23E1 d	1.7E-9	5.9E-9	4
Tb 161	6.91 d	7.1E-10	8.4E-10	4
Tb 162	7.7 m	1.5E-11	9.0E-12	this work
Tb 163	1.95E1 m	2.6E-11	1.6E-11	this work
Tb 164	3.0 m	9.7E-12	5.9E-12	this work
Tb 165	3.0E1 s	1.1E-12	6.8E-13	this work
Tb 166	5.2E1 s	3.1E-12	2.1E-12	this work
Dy 153	6.4 h	5.6E-10	6.2E-10	this work
Dy 154	2.9E6 y	5.8E-8	2.3E-5	7
Dy 155	1.0E1 h	1.5E-10	5.3E-11	4
Dy 157	8.1 h	7.3E-11	2.1E-11	4
Dy 159	1.44E2 d	1.1E-10	5.6E-10	4
Dy 165	2.33 h	9.7E-11	2.9E-11	4,5
Dy 165m	1.26 m	1.1E-12	1.1E-12	this work
Dy 166	3.4 d	1.7E-9	1.9E-9	4,5
Dy 167	6.2 m	1.8E-11	1.8E-11	this work
Dy 168	1.6 h	3.1E-10	3.1E-10	this work
Dy 169	7.1 s	5.1E-13	5.2E-13	this work
Dy 170	1.6 m	1.2E-11	1.2E-11	this work
Ho 158	1.13E1 m	7.8E-11	2.8E-10	this work
Ho 158m	2.13E1 m	1.5E-10	5.3E-10	this work
Ho 158n	2.7E1 m	2.3E-10	8.4E-10	this work
Ho 159	3.3E1 m	6.3E-12	1.3E-12	4
Ho 159m	8.3 s	3.5E-13	1.2E-13	this work
Ho 160	2.56E1 m	2.0E-10	6.6E-11	this work
Ho 160m	5.02 h	3.2E-9	1.1E-9	this work
Ho 160n	3.0 s	5.5E-13	2.0E-12	this work
Ho 161	2.48 h	1.3E-11	3.2E-12	4
Ho 161m	6.73 s	1.5E-13	4.9E-14	this work
Ho 162	1.5E1 m	1.8E-12	5.6E-13	4

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Ho 162m	1.13 h	2.5E-11	5.0E-11	4
Ho 163	3.3E1 y	3.6E-11	3.1E-10	this work
Ho 163m	1.09 s	2.3E-14	8.4E-14	this work
Ho 164	2.9E1 m	6.5E-12	2.2E-12	4
Ho 164m	3.75E1 m	1.3E-11	4.5E-12	4
Ho 166	1.12 d	1.5E-9	7.7E-10	5
Ho 166m	1.2E3 y	2.1E-9	2.0E-7	4
Ho 167	3.1 h	8.5E-11	2.3E-11	4
Ho 168	3.0 m	2.0E-11	6.8E-12	this work
Ho 169	4.4 m	2.0E-11	6.8E-12	this work
Ho 170	4.3E1 s	1.1E-11	3.8E-12	this work
Ho 170m	2.8 m	2.9E-11	9.8E-12	this work
Ho 171	1.0 m	6.2E-12	2.1E-12	this work
Ho 172	1.0 m	6.1E-12	2.9E-12	this work
Er 160	1.191 d	4.8E-9	4.0E-9	this work
Er 161	3.24 h	9.0E-11	2.1E-11	4
Er 163	1.25 h	4.9E-12	3.4E-12	this work
Er 165	1.04E1 h	2.1E-11	7.3E-12	4
Er 167m	2.28 s	1.1E-14	7.6E-15	this work
Er 169	9.3 d	3.8E-10	5.4E-10	5
Er 171	7.52 h	3.8E-10	1.4E-10	4,5
Er 172	2.05 d	1.0E-9	9.4E-10	4
Er 173	1.4 m	4.2E-12	3.0E-12	this work
Tm 163	1.81 h	2.1E-10	4.1E-10	this work
Tm 164	2.0 m	3.6E-12	7.1E-12	this work
Tm 164m	5.1 m	1.5E-11	3.0E-11	this work
Tm 165	1.25 d	1.4E-9	3.3E-9	this work
Tm 166	7.7 h	3.2E-10	9.3E-11	4
Tm 167	9.24 d	5.6E-10	7.1E-10	4
Tm 168	9.31E1 d	5.1E-9	2.3E-8	this work
Tm 170	1.28E2 d	1.4E-9	6.3E-9	5
Tm 171	1.92 y	1.1E-10	2.3E-9	4,5
Tm 172	2.65 d	1.6E-9	1.2E-9	4
Tm 173	8.24 h	3.3E-10	1.2E-10	4
Tm 174	5.4 m	1.7E-11	3.4E-11	this work
Tm 175	1.52E1 m	1.5E-11	5.3E-12	4
Tm 176	1.9 m	7.5E-12	1.5E-11	this work
Yb 164	1.26 h	1.5E-10	9.1E-11	this work
Yb 165	9.9 m	1.2E-11	7.7E-12	this work
Yb 166	2.36 d	1.0E-9	7.4E-10	4
Yb 167	1.75E1 m	4.6E-12	1.9E-12	4
Yb 169	3.2E1 d	7.6E-10	1.9E-9	4,5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Yb 169m	4.6E1 s	4.4E-14	4.4E-14	this work
Yb 175	4.19 d	4.3E-10	4.2E-10	5
Yb 176m	1.14E1 s	2.2E-13	1.3E-13	this work
Yb 177	1.9 h	8.4E-11	3.0E-11	4
Yb 177m	6.41 s	1.2E-13	7.6E-14	this work
Yb 178	1.23 h	1.1E-10	3.7E-11	4
Yb 179	8.0 m	8.3E-12	5.0E-12	this work
Lu 167	5.15E1 m	1.7E-9	6.0E-10	this work
Lu 168	5.5 m	1.0E-11	3.6E-12	this work
Lu 168m	6.7 m	2.3E-11	8.0E-12	this work
Lu 169	1.42 d	5.4E-10	3.3E-10	4
Lu 169m	2.67 m	4.2E-11	1.9E-11	this work
Lu 170	2.0 d	1.2E-9	6.8E-10	4
Lu 170m	6.7E2 ms	3.0E-13	1.5E-13	this work
Lu 171	8.24 d	7.0E-10	7.1E-10	4
Lu 171m	1.32 m	4.5E-12	2.7E-12	this work
Lu 172	6.7 d	1.4E-9	1.2E-9	4
Lu 172m	3.7 m	3.2E-11	2.1E-11	this work
Lu 173	1.37 y	2.7E-10	5.0E-9	4
Lu 174	3.31 y	2.7E-10	8.5E-9	4,5
Lu 174m	1.42E2 d	5.0E-10	6.1E-9	4
Lu 176	3.59E10 y	1.8E-9	1.7E-7	4
Lu 176m	3.64 h	1.7E-10	5.9E-11	4
Lu 177	6.71 d	5.3E-10	6.4E-10	5
Lu 177m	1.61E2 d	1.8E-9	1.7E-8	4
Lu 178	2.84E1 m	3.3E-11	1.2E-11	4
Lu 178m	2.31E1 m	2.4E-11	7.9E-12	4
Lu 179	4.59 h	2.2E-10	8.6E-11	4
Lu 180	5.7 m	2.0E-10	6.8E-11	this work
Lu 181	3.5 m	8.3E-11	3.0E-11	this work
Lu 182	2.0 m	6.1E-11	2.1E-11	this work
Hf 169	3.24 m	7.0E-12	6.8E-12	this work
Hf 170	1.6E1 h	5.1E-10	3.0E-10	4
Hf 171	1.21E1 h	5.3E-10	5.5E-10	this work
Hf 172	1.87 y	1.1E-9	7.2E-8	4
Hf 173	1.0 d	2.6E-10	1.2E-10	4
Hf 174	2.0E15 y	4.8E-8	7.6E-5	this work
Hf 175	7.0E1 d	4.4E-10	1.4E-9	5
Hf 177m	1.08 s	1.9E-14	1.7E-14	this work
Hf 177n	5.14E1 m	6.9E-11	2.3E-11	4
Hf 178m	4.0 s	1.3E-13	1.1E-13	this work
Hf 178n	3.1E1 y	5.4E-9	5.4E-7	4

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Hf 179m	1.87E1 s	9.4E-14	8.2E-14	this work
Hf 179n	2.51E1 d	1.3E-9	2.3E-9	4
Hf 180m	5.5 h	1.9E-10	6.1E-11	4
Hf 181	4.24E1 d	1.2E-9	3.4E-9	4,5
Hf 182	9.0E6 y	3.8E-9	7.6E-7	4
Hf 182m	1.03 h	3.8E-11	1.5E-11	4
Hf 183	1.07 h	6.6E-11	2.9E-11	4
Hf 184	4.12 h	5.7E-10	2.1E-10	4
Hf 185	1.0 s	6.7E-14	5.8E-14	this work
Ta 175	1.05E1 h	2.4E-10	9.2E-11	4
Ta 176	8.08 h	3.6E-10	1.1E-10	4
Ta 177	2.36 d	1.1E-10	7.7E-11	4
Ta 178	9.31 m	7.7E-11	1.9E-11	4
Ta 178m	2.45 h	1.8E-9	5.3E-10	this work
Ta 179	1.82 y	6.6E-11	1.5E-9	4,5
Ta 180	2.8E13 y	9.0E-10	5.8E-8	4
Ta 180m	8.1 h	5.8E-11	2.3E-11	4
Ta 182	1.15E2 d	1.6E-9	9.9E-9	4,5
Ta 182m	2.83E2 ms	6.6E-16	3.6E-16	this work
Ta 182n	1.58E1 m	6.5E-12	3.3E-12	4
Ta 183	5.1 d	1.2E-9	1.3E-9	4
Ta 184	8.7 h	7.2E-10	2.8E-10	4
Ta 185	4.9E1 m	5.2E-11	2.1E-11	4
Ta 186	1.05E1 m	1.8E-11	6.1E-12	4
Ta 187	1.0 s	2.5E-13	7.7E-14	this work
Ta 188	1.0 s	2.2E-13	6.5E-14	this work
W 176	2.5 h	1.3E-10	2.6E-11	4
W 177	2.21 h	6.5E-11	1.6E-11	4
W 178	2.15E1 d	2.5E-10	7.0E-11	4
W 179	3.75E1 m	2.5E-12	8.0E-13	4
W 179m	6.4 m	1.8E-12	3.3E-13	this work
W 181	1.21E2 d	8.3E-11	4.1E-11	5
W 183m	5.15 s	3.4E-14	6.1E-15	this work
W 185	7.51E1 d	5.1E-10	2.1E-10	5
W 185m	1.67 m	4.4E-13	8.1E-14	this work
W 187	2.39E1 h	7.4E-10	1.7E-10	5
W 188	6.94E1 d	2.5E-9	1.1E-9	4
W 189	1.15E1 m	3.0E-11	5.6E-12	this work
W 190	3.0E1 m	1.1E-10	1.9E-11	this work
W 191	1.0 s	1.2E-13	2.1E-14	this work
Re 179	1.97E1 m	2.9E-11	2.1E-11	this work
Re 180	2.46 m	3.2E-12	2.3E-12	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Re 181	1.99E1 h	2.7E-10	1.6E-10	4
Re 182	2.67 d	9.1E-10	6.4E-10	4
Re 182m	1.27E1 h	2.0E-10	1.1E-10	4
Re 183	7.0E1 d	4.1E-10	1.3E-9	7
Re 184	3.8E1 d	5.8E-10	9.9E-10	4
Re 184m	1.65E2 d	6.5E-10	3.1E-9	4
Re 186	3.77 d	7.1E-10	8.1E-10	5
Re 186m	2.0E5 y	8.5E-10	8.9E-9	4
Re 187	5.0E10 y	2.3E-12	1.3E-11	5
Re 188	1.7E1 h	7.8E-10	5.0E-10	5
Re 188m	1.86E1 m	1.7E-11	1.0E-11	4
Re 189	1.01 d	4.1E-10	3.0E-10	4
Re 190	3.1 m	6.1E-12	4.5E-12	this work
Re 190m	3.2 h	6.2E-10	4.5E-10	this work
Re 191	9.8 m	1.3E-11	1.0E-11	this work
Re 192	1.6E1 s	7.0E-13	5.1E-13	this work
Re 193	1.0 s	7.0E-14	5.2E-14	this work
Re 194	1.0 s	6.4E-14	4.7E-14	this work
Os 181	1.75 h	9.5E-11	3.2E-11	4
Os 181m	2.7 m	6.2E-12	2.8E-12	this work
Os 182	2.1944E1 h	5.9E-10	3.4E-10	4
Os 183	1.3E1 h	8.3E-10	3.7E-10	this work
Os 183m	9.9 h	1.1E-9	4.8E-10	this work
Os 185	9.36E1 d	5.6E-10	2.7E-9	5
Os 186	2.0E15 y	5.2E-8	8.3E-5	this work
Os 189m	5.8 h	1.8E-11	7.7E-12	4
Os 190m	9.9 m	3.0E-11	1.3E-11	this work
Os 191	1.54E1 d	5.4E-10	1.0E-9	4,5
Os 191m	1.31E1 h	9.6E-11	7.6E-11	5
Os 192m	5.9 s	3.6E-13	1.5E-13	this work
Os 193	1.27 d	8.4E-10	5.1E-10	5
Os 194	6.0 y	2.4E-9	1.8E-7	4
Os 195	6.5 m	2.0E-11	8.7E-12	this work
Os 196	3.49E1 m	1.2E-10	5.3E-11	this work
Os 197	3.41 s	3.1E-13	1.4E-13	this work
Ir 184	3.019 h	1.7E-10	5.4E-11	4
Ir 185	1.4E1 h	2.8E-10	1.3E-10	4
Ir 186	1.58E1 h	5.7E-10	2.3E-10	4
Ir 186m	1.75 h	2.6E-10	1.6E-10	this work
Ir 187	1.05E1 h	1.3E-10	5.1E-11	4
Ir 188	1.73 d	7.3E-10	4.1E-10	4
Ir 189	1.32E1 d	2.5E-10	3.7E-10	4

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Ir 190	1.18E1 d	1.3E-9	1.5E-9	4,5
Ir 190m	1.2 h	8.1E-12	7.0E-12	4
Ir 190n	3.2 h	9.6E-10	5.9E-10	this work
Ir 191m	4.94 s	2.0E-14	1.2E-14	this work
Ir 191n	5.5 s	2.7E-13	1.7E-13	this work
Ir 192	7.4E1 d	1.4E-9	6.3E-9	4,5
Ir 192m	1.44 m	1.8E-13	1.6E-13	this work
Ir 192n	2.41E2 y	4.2E-10	9.0E-8	4
Ir 193m	1.06E1 d	2.8E-10	4.5E-10	7
Ir 194	1.92E1 h	1.4E-9	7.3E-10	4,5
Ir 194m	1.71E2 d	2.2E-9	1.4E-8	4
Ir 195	2.8 h	9.1E-11	3.3E-11	4
Ir 195m	3.8 h	1.7E-10	6.1E-11	4
Ir 196	5.2E1 s	1.8E-12	1.1E-12	this work
Ir 196m	1.4 h	3.6E-10	2.2E-10	this work
Ir 197	5.8 m	1.4E-11	8.8E-12	this work
Ir 197m	8.9 m	2.2E-11	1.4E-11	this work
Ir 198	8.0 s	5.2E-13	3.2E-13	this work
Ir 199	5.07E1 s	2.8E-12	2.8E-12	this work
Ir 200	5.19 s	4.8E-13	4.7E-13	this work
Pt 187	2.35 h	2.4E-10	7.7E-11	this work
Pt 188	1.02E1 d	8.1E-10	8.3E-10	4
Pt 189	1.09E1 h	1.3E-10	4.8E-11	4
Pt 190	6.0E11 y	9.3E-9	3.8E-7	7
Pt 191	2.9 d	3.6E-10	1.6E-10	4,5
Pt 193	5.0E1 y	2.9E-11	5.7E-11	4
Pt 193m	4.33 d	4.5E-10	2.3E-10	4,5
Pt 195m	4.02 d	6.1E-10	3.1E-10	5
Pt 197	1.83E1 h	4.1E-10	1.4E-10	5
Pt 197m	1.57 h	8.3E-11	3.1E-11	5
Pt 199	3.08E1 m	2.8E-11	9.6E-12	4
Pt 199m	1.36E1 s	4.2E-13	1.4E-13	this work
Pt 200	1.25E1 h	1.2E-9	4.1E-10	4
Pt 201	2.5 m	8.2E-12	2.6E-12	this work
Au 190	4.28E1 m	1.1E-10	3.1E-10	this work
Au 191	3.18 h	2.1E-10	6.3E-10	this work
Au 191m	9.2E2 ms	2.2E-14	6.5E-14	this work
Au 192	4.94 h	7.7E-10	2.1E-9	this work
Au 192m	1.67E2 ms	8.8E-15	2.4E-14	this work
Au 193	1.77E1 h	1.4E-10	7.1E-11	5
Au 193m	3.9 s	4.3E-14	1.2E-13	this work
Au 194	1.65 d	4.9E-10	2.7E-10	4,5

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Au 194m	6.0E2 ms	1.2E-14	4.1E-14	this work
Au 194n	4.2E2 ms	1.2E-14	3.8E-14	this work
Au 195	1.86E2 d	2.5E-10	3.2E-9	5
Au 195m	3.05E1 s	2.1E-13	5.8E-13	this work
Au 196	6.18 d	3.8E-10	3.0E-10	7
Au 196m	8.1 s	4.0E-14	1.7E-13	this work
Au 196n	9.7 h	6.3E-10	2.0E-9	this work
Au 197m	7.8 s	7.0E-14	1.9E-13	this work
Au 198	2.7 d	1.1E-9	7.9E-10	4,5
Au 198m	1.3 d	1.4E-9	1.2E-9	4
Au 199	3.14 d	4.1E-10	3.7E-10	5
Au 200	4.84E1 m	5.2E-11	2.1E-11	4
Au 200m	1.87E1 h	1.1E-9	5.5E-10	4
Au 201	2.6E1 m	1.6E-11	6.3E-12	4
Au 202	2.8E1 s	8.5E-13	2.3E-12	this work
Au 203	5.3E1 s	1.7E-12	4.5E-12	this work
Au 204	4.0E1 s	2.8E-12	7.6E-12	this work
Hg 192	4.861 h	1.9E-9	5.1E-10	this work
Hg 193	3.8 h	8.7E-11	3.2E-11	4
Hg 193m	1.18E1 h	4.3E-10	1.7E-10	4
Hg 194	5.2E2 y	7.5E-8	4.7E-8	5
Hg 195	9.5 h	1.0E-10	4.1E-11	4
Hg 195m	1.73 d	5.8E-10	3.7E-10	4
Hg 197	2.67 d	2.4E-10	1.6E-10	4
Hg 197m	2.38E1 h	4.7E-10	2.7E-10	4,5
Hg 199m	4.26E1 m	2.3E-11	9.1E-12	4
Hg 203	4.66E1 d	2.7E-9	1.7E-9	5
Hg 205	5.2 m	7.7E-12	2.1E-12	this work
Hg 206	8.15 m	2.4E-11	6.7E-12	this work
Hg 207	2.9 m	2.2E-11	6.1E-12	this work
Tl 197	2.839 h	1.9E-11	1.1E-11	4
Tl 197m	5.4E2 ms	3.1E-15	1.8E-15	this work
Tl 198	5.3 h	7.1E-11	4.4E-11	4
Tl 198m	1.87 h	4.5E-11	2.5E-11	4
Tl 199	7.42 h	2.2E-11	1.6E-11	4
Tl 200	1.09 d	1.8E-10	1.2E-10	4,5
Tl 201	3.05 d	7.8E-11	6.0E-11	5
Tl 202	1.22E1 d	3.9E-10	2.6E-10	5
Tl 204	3.78 y	8.7E-10	6.3E-10	5
Tl 206	4.2 m	6.5E-13	3.6E-13	this work
Tl 206m	3.8 m	3.5E-12	1.9E-12	this work
Tl 207	4.77 m	6.8E-13	3.8E-13	this work

Table 1 contd.

Radionuclide	half life	$CEDE_{ing}$ (Sv/Bq)	$CEDE_{inh}$ (Sv/Bq)	Reference
Tl 207m	1.33 s	1.2E-14	6.5E-15	this work
Tl 208	3.07 m	3.5E-12	2.0E-12	this work
Tl 209	2.2 m	1.9E-12	1.1E-12	this work
Tl 210	1.3 m	1.3E-12	7.4E-13	this work
Pb 199	1.5 h	5.8E-11	1.9E-11	4
Pb 199m	1.22E1 m	4.7E-11	2.0E-11	this work
Pb 200	2.15E1 h	4.2E-10	2.1E-10	4
Pb 201	9.33 h	1.8E-10	6.9E-11	5
Pb 201m	1.02 m	2.2E-12	9.9E-13	this work
Pb 202	5.3E4 y	1.1E-8	2.6E-8	4
Pb 202m	3.62 h	1.5E-10	4.6E-11	4
Pb 203	2.17 d	2.6E-10	1.4E-10	4
Pb 203m	6.3 m	1.6E-13	7.6E-14	this work
Pb 203n	4.8E2 ms	3.6E-14	1.6E-14	this work
Pb 204m	1.12 h	2.1E-10	9.2E-11	this work
Pb 205	1.43E7 y	4.0E-10	1.0E-9	4
Pb 207m	7.96E2 ms	3.1E-14	1.3E-14	this work
Pb 209	3.25 h	5.5E-11	2.4E-11	4
Pb 210	2.23E1 y	1.4E-6	3.4E-6	4,5
Pb 211	3.61E1 m	1.2E-10	2.1E-9	4
Bi 202	1.669 h	9.5E-11	3.4E-11	4
Bi 203	1.18E1 h	5.7E-10	2.2E-10	4
Bi 204	1.12E1 h	1.4E-9	1.0E-8	this work
Bi 205	1.53E1 d	1.0E-9	1.1E-9	4
Bi 206	6.24 d	2.1E-9	1.6E-9	4,5
Bi 207	3.8E1 y	1.3E-9	3.8E-9	4,5
Bi 207m	1.0 s	2.3E-18	1.7E-17	this work
Bi 208	3.68E5 y	1.3E-9	3.3E-9	7
Bi 210	5.01 d	1.6E-9	5.1E-8	4,5
Bi 210m	3.0E6 y	2.3E-8	2.0E-6	4
Bi 211	2.17 m	1.1E-10	8.0E-10	this work
Po 205	1.8 h	6.4E-11	3.6E-11	4
Po 206	8.8 d	8.6E-8	4.5E-7	7
Po 207	5.83 h	1.7E-10	5.4E-11	4
Po 207m	2.8 s	1.5E-13	3.4E-13	this work
Po 208	2.9 y	5.5E-7	2.8E-6	7
Po 209	1.02E2 y	8.2E-12	2.8E-11	7
Po 210	1.38E2 d	4.3E-7	2.2E-6	5
Po 211	5.16E2 ms	1.7E-12	3.9E-12	this work
Po 211m	2.55E1 s	8.7E-11	1.9E-10	this work

A METHODOLOGIES FOR THE ESTIMATION OF DOSIMETRIC DATA

A.1 Short-lived radionuclides

The following method was used for all radionuclides with half-lives of less than 3 days. It is assumed that the value of $CEDE_{ing}$ for a radionuclide with a stable daughter is given by the following formula,

$$(CEDE_{ing})_i = (C_{ing})_e (ND_{ing})_i E_i \quad (1)$$

where $(ND_{ing})_i$ is the number of disintegrations within the body per unit activity intake of radionuclide i by ingestion (Bq^{-1}), E_i is the total energy equivalent of emissions from radionuclide i for each radioactive decay (MeV), and $(C_{ing})_e$ is a constant for the particular element, e, (Sv/MeV). A similar expression is used for predicting $CEDE_{inh}$. The value of E is determined by the following formula,

$$E = 20E_\alpha + E_\beta + E_\gamma \quad (2)$$

where E_α is the total average alpha particle energy per decay (MeV), E_β is the total average beta particle energy per decay (MeV), and E_γ is the total average gamma energy per decay (MeV). The factor of 20 by which E_α is multiplied is the value of the quality factor for alpha particles recommended by the ICRP(3), and accounts for the greater biological damage potential of alpha particles in comparison with beta particles and gamma rays. The values of E_α, E_β and E_γ used are taken from the data library UKDECAY3.

The values of ND_{ing} and ND_{inh} are determined using the following expressions,

$$ND_{ing} = (1 - exp(-\lambda t_{ing}))/\lambda \quad (3)$$

$$ND_{inh} = (1 - exp(-\lambda t_{inh}))/\lambda \quad (4)$$

which were derived using basic radioactive decay theory. The parameters t_{ing} and t_{inh} are the mean residence times of the radionuclide within the body taken in by ingestion and inhalation respectively. The time food takes to pass through the gastrointestinal tract is approximately 3 days (4) and this, therefore, is the minimum time that a radionuclide would spend in the body. In fact the majority of the short-lived radionuclides considered in this section would have decayed almost completely within the body in this time. It was therefore conservatively assumed that the mean residence time of a radionuclide taken into the body via ingestion was three days. The minimum time a radionuclide spends in the body following inhalation is slightly longer. From examination of the metabolic model of the lung presented in reference 4 a value of 7 days was deemed a reasonable conservative assumption in this case.

The constants C_{ing} and C_{inh} for each element are determined by considering all those radionuclides of the element with half lives less than 1 year for which values

of $CEDE_{ing}$ and $CEDE_{inh}$ were available in references 4 and 5. Substituting values of $CEDE_{ing}$ and E into equation 1 for each of these radionuclides allows values of C_{ing} to be determined. The range in the values of C_{ing} generated was generally less than an order of magnitude, which indicated that the method being adopted was reasonable. The largest value of C_{ing} calculated in this manner was defined as $(C_{ing})_E$ and was then used to determine values of $CEDE_{ing}$ for the remaining radionuclides of the element. A similar process was used to determine the values of $CEDE_{inh}$. As an illustration, the values of C_{ing} and C_{inh} for radionuclides of Scandium are presented in Table 1. The variation in values is less than an order of magnitude and values of $(C_{ing})_e$ and $(C_{inh})_e$ of 1.6 10^{-14} and 1.0 10^{-14} respectively were chosen. It was necessary to use radionuclides with half lives of up to 1 year so that a sufficient number of values of C_{ing} and C_{inh} could be generated.

Radionuclide	$CEDE_{ing}$ (a)	C_{ing}	$CEDE_{inh}$ (a)	C_{inh}
Sc 43	1.9E-10	6.7E-15	5.9E-11	2.1E-15
Sc 44	3.6E-10	6.4E-15	1.1E-10	2.0E-15
Sc 44m	2.7E-9	5.1E-15	1.9E-9	3.6E-15
Sc 46	1.5E-9	2.8E-15	5.5E-9	1.0E-14
Sc 47	5.2E-10	9.9E-15	4.6E-10	8.7E-15
Sc 48	1.7E-9	3.1E-15	9.9E-10	1.8E-15
Sc 49	6.6E-11	1.6E-14	2.5E-11	6.1E-15

Table 1: Values of C_{ing} and C_{inh} for isotopes of Scandium.
((a) - Data from references 4 and 5)

For some of the radionuclides for which it was necessary to predict dosimetric data no values of $CEDE_{ing}$ and $CEDE_{inh}$ for other radionuclides of the same element existed. In this case, values of C_{ing} and C_{inh} for an element which was expected to behave in a similar metabolic manner were used. Thus lithium was assumed to behave in a similar manner to sodium, nitrogen and oxygen in a similar manner to carbon, and boron in a similar manner to silicon. The information on metabolic behaviour used to determine which elements to choose as analogues was obtained from reference 4.

For radionuclides with a radioactive daughter equation 1 must be extended to include energy deposited by emissions from the daughter nuclide. Thus,

$$CEDE_p = C.ND_p(E_p + \lambda_d ND_d E_d) \tag{5}$$

where subscripts p and d denote parent and daughter respectively and λ is the radioactive decay constant (s^{-1}). For radionuclides which form part of a longer decay chain the formula can be extended accordingly.

It should also be noted that this method was applied to some longer lived radionuclides. Although this strictly is incorrect it was the only method available for determining values for Te-118 (half life 6 days), Tm-168 (half life 93 days) and Ho-163 (half life 33 years).

A.2 Noble gases

In order to determine equivalent values of $CEDE_{ing}$ and $CEDE_{inh}$ for the noble gases, to use with those for the other elements, it was assumed that they existed as solids. This is equivalent to assuming that noble gases are taken into the body in the matrix of another material such as dust. For the short lived noble gas radionuclides (half lives less than 1 year) values of dosimetric data were determined in the manner described in section A.1. Since no values of $CEDE_{ing}$ and $CEDE_{inh}$ for the noble gases existed in the literature, it was necessary to use values of C_{ing} and C_{inh} for an element which it was expected would behave in a similar metabolic manner. Values of C_{ing} and C_{inh} for Yttrium were used as, like noble gases, it is very insoluble (3).

There were a few longer lived noble gas radionuclides for which dosimetric data were required, namely Ar-39, Ar-42, Kr-81 and Kr-85. For these radionuclides values of $CEDE_{ing}$ and $CEDE_{inh}$ were predicted using the same basic method as for the other noble gases, with the following alteration: the biological residence times used to determine ND were conservatively made longer, 7 days for ingestion and 500 days for inhalation. The results were compared with those for other long-lived radionuclides of metabolically similar elements.

A.3 Long-lived alpha emitters

The following method was used to predict values of $CEDE_{ing}$ and $CEDE_{inh}$ for long-lived alpha emitters (half lives exceeding 10^{11} years). The value of $CEDE_{ing}$ is given by the following formula,

$$(CEDE_{ing})_i = (C^*_{ing})_e E_i \qquad (6)$$

where the parameter definitions are the same as those in section A.1, and a similar expression exists for $CEDE_{inh}$. There is no necessity in this case to determine values for ND_{ing} or ND_{inh} as, by expanding the exponential terms in equations 3 and 4, it is clear that these will be constant for all long-lived alpha emitters of the same element. Values of C were generated in a similar manner to those in A.1 except that only long-lived alpha emitters of the same element were considered. As in A.1, it was sometimes necessary to use values for C for another element which behaves in a metabolically similar manner. For example Ce and Nd were assumed to behave in a similar manner to Sm, and Hf and Os to behave in a similar manner to Gd.

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