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Compendium of Dose Coefficients based
on ICRP Publication 60



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Compendium of Dose Coefficients based on ICRP Publication 60

Editor

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Compendium of Dose Coefficients based on ICRP Publication 60

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Abstract—This report is a compilation of dose coefficients for intakes of radionuclides by workers and members of the public, and conversion coefficients for use in occupational radiological protection against external radiation from *Publications 68, 72, and 74* (ICRP, 1994b, 1996a,b). It serves as a comprehensive reference for dose coefficients based on the primary radiation protection guidance given in the *Publication 60* recommendations (ICRP, 1991). The coefficients tabulated in this publication will be superseded in due course by values based on the *Publication 103* recommendations (ICRP, 2007).

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PREFACE

In addition to the development of a system of radiological protection that is used as the basis for regulations and practices worldwide, the International Commission on Radiological Protection (ICRP) also provides information essential to the implementation of the system. Central to the application of the system is the use of the protection quantities ‘equivalent dose’ and ‘effective dose’. ICRP has provided sets of dose coefficients (dose per unit exposure) to allow users to calculate equivalent and effective doses for intakes of radionuclides or exposure to external radiation for comparison with dose limits, constraints, and reference levels as recommended by ICRP.

Over the years, dose coefficients have been published in various ICRP reports. The present publication compiles coefficients provided previously in *Publications 68, 72, and 74* (ICRP, 1994b, 1996a,b) for intakes of radionuclides by workers and members of the public, and occupational exposures to external sources of radiation. The dose coefficients in this compendium are calculated as specified in the *Publication 60* recommendations (ICRP, 1991).

As this report is published, work is in progress to develop a new set of coefficients calculated in accordance with the *Publication 103* recommendations (ICRP, 2007). However, that effort will require several years to complete. In the meantime, the present publication serves as a comprehensive tabulation of pre-*Publication 103* coefficients.

The membership of the Task Group on Dose Calculations at the time of completion of this report was:

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GLOSSARY

Absorbed dose (D)

The physical dose quantity given by $D = \frac{d\bar{\epsilon}}{dm}$ where $d\bar{\epsilon}$ is the mean energy imparted by ionising radiation to matter in a volume element, and dm is the mass of matter in this volume element. The SI unit for absorbed dose is joule per kilogram (J/kg) and its special name is gray (Gy).

Absorption

Movement of material to blood regardless of mechanism. Generally applies to dissociation of particles and uptake into blood of soluble substances and material dissociated from particles.

Aerodynamic diameter (d_{ae})

Diameter (μm) of unit density sphere that has same terminal settling velocity in air as the particle of interest.

Activity median aerodynamic diameter (AMAD)

Fifty percent of the activity in an aerosol is associated with particles of aerodynamic diameter (d_{ae}) greater than the AMAD. Applies to an aerosol where its deposition depends upon the inertial impaction and sedimentation, typically when $\text{AMAD} > 0.5 \mu\text{m}$.

Becquerel (Bq)

The name for the SI unit of activity, $1 \text{ Bq} = 1/\text{s}$.

Class SR-1 gases

Soluble and reactive gases and vapours.

Class SR-2 gases

Highly soluble and reactive gases and vapours.

Class SR-0 gases

Insoluble and non-reactive gases and vapours.

Clearance

The removal of material from the respiratory tract by particle transport and absorption into blood.

Committed effective dose [$E(\tau)$]

The sum of the products of the committed organ or tissue equivalent doses and the appropriate organ or tissue weighting factors (w_T), where τ is the integration time in years following the intake. The integration time is 50 years for adults and up to age 70 years for children.

Committed equivalent dose [$H_T(\tau)$]

The time integral of the equivalent dose rate in organ or tissue T that will be received by an individual following intake of radioactive material into the body, where τ is the integration time in years following the intake. The integration time is 50 years for adults and up to age 70 years for children.

Deposition

Refers to the initial processes determining how much of the material in the inspired air remains behind after expiration. Deposition of material may occur during inspiration and expiration.

Dose coefficient

Committed tissue equivalent dose per unit acute intake $h_T(\tau)$ or committed effective dose per unit acute intake $e(\tau)$, where τ is the time period in years over which the dose is calculated [e.g. $e(50)$].

Effective dose (E)

The sum of the weighted equivalent doses in all tissues and organs of the body, given by the expression $E = \sum_T w_T H_T$, where H_T is the equivalent dose in organ or tissue T , and w_T is the weighting factor for tissue T .

Equivalent dose (H_T)

The equivalent dose, $H_{T,R}$, in tissue or organ T due to radiation R , is given by $H_{T,R} = w_R D_{T,R}$ where $D_{T,R}$ is the average absorbed dose from radiation R in tissue T and w_R is the radiation weighting factor. Since w_R is dimensionless, the units are the same as for absorbed dose (J/kg) and its special name is sievert (Sv). The total equivalent dose H_T is the sum of $H_{T,R}$ over all radiation types: $H_T = \sum_R H_{T,R}$.

Fluence

Denoted as Φ , fluence is the quotient of dN by da , where dN is the number of particles incident on a sphere of cross-sectional area da , thus $\Phi = \frac{dN}{da}$.

Fractional absorption in the gastrointestinal tract (f_1)

The f_1 value is the fraction of an ingested element absorbed directly into body fluids.

Gray (Gy)

The special name for the SI unit of absorbed dose, 1 Gy = 1 J/kg.

Intake

Activity that enters the respiratory or gastrointestinal tract from the environment.

Kerma (K)

The quotient of dE_{tr} by dm , where dE_{tr} is the sum of the initial kinetic energies of all the charged ionising particles liberated by uncharged ionising particles in a volume element of mass dm , thus $K = \frac{dE_{tr}}{dm}$. The unit of kerma is joule per kilogram (J/kg) and its special name is gray (Gy).

Physical half life ($T_{1/2}$)

The time interval required for an amount of a certain radioactive nuclei to decay to half of its original value. The units of time are second-s, minute-m, hour-h, day-d, and year-y.

Radiation weighting factor (w_R)

The radiation weighting factor is a dimensionless factor to derive the equivalent dose from the absorbed dose averaged over a tissue or organ, and is based on the quality of the radiation.

Radiation weighting factors*	
Type and energy range	w_R
Photons, all energies	1
Electrons and muons, all energies	1
Neutrons, energy <10 keV	5
10 keV–100 keV	10
>100 keV–2 MeV	20
>2 MeV–20 MeV	10
>20 MeV	5
Protons, other than recoil, energy >2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

* See Table 1 of *Publication 60* for further details (ICRP, 1991).

Reference Man

A person with anatomical and physiological characteristics defined in reports by ICRP.

Sievert (Sv)

The name for the SI unit of equivalent and effective dose; 1 Sv = 1 J/kg.

Source region (S)

Region within the body containing the radionuclide. The region may be an organ, a tissue, the contents of the gastrointestinal tract or urinary bladder, or the surfaces of tissues (e.g. in the skeleton and the respiratory tract).

Specific effective energy $\{[SEE(T \leftarrow S)]_R\}$

The energy, suitably modified for radiation weighting factor, imparted per unit mass of a target tissue T as a consequence of the emission of a specified radiation R from a nuclear transformation occurring in source region S , expressed as J s/Bq kg or Sv/Bq s.

Target tissue (T)

Tissue or organ in which radiation is absorbed.

Tissue weighting factor (w_T)

The factor by which the equivalent dose in a tissue or organ is weighted to represent the relative contributions of that issue or organ to the total detriment resulting from uniform irradiation of the body.

Tissue weighting factors*		
Tissue or organ	w_T	$\sum w_T$
Gonads	0.20	0.20
Red marrow, colon, lung, stomach	0.12	0.48
Bladder, breast, liver, oesophagus, thyroid, remainder*	0.05	0.30
Skin, bone surface	0.01	0.02
	Total	1.0

* See Table 2 of *Publication 60* for further details (ICRP, 1991).

Type F materials

Deposited materials that are readily absorbed into blood from the respiratory tract (fast rate of absorption).

Type M materials

Deposited materials that have intermediate rates of absorption into blood from the respiratory tract (moderate rate of absorption).

Type S materials

Deposited materials that are relatively insoluble in the respiratory tract (slow rate of absorption).

Type V materials

Deposited materials that, for dosimetric purposes, are assumed to be instantaneously absorbed into body fluids from the respiratory tract; this only applies to certain gases and vapours (very fast absorption).

Uptake

Activity that enters the body fluids from the respiratory tract, gastrointestinal tract, or through the skin.

1. INFORMATION PROVIDED IN THIS PUBLICATION

1.1. Dose coefficients for intakes of radionuclides by workers

(1) Committed effective dose coefficients for inhalation and ingestion intakes of radionuclides by workers, as compiled in *Publication 68* (ICRP, 1994b), are reproduced in Annexes A, B, and C of this report. *Publication 68* dose coefficients were calculated using the *Publication 66* (ICRP, 1994a) model of the human respiratory tract and the *Publication 30* (ICRP, 1979) model of the gastrointestinal tract. The biokinetic models used to describe the distribution, tissue retention, and excretion of individual elements and their radioisotopes following their absorption into blood were those developed for the *Publication 30* series (ICRP, 1979, 1980, 1981, 1988), except for cases for which updates were provided in *Publications 56, 67, and 69* (ICRP, 1990, 1992, 1995a). The dosimetric models used were those specified in *Publications 30 and 66* (ICRP, 1979, 1994a). The radiation and tissue weighting factors used were those given in the *Publication 60* recommendations (ICRP, 1991).

(2) Annex A gives committed effective dose coefficients for radionuclides inhaled as particulates or ingested. The coefficients apply to a Reference Worker with an average breathing rate of 1.2 m³/h during an 8-h working day (daily air intake of 9.6 m³) (ICRP, 1994a). For particulate aerosols, a default activity median aerodynamic diameter (AMAD) of 5 µm was used, but values are also given in Annex A for 1-µm particles. Annex B gives dose coefficients for inhalation of soluble or reactive gases for workers, and Annex C gives effective dose rate coefficients for inert gases that apply to adult members of the public as well as workers.

(3) Annexes D and E tabulate f_1 values and lung clearance types used in the derivation of the dose coefficients given in Annex A. As explained in *Publications 30 and 68* (ICRP, 1979, 1994b), the fractional absorption of an ingested radionuclide from the gastrointestinal tract to blood is specified as an f_1 value. For most elements, a single f_1 value is used for all chemical forms, but in some cases, there is sufficient information to support the use of different f_1 values for compounds of an element exhibiting different solubilities and intestinal absorption (Annex D). As explained in *Publications 66 and 68* (ICRP, 1994a,b), the solubility of particulate materials deposited in the respiratory tract is specified in terms of lung clearance types, with Types 'F', 'M', and 'S' referring to fast, moderate, and slow rates of absorption into blood, respectively. *Publications 66 and 68* also explain the treatment of inhaled gases and vapours, with Classes SR-0, SR-1, and SR-2 depending on solubility and reactivity. Class SR-0 applies to inert gases that are insoluble and non-reactive, for which dose coefficients take account of external irradiation from submersion in the cloud of gas, and internal irradiation from gas within the respiratory tract (Annex C). Class SR-2 applies to highly soluble and reactive gases and vapours, for which there is assumed to be complete and instantaneous absorption of all inhaled activity into blood. Class SR-1 applies to soluble and reactive gases and vapours, for which absorption into blood may account for less than 100% of inhaled activity.

1.2. Dose coefficients for intakes of radionuclides by members of the public

(4) Dose coefficients for intakes of radionuclides by 3-month-old infants, 1-, 5-, 10-, and 15-year-old children, and adults, as compiled in *Publication 72* (ICRP, 1996a), are reproduced in Annexes F, G, and H of this report. *Publication 72* dose coefficients were calculated using the *Publication 66* (ICRP, 1994a) model of the human respiratory tract and the *Publication 30* (ICRP, 1979) model of the gastrointestinal tract. The biokinetic models used to describe the distribution, retention, and excretion of radionuclides were developed to consider age dependence in the case of radioisotopes of the 31 elements for which dose coefficients were given in *Publications 56, 67, 69, and 71* (ICRP, 1990, 1992, 1995a,b). *Publication 72* also gave dose coefficients for radioisotopes of an additional 60 elements using biokinetic models developed for the *Publication 30* series (ICRP, 1979, 1980, 1981, 1988) for workers. The dose coefficients for the radioisotopes of these additional elements take account of age-related changes in intestinal absorption (f_1 values), body and organ masses, and excretion rates from the urinary bladder, but not in the biokinetics of organ retention and excretion following absorption into blood. It was stated in *Publication 72* that the use of adult biokinetic parameters in the calculation of dose coefficients for children will tend to overestimate doses because rates of elimination from tissues and excretion are generally greater at younger ages.

(5) Ingestion dose coefficients are given in Annex F, inhalation dose coefficients for intakes of particulate aerosols are given in Annex G, and dose coefficients for inhalation of soluble and reactive gases are given in Annex H. As explained in *Publications 56 and 72* (ICRP, 1990, 1996a), ingestion dose coefficients are calculated using higher f_1 values for 3-month-old infants than older individuals. For most elements, adult values are applied to 1-, 5-, 10-, and 15-year-old children. However, intermediate values are used for children in the cases of calcium, iron, cobalt, strontium, barium, lead, and radium (ICRP, 1990, 1996b). As explained in *Publications 71 and 72* (ICRP, 1995b, 1996a), inhalation dose coefficients are calculated assuming that clearance from the respiratory tract and absorption into blood is independent of age and sex. For particulate aerosols, an AMAD of 1 μm was used. Daily air intake, averaged over a 24-h period, was taken to be 2.9, 5.2, 8.7, 15, 20, and 22 m^3 for the 3-month-old infant, 1-, 5-, 10-, and 15-year-old children, and adult, respectively.

(6) The dose coefficients compiled in *Publications 68 and 72* (ICRP, 1994b, 1996a) have also been made available in electronic form on CD (ICRP, 1996c). In preparing the CD, small errors and methodological discrepancies were identified and rectified, leading to small changes in dose coefficients. The corrected values given on the CD are included in this report, and the changes are detailed in Chapter 2.

1.3. Conversion coefficients for external radiation

(7) Conversion coefficients for use in occupational radiological protection against external radiation, abstracted from *Publication 74* (ICRP, 1996b), are given in Annexes I, J, and K. These conversion coefficients were derived assuming whole-body irradiation by mono-energetic photons, electrons, and neutrons in a number of

idealised standard exposure geometries. The following describes the irradiation geometries used, shown schematically in Fig. 1.1.

(8) Antero-posterior geometry – the irradiation geometry in which a mono-energetic parallel beam of ionising radiation is incident on the front of the body in a direction orthogonal to the long axis of the body.

(9) Postero-anterior geometry – the irradiation geometry in which a mono-energetic parallel beam of ionising radiation is incident on the back of the body in a direction orthogonal to the long axis of the body.

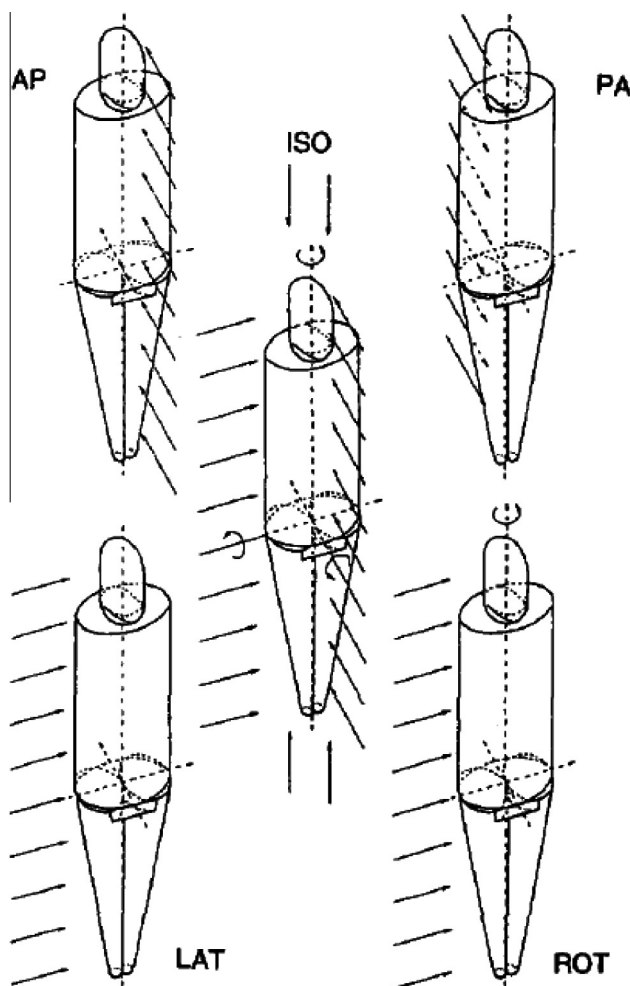


Fig. 1.1. Irradiation geometries of an anthropomorphic phantom. AP, antero-posterior; PA, postero-anterior; LAT, lateral; ROT, rotational; ISO, isotropic.

(10) Lateral geometry – the irradiation geometry in which a mono-energetic parallel beam of ionising radiation is incident from either side of the body in a direction orthogonal to the long axis of the body. When it is necessary to be more specific, right lateral (from the right side to the left side of the body) and left lateral (from the left side to the right side of the body) are used.

(11) Rotational geometry – the geometry in which the body is irradiated by a mono-energetic parallel beam of ionising radiation, from a direction orthogonal to the long axis of the body, which rotates at a uniform rate around the long axis. Alternatively, this geometry may be defined by rotating the body at a uniform rate about its long axis, while irradiating the body by a broad beam of ionising radiation from a stationary source located on an axis at right angles to the long axis of the body.

(12) Isotropic geometry – defined by a radiation field in which the mono-energetic particle fluence per unit of solid angle is independent of direction.

(13) The reader should refer to *Publication 74* (ICRP, 1996b) for additional information on these coefficients.

1.4. Contents of the supplemental Excel file

(14) A Microsoft Excel workbook accompanies this publication to provide the coefficients in machine-readable form. This file, named 'ICRP_2011.xls', includes one worksheet for each of the tables in the annexes of this publication. Comma separated variable (CSV) and flat ASCII files are also provided, containing exactly the same data as the Excel workbook but in more flexible formats. Further details regarding these files are given in Annex L.

2. DIFFERENCES BETWEEN THIS PUBLICATION AND *PUBLICATIONS 68 AND 72*

(15) During preparation of the ICRP Database of Dose Coefficients: Workers and Members of the Public CD1 (ICRP, 1996c), small errors were discovered in dose coefficients for protactinium-232 and uranium-231 in *Publications 68* and *72* (ICRP, 1994b, 1996a). These errors were addressed in the CD1 database, thus resulting in discrepancies between the database and the publications. For both radionuclides, the differences are less than 30%; the corrected values in the database are included in this report and shown in [Tables 2.1 and 2.2](#).

(16) In the calculation of dose coefficients for members of the public, improved biokinetic modelling was applied to radioactive progeny formed in body organs, as described in *Publication 71* (ICRP, 1995b). The revised methodology was applied consistently in the calculation of coefficients for the CD compilation (ICRP, 1996c), leading to some discrepancies from values given in *Publications 68* and *72* (ICRP, 1994b, 1996a). In most cases, the impact on effective dose coefficients is negligible, but differences of up to 30% were found for thorium-228.

(17) The ICRP Database of Dose Coefficients included dose coefficients for gases and vapour forms in the workplace that were not addressed in *Publication 68* (ICRP, 1994b) but were considered later in *Publication 71* (ICRP, 1996a). Thus, Annex B tabulates dose coefficients for tritiated methane, radiocarbon-labelled methane, ruthenium tetroxide, tellurium vapour, and methyl iodide that do not appear in *Publication 68*.

(18) The nuclear decay data used in the calculations of the dose coefficients of *Publications 68* and *72* (ICRP, 1994b, 1996a) were taken from *Publication 38* (ICRP, 1983). The physical data available during the preparation of *Publication 38* were insufficient to identify the ground and excited state of a few radionuclides. These nuclides were assigned an ad-hoc designation for the CD compilation (ICRP, 1996c) based on their physical half-life. The *Publication 107* (ICRP, 2008) update of *Publication 38* identified ground and excited states for these nuclides. The notation of *Publication 107* is used in the tabulations of this publication as shown in [Table 2.3](#).

Table 2.1. Correction to effective dose coefficients for ingested activity.

Nuclide	Age	f_1	Current*	Previous
Th-228	10 y	5.0E-04	1.4E-07	1.5E-07 [†]
Th-228	Worker	5.0E-04	7.2E-08	7.0E-08 [‡]
Pa-232	3 m	0.005	7.2E-09	6.3E-09 [†]
Pa-232	1 y	5.0E-04	4.3E-09	4.2E-09 [†]
Pa-232	5 y	5.0E-04	2.3E-09	2.2E-09 [†]
U-231	15 y	0.02	3.6E-10	3.5E-10 [†]

f_1 , fractional absorption in the gastrointestinal tract; m, months; y, years.

* Values given in CD1 (ICRP, 1996c) and included in Annexes A and F.

[†] Value given in *Publication 72* (ICRP, 1996a).

[‡] Value given in *Publication 68* (ICRP, 1994b).

Table 2.2. Corrections to effective dose coefficients for inhaled activity.

Nuclide	Age	AMAD	Type	Current*	Previous
Th-228	20 y	1	F	3.0E-05	2.9E-05 [†]
Th-228	15 y	1	F	3.5E-05	3.6E-05 [†]
Th-228	Worker	1	M	3.0E-05	3.1E-05 [‡]
Th-228	Worker	5	M	2.2E-05	2.3E-05 [‡]
Th-228	Worker	1	S	3.7E-05	3.9E-05 [‡]
Th-228	Worker	5	S	2.5E-05	3.2E-05 [‡]
U-231	20 y	1	F	6.4E-11	6.2E-11 [†]
U-231	20 y	1	M	4.7E-10	3.8E-10 [†]
U-231	20 y	1	S	5.2E-10	4.0E-10 [†]
U-231	3 m	1	F	1.0E-09	8.9E-10 [†]
U-231	3 m	1	M	2.5E-09	2.4E-09 [†]
U-231	3 m	1	S	2.7E-09	2.6E-09 [†]
U-231	1 y	1	F	6.8E-10	6.2E-10 [†]
U-231	1 y	1	M	2.0E-09	1.7E-09 [†]
U-231	1 y	1	S	2.0E-09	1.9E-09 [†]
U-231	5 y	1	F	3.2E-10	3.1E-10 [†]
U-231	5 y	1	M	1.0E-09	9.4E-10 [†]
U-231	5 y	1	S	1.1E-09	9.0E-10 [†]
U-231	10 y	1	F	1.5E-10	1.4E-10 [†]
U-231	10 y	1	M	6.9E-10	5.5E-10 [†]
U-231	10 y	1	S	7.7E-10	6.1E-10 [†]
U-231	15 y	1	M	5.7E-10	4.6E-10 [†]
U-231	15 y	1	S	6.3E-10	4.9E-10 [†]
U-231	Worker	1	F	6.7E-11	8.3E-11 [‡]
U-231	Worker	5	F	1.6E-10	1.4E-10 [‡]
U-231	Worker	1	M	4.3E-10	3.4E-10 [‡]
U-231	Worker	5	M	4.5E-10	3.7E-10 [‡]
U-231	Worker	1	S	4.8E-10	3.7E-10 [‡]
U-231	Worker	5	S	4.9E-10	4.0E-10 [‡]

* Values given in CD1 (ICRP, 1996c) and included in Annexes A and G.

[†] Value given in *Publication 72* (ICRP, 1996a).

[‡] Value given in *Publication 68* (ICRP, 1994b).

Table 2.3. Radionuclides for which *Publication 107* (ICRP, 2008) identifies ground and excited states.

CD1 Nuclide*	T _{1/2}	<i>Publication 107</i> Nuclide [†]
Nb-89s	66 m	Nb-89m
Nb-89l	122 m	Nb-89
Nb-98	51.5 m	Nb-98m
Rh-102	2.9 y	Rh-102m
Rh-102m	207 d	Rh-102
In-110s	69.1 m	In-110m
In-110l	4.9 h	In-110
Sb-120s	15.98 m	Sb-120
Sb-120l	5.76 d	Sb-120m
Sb-124ml	20.2 m	Sb-124n [‡]
Sb-128s	10.4 m	Sb-128m
Sb-128l	9.01 h	Sb-128
Eu-150s	12.62 h	Eu-150m
Eu-150l	34.2 y	Eu-150
Tb-156ms	5.0 h	Tb-156n [‡]
Tb-156ml	24.4 h	Tb-156m
Ta-178s	9.31 m	Ta-178
Ta-178l	2.2 h	Ta-178m
Ta-180m	8.1h	Ta-180
Ta-180	1.0E13 y	Ta-180m [§]
Re-182s	12.7 h	Re-182m
Re-182l	64.0 h	Re-182
Ir-186s	1.75 h	Ir-186m
Ir-186l	15.8 h	Ir-186
Ir-190ms	1.2 h	Ir-190m
Ir-190ml	3.1 h	Ir-190n [‡]
Ir-192m	241 y	Ir-192n [‡]
Np-236s	22.5 h	Np-236m
Np-236l	115E3 y	Np-236
Es-250	2.1 h	Es-250m

T_{1/2}, half-life; h, hours; d, days; m, months; y, years.

* Ad-hoc notations 's' and 'l' denote short and long physical half-lives employed in CD1 (ICRP, 1996c).

[†] W-176 and Re-177 are included in this compilation as addressed in CD1; however they were not addressed in *Publication 107*.

[‡] This metastable state is of higher energy than the first metastable state, and is hence denoted by 'n'.

[§] Half-life so long that the metastable state has never been observed to decay; Ta-180m is observationally stable and not addressed in *Publication 107*.

3. ASSESSMENT OF EFFECTIVE DOSE USING DOSE COEFFICIENTS

(19) The protection quantity ‘effective dose’ is the primary dose quantity of ICRP’s system of radiation protection. Effective dose, in a single quantity, characterises the exposure of an individual to both internal and external radiation sources in a manner that is independent of the individual’s body-related parameters, such as sex, age (for adults), anatomy, physiology, race, and other factors. In order to achieve wide applicability, the protection quantities (effective dose and equivalent dose) are defined using mathematical models with broad averaging of body-related parameter values. Specifically, anatomical and physiological parameters of reference individuals, collectively referred to as Reference Man, are given in *Publications* 23 and 89 (ICRP, 1975, 2002) which serve as the basis of reference biokinetic models describing the fate of inhaled and ingested radionuclides and as the basis of computational phantoms (Cristy and Eckerman, 1987) used in the calculation of dose coefficients for Reference Worker and members of the public (ICRP, 1994b, 1996c).

(20) Effective dose is not an individual-specific dose quantity, but rather the dose to a Reference Person under the specified exposure conditions. The Reference Person can be either a worker or a member of the public of a specified age.

(21) The model-based protection quantities, equivalent dose and effective dose, are not directly measurable and their values must be assessed using the results of measurements of the related physical quantities in combination with the dose coefficients given in this publication. For internal exposure, the dose can be inferred by measurement of the radionuclides in the air or in the human body and its excretions. In contrast, the operational quantities for exposure to external radiation fields are directly measurable.

3.1. Occupational exposures

(22) For external radiation of the body, it is possible to define a set of operational quantities for specific external exposure geometries which are measurable in terms of the basic physical quantities ‘fluence’ and ‘air kerma free-in-air’. The relationship between the physical and operational quantities is detailed in *Publication* 74 (ICRP, 1996b). Workplace and individual monitoring of external exposure by active or passive means is carried out with devices calibrated in terms of the operational quantities. Additional guidance on assessment of occupational exposure due to external sources of radiation is given by IAEA (1999a).

(23) The assessments of internal exposure of workers should be based on:

- prospective exposure parameters, such as the duration of exposure, concentration of radionuclides in the breathing zone, AMAD, and type of materials of radioactive aerosols; and/or
- retrospective parameters based on individual and workplace monitoring programmes, such as the content of radionuclides in the body and excreta, and integrated air concentrations.

(24) *Publication 78* (ICRP, 1997) and IAEA Safety Series 37 (IAEA, 2004) provide general guidance on the design of individual monitoring programmes and the interpretation of results of bioassay monitoring data. The intake (activity of a radionuclide entering the body by inhalation or ingestion) can be assessed from measurements of the retained or excreted activity using information in the ‘special monitoring’ tables in the annex of *Publication 78*. IAEA Safety Series 37 also contains information on the retention and excretion of selected radionuclides. In the case of air sampling, the intake is approximated by the product of the reference breathing rate, the observed air concentration, and the duration of the exposure. The committed effective dose is obtained by multiplying the worker’s activity intake by the tabulated effective dose coefficient for the indicated route of intake, typically inhalation. Additional guidance on assessment of occupational exposure due to intake of radionuclides is given by IAEA (1999b, 2004).

3.2. Public exposures

(25) The assessment of public exposure is typically based on so-called ‘source terms’ that list the radionuclides and their activity discharged from a nuclear facility through monitored release points, information on direct radiation from the facility, observed content of radionuclides in monitored environmental media (foodstuffs, drinking water, etc.), and information on habit data with regard to use of environmental media (exposure scenarios). To derive the annual committed effective dose, the dose coefficients given in this publication should be applied to the annual integrated airborne concentration of the radionuclide, or to the annual intake by inhalation and ingestion of environmental media.

(26) The individual monitoring of members of the public may be used in assessment of public exposure in emergency situations. In such situations, the interpretation of results of individual monitoring should be similar to the procedures described for workers, although dose coefficients for members of the public would be used.

(27) *Publication 101* (ICRP, 2006) provides further guidance on estimating dose to the representative person for public exposures. Detailed approaches to the formulation of monitoring programmes and the assessment of public exposure in planned, existing, and emergency exposure situations are provided by IAEA (2010).

APPENDIX A. SUPPLEMENTARY MATERIAL

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.ympev.2012.04.018>.

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ANNEX A. EFFECTIVE DOSE COEFFICIENTS FOR INGESTED AND INHALED PARTICULATES FOR WORKERS

Table A.1. Effective dose coefficients (e) for ingested and inhaled particulates (activity median aerodynamic diameters of 1 and 5 μm) for workers.

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Hydrogen							
H-3	12.35 y	See Table B.1 for inhalation dose coefficients				1.0 OBT 1.0 HTO	4.2E-11 1.8E-11
Beryllium							
Be-7	53.3 d	M	0.005	4.8E-11	4.3E-11	0.005	2.8E-11
		S	0.005	5.2E-11	4.6E-11		
Be-10	1.6E6 y	M	0.005	9.1E-09	6.7E-09	0.005	1.1E-09
		S	0.005	3.2E-08	1.9E-08		
Carbon							
C-11	20.38 m	See Table B.1 for inhalation dose coefficients				1.0	2.4E-11
C-14	5730 y	See Table B.1 for inhalation dose coefficients				1.0	5.8E-10
Fluorine							
F-18	109.77 m	F	1.0	3.0E-11	5.4E-11	1.0	4.9E-11
		M	1.0	5.7E-11	8.9E-11		
		S	1.0	6.0E-11	9.3E-11		
Sodium							
Na-22	2.602 y	F	1.0	1.3E-09	2.0E-09	1.0	3.2E-09
Na-24	15.00 h	F	1.0	2.9E-10	5.3E-10	1.0	4.3E-10
Magnesium							
Mg-28	20.91 h	F	0.5	6.4E-10	1.1E-09	0.5	2.2E-09
		M	0.5	1.2E-09	1.7E-09		
Aluminium							
Al-26	7.16E5 y	F	0.01	1.1E-08	1.4E-08	0.01	3.5E-09
		M	0.01	1.8E-08	1.2E-08		
Silicon							
Si-31	157.3 m	F	0.01	2.9E-11	5.1E-11	0.01	1.6E-10
		M	0.01	7.5E-11	1.1E-10		
		S	0.01	8.0E-11	1.1E-10		
Si-32	450 y	F	0.01	3.2E-09	3.7E-09	0.01	5.6E-10
		M	0.01	1.5E-08	9.6E-09		
		S	0.01	1.1E-07	5.5E-08		
Phosphorus							
P-32	14.29 d	F	0.8	8.0E-10	1.1E-09	0.8	2.4E-09
		M	0.8	3.2E-09	2.9E-09		

(continued on next page)

Table A.1. (*continued*)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
P-33	25.4 d	F	0.8	9.6E−11	1.4E−10	0.8	2.4E−10
		M	0.8	1.4E−09	1.3E−09		
Sulphur							
S-35	87.44 d	F	0.8	5.3E−11	8.0E−11	0.8*	1.4E−10
		M	0.8	1.3E−09	1.1E−09	0.1*	1.9E−10
		See Table B.1 for inhalation of organic sulphur				1.0†	7.7E−10
Chlorine							
Cl-36	3.01E5 y	F	1.0	3.4E−10	4.9E−10	1.0	9.3E−10
		M	1.0	6.9E−09	5.1E−09		
Cl-38	37.21 m	F	1.0	2.7E−11	4.6E−11	1.0	1.2E−10
		M	1.0	4.7E−11	7.3E−11		
Cl-39	55.6 m	F	1.0	2.7E−11	4.8E−11	1.0	8.5E−11
		M	1.0	4.8E−11	7.6E−11		
Potassium							
K-40	1.28E9 y	F	1.0	2.1E−09	3.0E−09	1.0	6.2E−09
K-42	12.36 h	F	1.0	1.3E−10	2.0E−10	1.0	4.3E−10
K-43	22.6 h	F	1.0	1.5E−10	2.6E−10	1.0	2.5E−10
K-44	22.13 m	F	1.0	2.1E−11	3.7E−11	1.0	8.4E−11
K-45	20 m	F	1.0	1.6E−11	2.8E−11	1.0	5.4E−11
Calcium							
Ca-41	1.4E5 y	M	0.3	1.7E−10	1.9E−10	0.3	2.9E−10
Ca-45	163 d	M	0.3	2.7E−09	2.3E−09	0.3	7.6E−10
Ca-47	4.53 d	M	0.3	1.8E−09	2.1E−09	0.3	1.6E−09
Scandium							
Sc-43	3.891 h	S	0.0001	1.2E−10	1.8E−10	0.0001	1.9E−10
Sc-44	3.927 h	S	0.0001	1.9E−10	3.0E−10	0.0001	3.5E−10
Sc-44m	58.6 h	S	0.0001	1.5E−09	2.0E−09	0.0001	2.4E−09
Sc-46	83.83 d	S	0.0001	6.4E−09	4.8E−09	0.0001	1.5E−09
Sc-47	3.351 d	S	0.0001	7.0E−10	7.3E−10	0.0001	5.4E−10
Sc-48	43.7 h	S	0.0001	1.1E−09	1.6E−09	0.0001	1.7E−09
Sc-49	57.4 m	S	0.0001	4.1E−11	6.1E−11	0.0001	8.2E−11
Titanium							
Ti-44	47.3 y	F	0.01	6.1E−08	7.2E−08	0.01	5.8E−09
		M	0.01	4.0E−08	2.7E−08		
		S	0.01	1.2E−07	6.2E−08		
Ti-45	3.08 h	F	0.01	4.6E−11	8.3E−11	0.01	1.5E−10
		M	0.01	9.1E−11	1.4E−10		
		S	0.01	9.6E−11	1.5E−10		
Vanadium							
V-47	32.6 m	F	0.01	1.9E−11	3.2E−11	0.01	6.3E−11
		M	0.01	3.1E−11	5.0E−11		

* Inorganic sulphur.

† Organic sulphur.

Table A.1. (continued)

Nuclide	$T_{1/2}$	Inhalation				Ingestion	
		Type	f_1	e (Sv/Bq) (1 μ m)	e (Sv/Bq) (5 μ m)	f_1	e (Sv/Bq)
V-48	16.238 d	F	0.01	1.1E-09	1.7E-09	0.01	2.0E-09
		M	0.01	2.3E-09	2.7E-09		
V-49	330 d	F	0.01	2.1E-11	2.6E-11	0.01	1.8E-11
		M	0.01	3.2E-11	2.3E-11		
Chromium							
Cr-48	22.96 h	F	0.1	1.0E-10	1.7E-10	0.1	2.0E-10
		M	0.1	2.0E-10	2.3E-10	0.01	2.0E-10
		S	0.1	2.2E-10	2.5E-10		
Cr-49	42.09 m	F	0.1	2.0E-11	3.5E-11	0.1	6.1E-11
		M	0.1	3.5E-11	5.6E-11	0.01	6.1E-11
		S	0.1	3.7E-11	5.9E-11		
Cr-51	27.704 d	F	0.1	2.1E-11	3.0E-11	0.1	3.8E-11
		M	0.1	3.1E-11	3.4E-11	0.01	3.7E-11
		S	0.1	3.6E-11	3.6E-11		
Manganese							
Mn-51	46.2 m	F	0.1	2.4E-11	4.2E-11	0.1	9.3E-11
		M	0.1	4.3E-11	6.8E-11		
Mn-52	5.591 d	F	0.1	9.9E-10	1.6E-09	0.1	1.8E-09
		M	0.1	1.4E-09	1.8E-09		
Mn-52m	21.1 m	F	0.1	2.0E-11	3.5E-11	0.1	6.9E-11
		M	0.1	3.0E-11	5.0E-11		
Mn-53	3.7E6 y	F	0.1	2.9E-11	3.6E-11	0.1	3.0E-11
		M	0.1	5.2E-11	3.6E-11		
Mn-54	312.5 d	F	0.1	8.7E-10	1.1E-09	0.1	7.1E-10
		M	0.1	1.5E-09	1.2E-09		
Mn-56	2.5785 h	F	0.1	6.9E-11	1.2E-10	0.1	2.5E-10
		M	0.1	1.3E-10	2.0E-10		
Iron							
Fe-52	8.275 h	F	0.1	4.1E-10	6.9E-10	0.1	1.4E-09
		M	0.1	6.3E-10	9.5E-10		
Fe-55	2.7 y	F	0.1	7.7E-10	9.2E-10	0.1	3.3E-10
		M	0.1	3.7E-10	3.3E-10		
Fe-59	44.529 d	F	0.1	2.2E-09	3.0E-09	0.1	1.8E-09
		M	0.1	3.5E-09	3.2E-09		
Fe-60	1E5 y	F	0.1	2.8E-07	3.3E-07	0.1	1.1E-07
		M	0.1	1.3E-07	1.2E-07		
Cobalt							
Co-55	17.54 h	M	0.1	5.1E-10	7.8E-10	0.1	1.0E-09
		S	0.05	5.5E-10	8.3E-10	0.05	1.1E-09
Co-56	78.76 d	M	0.1	4.6E-09	4.0E-09	0.1	2.5E-09
		S	0.05	6.3E-09	4.9E-09	0.05	2.3E-09
Co-57	270.9 d	M	0.1	5.2E-10	3.9E-10	0.1	2.1E-10
		S	0.05	9.4E-10	6.0E-10	0.05	1.9E-10
Co-58	70.80 d	M	0.1	1.5E-09	1.4E-09	0.1	7.4E-10
		S	0.05	2.0E-09	1.7E-09	0.05	7.0E-10

(continued on next page)

Table A.1. (*continued*)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Co-58m	9.15 h	M	0.1	1.3E−11	1.5E−11	0.1	2.4E−11
		S	0.05	1.6E−11	1.7E−11	0.05	2.4E−11
Co-60	5.271 y	M	0.1	9.6E−09	7.1E−09	0.1	3.4E−09
		S	0.05	2.9E−08	1.7E−08	0.05	2.5E−09
Co-60m	10.47 m	M	0.1	1.1E−12	1.2E−12	0.1	1.7E−12
		S	0.05	1.3E−12	1.2E−12	0.05	1.7E−12
Co-61	1.65 h	M	0.1	4.8E−11	7.1E−11	0.1	7.4E−11
		S	0.05	5.1E−11	7.5E−11	0.05	7.4E−11
Co-62m	13.91 m	M	0.1	2.1E−11	3.6E−11	0.1	4.7E−11
		S	0.05	2.2E−11	3.7E−11	0.05	4.7E−11
Nickel							
Ni-56	6.10 d	F	0.05	5.1E−10	7.9E−10	0.05	8.6E−10
		M	0.05	8.6E−10	9.6E−10		
Ni-57	36.08 h	F	0.05	2.8E−10	5.0E−10	0.05	8.7E−10
		M	0.05	5.1E−10	7.6E−10		
Ni-59	7.5E4 y	F	0.05	1.8E−10	2.2E−10	0.05	6.3E−11
		M	0.05	1.3E−10	9.4E−11		
Ni-63	96 y	F	0.05	4.4E−10	5.2E−10	0.05	1.5E−10
		M	0.05	4.4E−10	3.1E−10		
Ni-65	2.520 h	F	0.05	4.4E−11	7.5E−11	0.05	1.8E−10
		M	0.05	8.7E−11	1.3E−10		
Ni-66	54.6 h	F	0.05	4.5E−10	7.6E−10	0.05	3.0E−09
		M	0.05	1.6E−09	1.9E−09		
Copper							
Cu-60	23.2 m	F	0.5	2.4E−11	4.4E−11	0.5	7.0E−11
		M	0.5	3.5E−11	6.0E−11		
		S	0.5	3.6E−11	6.2E−11		
Cu-61	3.408 h	F	0.5	4.0E−11	7.3E−11	0.5	1.2E−10
		M	0.5	7.6E−11	1.2E−10		
		S	0.5	8.0E−11	1.2E−10		
Cu-64	12.701 h	F	0.5	3.8E−11	6.8E−11	0.5	1.2E−10
		M	0.5	1.1E−10	1.5E−10		
		S	0.5	1.2E−10	1.5E−10		
Cu-67	61.86 h	F	0.5	1.1E−10	1.8E−10	0.5	3.4E−10
		M	0.5	5.2E−10	5.3E−10		
		S	0.5	5.8E−10	5.8E−10		
Zinc							
Zn-62	9.26 h	S	0.5	4.7E−10	6.6E−10	0.5	9.4E−10
Zn-63	38.1 m	S	0.5	3.8E−11	6.1E−11	0.5	7.9E−11
Zn-65	243.9 d	S	0.5	2.9E−09	2.8E−09	0.5	3.9E−09
Zn-69	57 m	S	0.5	2.8E−11	4.3E−11	0.5	3.1E−11
Zn-69m	13.76 h	S	0.5	2.6E−10	3.3E−10	0.5	3.3E−10
Zn-71m	3.92 h	S	0.5	1.6E−10	2.4E−10	0.5	2.4E−10
Zn-72	46.5 h	S	0.5	1.2E−09	1.5E−09	0.5	1.4E−09

Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Gallium							
Ga-65	15.2 m	F	0.001	1.2E−11	2.0E−11	0.001	3.7E−11
		M	0.001	1.8E−11	2.9E−11		
Ga-66	9.40 h	F	0.001	2.7E−10	4.7E−10	0.001	1.2E−09
		M	0.001	4.6E−10	7.1E−10		
Ga-67	78.26 h	F	0.001	6.8E−11	1.1E−10	0.001	1.9E−10
		M	0.001	2.3E−10	2.8E−10		
Ga-68	68.0 m	F	0.001	2.8E−11	4.9E−11	0.001	1.0E−10
		M	0.001	5.1E−11	8.1E−11		
Ga-70	21.15 m	F	0.001	9.3E−12	1.6E−11	0.001	3.1E−11
		M	0.001	1.6E−11	2.6E−11		
Ga-72	14.1 h	F	0.001	3.1E−10	5.6E−10	0.001	1.1E−09
		M	0.001	5.5E−10	8.4E−10		
Ga-73	4.91 h	F	0.001	5.8E−11	1.0E−10	0.001	2.6E−10
		M	0.001	1.5E−10	2.0E−10		
Germanium							
Ge-66	2.27 h	F	1.0	5.7E−11	9.9E−11	1.0	1.0E−10
		M	1.0	9.2E−11	1.3E−10		
Ge-67	18.7 m	F	1.0	1.6E−11	2.8E−11	1.0	6.5E−11
		M	1.0	2.6E−11	4.2E−11		
Ge-68	288 d	F	1.0	5.4E−10	8.3E−10	1.0	1.3E−09
		M	1.0	1.3E−08	7.9E−09		
Ge-69	39.05 h	F	1.0	1.4E−10	2.5E−10	1.0	2.4E−10
		M	1.0	2.9E−10	3.7E−10		
Ge-71	11.8 d	F	1.0	5.0E−12	7.8E−12	1.0	1.2E−11
		M	1.0	1.0E−11	1.1E−11		
Ge-75	82.78 m	F	1.0	1.6E−11	2.7E−11	1.0	4.6E−11
		M	1.0	3.7E−11	5.4E−11		
Ge-77	11.30 h	F	1.0	1.5E−10	2.5E−10	1.0	3.3E−10
		M	1.0	3.6E−10	4.5E−10		
Ge-78	87 m	F	1.0	4.8E−11	8.1E−11	1.0	1.2E−10
		M	1.0	9.7E−11	1.4E−10		
Arsenic							
As-69	15.2 m	M	0.5	2.2E−11	3.5E−11	0.5	5.7E−11
As-70	52.6 m	M	0.5	7.2E−11	1.2E−10	0.5	1.3E−10
As-71	64.8 h	M	0.5	4.0E−10	5.0E−10	0.5	4.6E−10
As-72	26.0 h	M	0.5	9.2E−10	1.3E−09	0.5	1.8E−09
As-73	80.30 d	M	0.5	9.3E−10	6.5E−10	0.5	2.6E−10
As-74	17.76 d	M	0.5	2.1E−09	1.8E−09	0.5	1.3E−09
As-76	26.32 h	M	0.5	7.4E−10	9.2E−10	0.5	1.6E−09
As-77	38.8 h	M	0.5	3.8E−10	4.2E−10	0.5	4.0E−10
As-78	90.7 m	M	0.5	9.2E−11	1.4E−10	0.5	2.1E−10
Selenium							
Se-70	41.0 m	F	0.8	4.5E−11	8.2E−11	0.8	1.2E−10
		M	0.8	7.3E−11	1.2E−10	0.05	1.4E−10

(continued on next page)

Table A.1. (continued)

Nuclide	T _{1/2}	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Se-73	7.15 h	F	0.8	8.6E−11	1.5E−10	0.8	2.1E−10
		M	0.8	1.6E−10	2.4E−10	0.05	3.9E−10
Se-73m	39 m	F	0.8	9.9E−12	1.7E−11	0.8	2.8E−11
		M	0.8	1.8E−11	2.7E−11	0.05	4.1E−11
Se-75	119.8 d	F	0.8	1.0E−09	1.4E−09	0.8	2.6E−09
		M	0.8	1.4E−09	1.7E−09	0.05	4.1E−10
Se-79	65000 y	F	0.8	1.2E−09	1.6E−09	0.8	2.9E−09
		M	0.8	2.9E−09	3.1E−09	0.05	3.9E−10
Se-81	18.5 m	F	0.8	8.6E−12	1.4E−11	0.8	2.7E−11
		M	0.8	1.5E−11	2.4E−11	0.05	2.7E−11
Se-81m	57.25 m	F	0.8	1.7E−11	3.0E−11	0.8	5.3E−11
		M	0.8	4.7E−11	6.8E−11	0.05	5.9E−11
Se-83	22.5 m	F	0.8	1.9E−11	3.4E−11	0.8	4.7E−11
		M	0.8	3.3E−11	5.3E−11	0.05	5.1E−11
Bromine							
Br-74	25.3 m	F	1.0	2.8E−11	5.0E−11	1.0	8.4E−11
		M	1.0	4.1E−11	6.8E−11		
Br-74m	41.5 m	F	1.0	4.2E−11	7.5E−11	1.0	1.4E−10
		M	1.0	6.5E−11	1.1E−10		
Br-75	98 m	F	1.0	3.1E−11	5.6E−11	1.0	7.9E−11
		M	1.0	5.5E−11	8.5E−11		
Br-76	16.2 h	F	1.0	2.6E−10	4.5E−10	1.0	4.6E−10
		M	1.0	4.2E−10	5.8E−10		
Br-77	56 h	F	1.0	6.7E−11	1.2E−10	1.0	9.6E−11
		M	1.0	8.7E−11	1.3E−10		
Br-80	17.4 m	F	1.0	6.3E−12	1.1E−11	1.0	3.1E−11
		M	1.0	1.0E−11	1.7E−11		
Br-80m	4.42 h	F	1.0	3.5E−11	5.8E−11	1.0	1.1E−10
		M	1.0	7.6E−11	1.0E−10		
Br-82	35.30 h	F	1.0	3.7E−10	6.4E−10	1.0	5.4E−10
		M	1.0	6.4E−10	8.8E−10		
Br-83	2.39 h	F	1.0	1.7E−11	2.9E−11	1.0	4.3E−11
		M	1.0	4.8E−11	6.7E−11		
Br-84	31.80 m	F	1.0	2.3E−11	4.0E−11	1.0	8.8E−11
		M	1.0	3.9E−11	6.2E−11		
Rubidium							
Rb-79	22.9 m	F	1.0	1.7E−11	3.0E−11	1.0	5.0E−11
Rb-81	4.58 h	F	1.0	3.7E−11	6.8E−11	1.0	5.4E−11
Rb-81m	32 m	F	1.0	7.3E−12	1.3E−11	1.0	9.7E−12
Rb-82m	6.2 h	F	1.0	1.2E−10	2.2E−10	1.0	1.3E−10
Rb-83	86.2 d	F	1.0	7.1E−10	1.0E−09	1.0	1.9E−09
Rb-84	32.77 d	F	1.0	1.1E−09	1.5E−09	1.0	2.8E−09
Rb-86	18.66 d	F	1.0	9.6E−10	1.3E−09	1.0	2.8E−09
Rb-87	4.7E10 y	F	1.0	5.1E−10	7.6E−10	1.0	1.5E−09
Rb-88	17.8 m	F	1.0	1.7E−11	2.8E−11	1.0	9.0E−11

Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Rb-89	15.2 m	F	1.0	1.4E−11	2.5E−11	1.0	4.7E−11
Strontium							
Sr-80	100 m	F	0.3	7.6E−11	1.3E−10	0.3	3.4E−10
		S	0.01	1.4E−10	2.1E−10	0.01	3.5E−10
Sr-81	25.5 m	F	0.3	2.2E−11	3.9E−11	0.3	7.7E−11
		S	0.01	3.8E−11	6.1E−11	0.01	7.8E−11
Sr-82	25.0 d	F	0.3	2.2E−09	3.3E−09	0.3	6.1E−09
		S	0.01	1.0E−08	7.7E−09	0.01	6.0E−09
Sr-83	32.4 h	F	0.3	1.7E−10	3.0E−10	0.3	4.9E−10
		S	0.01	3.4E−10	4.9E−10	0.01	5.8E−10
Sr-85	64.84 d	F	0.3	3.9E−10	5.6E−10	0.3	5.6E−10
		S	0.01	7.7E−10	6.4E−10	0.01	3.3E−10
Sr-85m	69.5 m	F	0.3	3.1E−12	5.6E−12	0.3	6.1E−12
		S	0.01	4.5E−12	7.4E−12	0.01	6.1E−12
Sr-87m	2.805 h	F	0.3	1.2E−11	2.2E−11	0.3	3.0E−11
		S	0.01	2.2E−11	3.5E−11	0.01	3.3E−11
Sr-89	50.5 d	F	0.3	1.0E−09	1.4E−09	0.3	2.6E−09
		S	0.01	7.5E−09	5.6E−09	0.01	2.3E−09
Sr-90	29.12 y	F	0.3	2.4E−08	3.0E−08	0.3	2.8E−08
		S	0.01	1.5E−07	7.7E−08	0.01	2.7E−09
Sr-91	9.5 h	F	0.3	1.7E−10	2.9E−10	0.3	6.5E−10
		S	0.01	4.1E−10	5.7E−10	0.01	7.6E−10
Sr-92	2.71 h	F	0.3	1.1E−10	1.8E−10	0.3	4.3E−10
		S	0.01	2.3E−10	3.4E−10	0.01	4.9E−10
Yttrium							
Y-86	14.74 h	M	0.0001	4.8E−10	8.0E−10	0.0001	9.6E−10
		S	0.0001	4.9E−10	8.1E−10		
Y-86m	48 m	M	0.0001	2.9E−11	4.8E−11	0.0001	5.6E−11
		S	0.0001	3.0E−11	4.9E−11		
Y-87	80.3 h	M	0.0001	3.8E−10	5.2E−10	0.0001	5.5E−10
		S	0.0001	4.0E−10	5.3E−10		
Y-88	106.64 d	M	0.0001	3.9E−09	3.3E−09	0.0001	1.3E−09
		S	0.0001	4.1E−09	3.0E−09		
Y-90	64.0 h	M	0.0001	1.4E−09	1.6E−09	0.0001	2.7E−09
		S	0.0001	1.5E−09	1.7E−09		
Y-90m	3.19 h	M	0.0001	9.6E−11	1.3E−10	0.0001	1.7E−10
		S	0.0001	1.0E−10	1.3E−10		
Y-91	58.51 d	M	0.0001	6.7E−09	5.2E−09	0.0001	2.4E−09
		S	0.0001	8.4E−09	6.1E−09		
Y-91m	49.71 m	M	0.0001	1.0E−11	1.4E−11	0.0001	1.1E−11
		S	0.0001	1.1E−11	1.5E−11		
Y-92	3.54 h	M	0.0001	1.9E−10	2.7E−10	0.0001	4.9E−10
		S	0.0001	2.0E−10	2.8E−10		
Y-93	10.1 h	M	0.0001	4.1E−10	5.7E−10	0.0001	1.2E−09
		S	0.0001	4.3E−10	6.0E−10		

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Table A.1. (*continued*)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Y-94	19.1 m	M	0.0001	2.8E−11	4.4E−11	0.0001	8.1E−11
		S	0.0001	2.9E−11	4.6E−11		
Y-95	10.7 m	M	0.0001	1.6E−11	2.5E−11	0.0001	4.6E−11
		S	0.0001	1.7E−11	2.6E−11		
Zirconium							
Zr-86	16.5 h	F	0.002	3.0E−10	5.2E−10	0.002	8.6E−10
		M	0.002	4.3E−10	6.8E−10		
		S	0.002	4.5E−10	7.0E−10		
Zr-88	83.4 d	F	0.002	3.5E−09	4.1E−09	0.002	3.3E−10
		M	0.002	2.5E−09	1.7E−09		
		S	0.002	3.3E−09	1.8E−09		
Zr-89	78.43 h	F	0.002	3.1E−10	5.2E−10	0.002	7.9E−10
		M	0.002	5.3E−10	7.2E−10		
		S	0.002	5.5E−10	7.5E−10		
Zr-93	1.53E6 y	F	0.002	2.5E−08	2.9E−08	0.002	2.8E−10
		M	0.002	9.6E−09	6.6E−09		
		S	0.002	3.1E−09	1.7E−09		
Zr-95	63.98 d	F	0.002	2.5E−09	3.0E−09	0.002	8.8E−10
		M	0.002	4.5E−09	3.6E−09		
		S	0.002	5.5E−09	4.2E−09		
Zr-97	16.90 h	F	0.002	4.2E−10	7.4E−10	0.002	2.1E−09
		M	0.002	9.4E−10	1.3E−09		
		S	0.002	1.0E−09	1.4E−09		
Niobium							
Nb-88	14.3 m	M	0.01	2.9E−11	4.8E−11	0.01	6.3E−11
		S	0.01	3.0E−11	5.0E−11		
Nb-89	122 m	M	0.01	1.2E−10	1.8E−10	0.01	3.0E−10
		S	0.01	1.3E−10	1.9E−10		
Nb-89m	66 m	M	0.01	7.1E−11	1.1E−10	0.01	1.4E−10
		S	0.01	7.4E−11	1.2E−10		
Nb-90	14.60 h	M	0.01	6.6E−10	1.0E−09	0.01	1.2E−09
		S	0.01	6.9E−10	1.1E−09		
Nb-93m	13.6 y	M	0.01	4.6E−10	2.9E−10	0.01	1.2E−10
		S	0.01	1.6E−09	8.6E−10		
Nb-94	2.03E4 y	M	0.01	1.0E−08	7.2E−09	0.01	1.7E−09
		S	0.01	4.5E−08	2.5E−08		
Nb-95	35.15 d	M	0.01	1.4E−09	1.3E−09	0.01	5.8E−10
		S	0.01	1.6E−09	1.3E−09		
Nb-95m	86.6 h	M	0.01	7.6E−10	7.7E−10	0.01	5.6E−10
		S	0.01	8.5E−10	8.5E−10		
Nb-96	23.35 h	M	0.01	6.5E−10	9.7E−10	0.01	1.1E−09
		S	0.01	6.8E−10	1.0E−09		
Nb-97	72.1 m	M	0.01	4.4E−11	6.9E−11	0.01	6.8E−11
		S	0.01	4.7E−11	7.2E−11		
Nb-98m	51.5 m	M	0.01	5.9E−11	9.6E−11	0.01	1.1E−10
		S	0.01	6.1E−11	9.9E−11		

Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Molybdenum							
Mo-90	5.67 h	F	0.8	1.7E−10	2.9E−10	0.8	3.1E−10
		S	0.05	3.7E−10	5.6E−10	0.05	6.2E−10
Mo-93	3.5E3 y	F	0.8	1.0E−09	1.4E−09	0.8	2.6E−09
		S	0.05	2.2E−09	1.2E−09	0.05	2.0E−10
Mo-93m	6.85 h	F	0.8	1.0E−10	1.9E−10	0.8	1.6E−10
		S	0.05	1.8E−10	3.0E−10	0.05	2.8E−10
Mo-99	66.0 h	F	0.8	2.3E−10	3.6E−10	0.8	7.4E−10
		S	0.05	9.7E−10	1.1E−09	0.05	1.2E−09
Mo-101	14.62 m	F	0.8	1.5E−11	2.7E−11	0.8	4.2E−11
		S	0.05	2.7E−11	4.5E−11	0.05	4.2E−11
Technetium							
Tc-93	2.75 h	F	0.8	3.4E−11	6.2E−11	0.8	4.9E−11
		M	0.8	3.6E−11	6.5E−11		
Tc-93m	43.5 m	F	0.8	1.5E−11	2.6E−11	0.8	2.4E−11
		M	0.8	1.7E−11	3.1E−11		
Tc-94	293 m	F	0.8	1.2E−10	2.1E−10	0.8	1.8E−10
		M	0.8	1.3E−10	2.2E−10		
Tc-94m	52 m	F	0.8	4.3E−11	6.9E−11	0.8	1.1E−10
		M	0.8	4.9E−11	8.0E−11		
Tc-95	20.0 h	F	0.8	1.0E−10	1.8E−10	0.8	1.6E−10
		M	0.8	1.0E−10	1.8E−10		
Tc-95m	61 d	F	0.8	3.1E−10	4.8E−10	0.8	6.2E−10
		M	0.8	8.7E−10	8.6E−10		
Tc-96	4.28 d	F	0.8	6.0E−10	9.8E−10	0.8	1.1E−09
		M	0.8	7.1E−10	1.0E−09		
Tc-96m	51.5 m	F	0.8	6.5E−12	1.1E−11	0.8	1.3E−11
		M	0.8	7.7E−12	1.1E−11		
Tc-97	2.6E6 y	F	0.8	4.5E−11	7.2E−11	0.8	8.3E−11
		M	0.8	2.1E−10	1.6E−10		
Tc-97m	87 d	F	0.8	2.8E−10	4.0E−10	0.8	6.6E−10
		M	0.8	3.1E−09	2.7E−09		
Tc-98	4.2E6 y	F	0.8	1.0E−09	1.5E−09	0.8	2.3E−09
		M	0.8	8.1E−09	6.1E−09		
Tc-99	2.13E5 y	F	0.8	2.9E−10	4.0E−10	0.8	7.8E−10
		M	0.8	3.9E−09	3.2E−09		
Tc-99m	6.02 h	F	0.8	1.2E−11	2.0E−11	0.8	2.2E−11
		M	0.8	1.9E−11	2.9E−11		
Tc-101	14.2 m	F	0.8	8.7E−12	1.5E−11	0.8	1.9E−11
		M	0.8	1.3E−11	2.1E−11		
Tc-104	18.2 m	F	0.8	2.4E−11	3.9E−11	0.8	8.1E−11
		M	0.8	3.0E−11	4.8E−11		
Ruthenium							
Ru-94	51.8 m	F	0.05	2.7E−11	4.9E−11	0.05	9.4E−11
		M	0.05	4.4E−11	7.2E−11		
		S	0.05	4.6E−11	7.4E−11		

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Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Ru-97	2.9 d	F	0.05	6.7E−11	1.2E−10	0.05	1.5E−10
		M	0.05	1.1E−10	1.6E−10		
		S	0.05	1.1E−10	1.6E−10		
Ru-103	39.28 d	F	0.05	4.9E−10	6.8E−10	0.05	7.3E−10
		M	0.05	2.3E−09	1.9E−09		
		S	0.05	2.8E−09	2.2E−09		
Ru-105	4.44 h	F	0.05	7.1E−11	1.3E−10	0.05	2.6E−10
		M	0.05	1.7E−10	2.4E−10		
		S	0.05	1.8E−10	2.5E−10		
Ru-106	368.2 d	F	0.05	8.0E−09	9.8E−09	0.05	7.0E−09
		M	0.05	2.6E−08	1.7E−08		
		S	0.05	6.2E−08	3.5E−08		
Rhodium							
Rh-99	16 d	F	0.05	3.3E−10	4.9E−10	0.05	5.1E−10
		M	0.05	7.3E−10	8.2E−10		
		S	0.05	8.3E−10	8.9E−10		
Rh-99m	4.7 h	F	0.05	3.0E−11	5.7E−11	0.05	6.6E−11
		M	0.05	4.1E−11	7.2E−11		
		S	0.05	4.3E−11	7.3E−11		
Rh-100	20.8 h	F	0.05	2.8E−10	5.1E−10	0.05	7.1E−10
		M	0.05	3.6E−10	6.2E−10		
		S	0.05	3.7E−10	6.3E−10		
Rh-101	3.2 y	F	0.05	1.4E−09	1.7E−09	0.05	5.5E−10
		M	0.05	2.2E−09	1.7E−09		
		S	0.05	5.0E−09	3.1E−09		
Rh-101m	4.34 d	F	0.05	1.0E−10	1.7E−10	0.05	2.2E−10
		M	0.05	2.0E−10	2.5E−10		
		S	0.05	2.1E−10	2.7E−10		
Rh-102m	2.9 y	F	0.05	7.3E−09	8.9E−09	0.05	2.6E−09
		M	0.05	6.5E−09	5.0E−09		
		S	0.05	1.6E−08	9.0E−09		
Rh-102	207 d	F	0.05	1.5E−09	1.9E−09	0.05	1.2E−09
		M	0.05	3.8E−09	2.7E−09		
		S	0.05	6.7E−09	4.2E−09		
Rh-103m	56.12 m	F	0.05	8.6E−13	1.2E−12	0.05	3.8E−12
		M	0.05	2.3E−12	2.4E−12		
		S	0.05	2.5E−12	2.5E−12		
Rh-105	35.36 h	F	0.05	8.7E−11	1.5E−10	0.05	3.7E−10
		M	0.05	3.1E−10	4.1E−10		
		S	0.05	3.4E−10	4.4E−10		
Rh-106m	132 m	F	0.05	7.0E−11	1.3E−10	0.05	1.6E−10
		M	0.05	1.1E−10	1.8E−10		
		S	0.05	1.2E−10	1.9E−10		
Rh-107	21.7 m	F	0.05	9.6E−12	1.6E−11	0.05	2.4E−11
		M	0.05	1.7E−11	2.7E−11		
		S	0.05	1.7E−11	2.8E−11		

Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Palladium							
Pd-100	3.63 d	F	0.005	4.9E−10	7.6E−10	0.005	9.4E−10
		M	0.005	7.9E−10	9.5E−10		
		S	0.005	8.3E−10	9.7E−10		
Pd-101	8.27 h	F	0.005	4.2E−11	7.5E−11	0.005	9.4E−11
		M	0.005	6.2E−11	9.8E−11		
		S	0.005	6.4E−11	1.0E−10		
Pd-103	16.96 d	F	0.005	9.0E−11	1.2E−10	0.005	1.9E−10
		M	0.005	3.5E−10	3.0E−10		
		S	0.005	4.0E−10	2.9E−10		
Pd-107	6.5E6 y	F	0.005	2.6E−11	3.3E−11	0.005	3.7E−11
		M	0.005	8.0E−11	5.2E−11		
		S	0.005	5.5E−10	2.9E−10		
Pd-109	13.427 h	F	0.005	1.2E−10	2.1E−10	0.005	5.5E−10
		M	0.005	3.4E−10	4.7E−10		
		S	0.005	3.6E−10	5.0E−10		
Silver							
Ag-102	12.9 m	F	0.05	1.4E−11	2.4E−11	0.05	4.0E−11
		M	0.05	1.8E−11	3.2E−11		
		S	0.05	1.9E−11	3.2E−11		
Ag-103	65.7 m	F	0.05	1.6E−11	2.8E−11	0.05	4.3E−11
		M	0.05	2.7E−11	4.3E−11		
		S	0.05	2.8E−11	4.5E−11		
Ag-104	69.2 m	F	0.05	3.0E−11	5.7E−11	0.05	6.0E−11
		M	0.05	3.9E−11	6.9E−11		
		S	0.05	4.0E−11	7.1E−11		
Ag-104m	33.5 m	F	0.05	1.7E−11	3.1E−11	0.05	5.4E−11
		M	0.05	2.6E−11	4.4E−11		
		S	0.05	2.7E−11	4.5E−11		
Ag-105	41.0 d	F	0.05	5.4E−10	8.0E−10	0.05	4.7E−10
		M	0.05	6.9E−10	7.0E−10		
		S	0.05	7.8E−10	7.3E−10		
Ag-106	23.96 m	F	0.05	9.8E−12	1.7E−11	0.05	3.2E−11
		M	0.05	1.6E−11	2.6E−11		
		S	0.05	1.6E−11	2.7E−11		
Ag-106m	8.41 d	F	0.05	1.1E−09	1.6E−09	0.05	1.5E−09
		M	0.05	1.1E−09	1.5E−09		
		S	0.05	1.1E−09	1.4E−09		
Ag-108m	127 y	F	0.05	6.1E−09	7.3E−09	0.05	2.3E−09
		M	0.05	7.0E−09	5.2E−09		
		S	0.05	3.5E−08	1.9E−08		
Ag-110m	249.9 d	F	0.05	5.5E−09	6.7E−09	0.05	2.8E−09
		M	0.05	7.2E−09	5.9E−09		
		S	0.05	1.2E−08	7.3E−09		

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Table A.1. (*continued*)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Ag-111	7.45 d	F	0.05	4.1E−10	5.7E−10	0.05	1.3E−09
		M	0.05	1.5E−09	1.5E−09		
		S	0.05	1.7E−09	1.6E−09		
Ag-112	3.12 h	F	0.05	8.2E−11	1.4E−10	0.05	4.3E−10
		M	0.05	1.7E−10	2.5E−10		
		S	0.05	1.8E−10	2.6E−10		
Ag-115	20.0 m	F	0.05	1.6E−11	2.6E−11	0.05	6.0E−11
		M	0.05	2.8E−11	4.3E−11		
		S	0.05	3.0E−11	4.4E−11		
Cadmium							
Cd-104	57.7 m	F	0.05	2.7E−11	5.0E−11	0.05	5.8E−11
		M	0.05	3.6E−11	6.2E−11		
		S	0.05	3.7E−11	6.3E−11		
Cd-107	6.49 h	F	0.05	2.3E−11	4.2E−11	0.05	6.2E−11
		M	0.05	8.1E−11	1.0E−10		
		S	0.05	8.7E−11	1.1E−10		
Cd-109	464 d	F	0.05	8.1E−09	9.6E−09	0.05	2.0E−09
		M	0.05	6.2E−09	5.1E−09		
		S	0.05	5.8E−09	4.4E−09		
Cd-113	9.3E15 y	F	0.05	1.2E−07	1.4E−07	0.05	2.5E−08
		M	0.05	5.3E−08	4.3E−08		
		S	0.05	2.5E−08	2.1E−08		
Cd-113m	13.6 y	F	0.05	1.1E−07	1.3E−07	0.05	2.3E−08
		M	0.05	5.0E−08	4.0E−08		
		S	0.05	3.0E−08	2.4E−08		
Cd-115	53.46 h	F	0.05	3.7E−10	5.4E−10	0.05	1.4E−09
		M	0.05	9.7E−10	1.2E−09		
		S	0.05	1.1E−09	1.3E−09		
Cd-115m	44.6 d	F	0.05	5.3E−09	6.4E−09	0.05	3.3E−09
		M	0.05	5.9E−09	5.5E−09		
		S	0.05	7.3E−09	5.5E−09		
Cd-117	2.49 h	F	0.05	7.3E−11	1.3E−10	0.05	2.8E−10
		M	0.05	1.6E−10	2.4E−10		
		S	0.05	1.7E−10	2.5E−10		
Cd-117m	3.36 h	F	0.05	1.0E−10	1.9E−10	0.05	2.8E−10
		M	0.05	2.0E−10	3.1E−10		
		S	0.05	2.1E−10	3.2E−10		
Indium							
In-109	4.2 h	F	0.02	3.2E−11	5.7E−11	0.02	6.6E−11
		M	0.02	4.4E−11	7.3E−11		
In-110	4.9 h	F	0.02	1.2E−10	2.2E−10	0.02	2.4E−10
		M	0.02	1.4E−10	2.5E−10		
In-110m	69.1 m	F	0.02	3.1E−11	5.5E−11	0.02	1.0E−10
		M	0.02	5.0E−11	8.1E−11		
In-111	2.83 d	F	0.02	1.3E−10	2.2E−10	0.02	2.9E−10
		M	0.02	2.3E−10	3.1E−10		

Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
In-112	14.4 m	F	0.02	5.0E−12	8.6E−12	0.02	1.0E−11
		M	0.02	7.8E−12	1.3E−11		
In-113m	1.658 h	F	0.02	1.0E−11	1.9E−11	0.02	2.8E−11
		M	0.02	2.0E−11	3.2E−11		
In-114m	49.51 d	F	0.02	9.3E−09	1.1E−08	0.02	4.1E−09
		M	0.02	5.9E−09	5.9E−09		
In-115	5.1E15 y	F	0.02	3.9E−07	4.5E−07	0.02	3.2E−08
		M	0.02	1.5E−07	1.1E−07		
In-115m	4.486 h	F	0.02	2.5E−11	4.5E−11	0.02	8.6E−11
		M	0.02	6.0E−11	8.7E−11		
In-116m	54.15 m	F	0.02	3.0E−11	5.5E−11	0.02	6.4E−11
		M	0.02	4.8E−11	8.0E−11		
In-117	43.8 m	F	0.02	1.6E−11	2.8E−11	0.02	3.1E−11
		M	0.02	3.0E−11	4.8E−11		
In-117m	116.5 m	F	0.02	3.1E−11	5.5E−11	0.02	1.2E−10
		M	0.02	7.3E−11	1.1E−10		
In-119m	18.0 m	F	0.02	1.1E−11	1.8E−11	0.02	4.7E−11
		M	0.02	1.8E−11	2.9E−11		
Tin							
Sn-110	4.0 h	F	0.02	1.1E−10	1.9E−10	0.02	3.5E−10
		M	0.02	1.6E−10	2.6E−10		
Sn-111	35.3 m	F	0.02	8.3E−12	1.5E−11	0.02	2.3E−11
		M	0.02	1.4E−11	2.2E−11		
Sn-113	115.1 d	F	0.02	5.4E−10	7.9E−10	0.02	7.3E−10
		M	0.02	2.5E−09	1.9E−09		
Sn-117m	13.61 d	F	0.02	2.9E−10	3.9E−10	0.02	7.1E−10
		M	0.02	2.3E−09	2.2E−09		
Sn-119m	293.0 d	F	0.02	2.9E−10	3.6E−10	0.02	3.4E−10
		M	0.02	2.0E−09	1.5E−09		
Sn-121	27.06 h	F	0.02	6.4E−11	1.0E−10	0.02	2.3E−10
		M	0.02	2.2E−10	2.8E−10		
Sn-121m	55 y	F	0.02	8.0E−10	9.7E−10	0.02	3.8E−10
		M	0.02	4.2E−09	3.3E−09		
Sn-123	129.2 d	F	0.02	1.2E−09	1.6E−09	0.02	2.1E−09
		M	0.02	7.7E−09	5.6E−09		
Sn-123m	40.08 m	F	0.02	1.4E−11	2.4E−11	0.02	3.8E−11
		M	0.02	2.8E−11	4.4E−11		
Sn-125	9.64 d	F	0.02	9.2E−10	1.3E−09	0.02	3.1E−09
		M	0.02	3.0E−09	2.8E−09		
Sn-126	1.0E5 y	F	0.02	1.1E−08	1.4E−08	0.02	4.7E−09
		M	0.02	2.7E−08	1.8E−08		
Sn-127	2.10 h	F	0.02	6.9E−11	1.2E−10	0.02	2.0E−10
		M	0.02	1.3E−10	2.0E−10		
Sn-128	59.1 m	F	0.02	5.4E−11	9.5E−11	0.02	1.5E−10
		M	0.02	9.6E−11	1.5E−10		

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Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Antimony							
Sb-115	31.8 m	F	0.1	9.2E−12	1.7E−11	0.1	2.4E−11
		M	0.01	1.4E−11	2.3E−11		
Sb-116	15.8 m	F	0.1	9.9E−12	1.8E−11	0.1	2.6E−11
		M	0.01	1.4E−11	2.3E−11		
Sb-116m	60.3 m	F	0.1	3.5E−11	6.4E−11	0.1	6.7E−11
		M	0.01	5.0E−11	8.5E−11		
Sb-117	2.80 h	F	0.1	9.3E−12	1.7E−11	0.1	1.8E−11
		M	0.01	1.7E−11	2.7E−11		
Sb-118m	5.00 h	F	0.1	1.0E−10	1.9E−10	0.1	2.1E−10
		M	0.01	1.3E−10	2.3E−10		
Sb-119	38.1 h	F	0.1	2.5E−11	4.5E−11	0.1	8.1E−11
		M	0.01	3.7E−11	5.9E−11		
Sb-120m	5.76 d	F	0.1	5.9E−10	9.8E−10	.1	1.2E−09
		M	0.01	1.0E−09	1.3E−09		
Sb-120	15.89 m	F	0.1	4.9E−12	8.5E−12	0.1	1.4E−11
		M	0.01	7.4E−12	1.2E−11		
Sb-122	2.70 d	F	0.1	3.9E−10	6.3E−10	0.1	1.7E−09
		M	0.01	1.0E−09	1.2E−09		
Sb-124	60.20 d	F	0.1	1.3E−09	1.9E−09	0.1	2.5E−09
		M	0.01	6.1E−09	4.7E−09		
Sb-124n	20.2 m	F	0.1	3.0E−12	5.3E−12	0.1	8.0E−12
		M	0.01	5.5E−12	8.3E−12		
Sb-125	2.77 y	F	0.1	1.4E−09	1.7E−09	0.1	1.1E−09
		M	0.01	4.5E−09	3.3E−09		
Sb-126	12.4 d	F	0.1	1.1E−09	1.7E−09	0.1	2.4E−09
		M	0.01	2.7E−09	3.2E−09		
Sb-126m	19.0 m	F	0.1	1.3E−11	2.3E−11	0.1	3.6E−11
		M	0.01	2.0E−11	3.3E−11		
Sb-127	3.85 d	F	0.1	4.6E−10	7.4E−10	0.1	1.7E−09
		M	0.01	1.6E−09	1.7E−09		
Sb-128	9.01 h	F	0.1	2.5E−10	4.6E−10	0.1	7.6E−10
		M	0.01	4.2E−10	6.7E−10		
Sb-128m	10.4 m	F	0.1	1.1E−11	1.9E−11	0.1	3.3E−11
		M	0.01	1.5E−11	2.6E−11		
Sb-129	4.32 h	F	0.1	1.1E−10	2.0E−10	0.1	4.2E−10
		M	0.01	2.4E−10	3.5E−10		
Sb-130	40 m	F	0.1	3.5E−11	6.3E−11	0.1	9.1E−11
		M	0.01	5.4E−11	9.1E−11		
Sb-131	23 m	F	0.1	3.7E−11	5.9E−11	0.1	1.0E−10
		M	0.01	5.2E−11	8.3E−11		
Tellurium							
Te-116	2.49 h	F	0.3	6.3E−11	1.2E−10	0.3	1.7E−10
		M	0.3	1.1E−10	1.7E−10		
Te-121	17 d	F	0.3	2.5E−10	3.9E−10	0.3	4.3E−10
		M	0.3	3.9E−10	4.4E−10		

Table A.1. (continued)

Nuclide	T _½	Inhalation				Ingestion	
		Type	f ₁	e (Sv/Bq) (1 μm)	e (Sv/Bq) (5 μm)	f ₁	e (Sv/Bq)
Te-121m	154 d	F	0.3	1.8E−09	2.3E−09	0.3	2.3E−09
		M	0.3	4.2E−09	3.6E−09		
Te-123	1E13 y	F	0.3	4.0E−09	5.0E−09	0.3	4.4E−09
		M	0.3	2.6E−09	2.8E−09		
Te-123m	119.7 d	F	0.3	9.7E−10	1.2E−09	0.3	1.4E−09
		M	0.3	3.9E−09	3.4E−09		
Te-125m	58 d	F	0.3	5.1E−10	6.7E−10	0.3	8.7E−10
		M	0.3	3.3E−09	2.9E−09		
Te-127	9.35 h	F	0.3	4.2E−11	7.2E−11	0.3	1.7E−10
		M	0.3	1.2E−10	1.8E−10		
Te-127m	109 d	F	0.3	1.6E−09	2.0E−09	0.3	2.3E−09
		M	0.3	7.2E−09	6.2E−09		
Te-129	69.6 m	F	0.3	1.7E−11	2.9E−11	0.3	6.3E−11
		M	0.3	3.8E−11	5.7E−11		
Te-129m	33.6 d	F	0.3	1.3E−09	1.8E−09	0.3	3.0E−09
		M	0.3	6.3E−09	5.4E−09		
Te-131	25.0 m	F	0.3	2.3E−11	4.6E−11	0.3	8.7E−11
		M	0.3	3.8E−11	6.1E−11		
Te-131m	30 h	F	0.3	8.7E−10	1.2E−09	0.3	1.9E−09
		M	0.3	1.1E−09	1.6E−09		
Te-132	78.2 h	F	0.3	1.8E−09	2.4E−09	0.3	3.7E−09
		M	0.3	2.2E−09	3.0E−09		
Te-133	12.45 m	F	0.3	2.0E−11	3.8E−11	0.3	7.2E−11
		M	0.3	2.7E−11	4.4E−11		
Te-133m	55.4 m	F	0.3	8.4E−11	1.2E−10	0.3	2.8E−10
		M	0.3	1.2E−10	1.9E−10		
Te-134	41.8 m	F	0.3	5.0E−11	8.3E−11	0.3	1.1E−10
		M	0.3	7.1E−11	1.1E−10		
Iodine							
I-120	81.0 m	F	1.0	1.0E−10	1.9E−10	1.00	3.4E−10
I-120m	53 m	F	1.0	8.7E−11	1.4E−10	1.00	2.1E−10
I-121	2.12 h	F	1.0	2.8E−11	3.9E−11	1.00	8.2E−11
I-123	13.2 h	F	1.0	7.6E−11	1.1E−10	1.00	2.1E−10
I-124	4.18 d	F	1.0	4.5E−09	6.3E−09	1.00	1.3E−08
I-125	60.14 d	F	1.0	5.3E−09	7.3E−09	1.00	1.5E−08
I-126	13.02 d	F	1.0	1.0E−08	1.4E−08	1.00	2.9E−08
I-128	24.99 m	F	1.0	1.4E−11	2.2E−11	1.00	4.6E−11
I-129	1.57E7 y	F	1.0	3.7E−08	5.1E−08	1.00	1.1E−07
I-130	12.36 h	F	1.0	6.9E−10	9.6E−10	1.00	2.0E−09
I-131	8.04 d	F	1.0	7.6E−09	1.1E−08	1.00	2.2E−08
I-132	2.30 h	F	1.0	9.6E−11	2.0E−10	1.00	2.9E−10
I-132m	83.6 m	F	1.0	8.1E−11	1.1E−10	1.00	2.2E−10
I-133	20.8 h	F	1.0	1.5E−09	2.1E−09	1.00	4.3E−09
I-134	52.6 m	F	1.0	4.8E−11	7.9E−11	1.00	1.1E−10
I-135	6.61 h	F	1.0	3.3E−10	4.6E−10	1.00	9.3E−10

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