RADIATION PROTECTION

ICRP PUBLICATION 71

Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 4 Inhalation Dose Coefficients

A report of a Task Group of Committee 2 of the International Commission on Radiological Protection

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1. INTRODUCTION

(1) This report gives age-dependent dose coefficients for members of the public from intakes by inhalation of radioisotopes of the 29 elements covered by *ICRP Publications 56* (ICRP, 1989), *67* (ICRP, 1993) and *69* (ICRP, 1995) and of calcium and curium. *ICRP Publications 56, 67* and *69* gave age-dependent ingestion dose coefficients. *ICRP Publication 56* also gave preliminary age-dependent inhalation dose coefficients for radioisotopes of 12 elements, using the lung model described in *ICRP Publication 30* (ICRP, 1979).

(2) Since issuing *ICRP Publication 56*, ICRP has adopted a revised kinetic and dosimetric model of the respiratory tract, which is age-specific (*ICRP Publication 66*, 1994a). Inhalation dose coefficients for workers using this new model were given in *ICRP Publication 68* (ICRP, 1994b). The main aim of the present report is to give inhalation dose coefficients for members of the public, for radioisotopes of the 29 elements covered in *ICRP Publications 56, 67* and *69*, which are expected to be released into the environment as a result of human activities and are considered to be of significance for radiation protection purposes. Some additional radionuclides with shorter half-lives have been included here, since consideration may need to be given to intakes by inhalation at a shorter time after release to the environment, than for ingestion; selected isotopes of calcium and curium are also included. The radionuclides are listed in the Preface to Section 5. The inhalation dose coefficients given in *ICRP Publication 56* are superseded by the corresponding values given in this report.

(3) The new Human Respiratory Tract Model for Radiological Protection (ICRP, 1994a) constitutes a comprehensive revision and updating of the lung model used in *ICRP Publication 30* for workers. The model is described in full in *ICRP Publication 66*, and summarized for the calculation of general-purpose dose coefficients for workers in *ICRP Publication 68*. The principal age-specific aspects are given below, and a summary of the model as it applies to exposure of the general population is given in Section 2.

(4) The new model for the respiratory tract takes into account extensive data on the behaviour of inhaled materials that have become available since development of the model by the Task Group on Lung Dynamics (TGLD, 1966), on which *ICRP Publication 30* was based. As in the earlier model, deposition and clearance are treated separately (see Sections 2.2 and 2.3, respectively). The scope of the model has been extended to apply explicitly to all members of the population, giving reference values for 3-mo-old infants, 1-, 5-, 10- and 15-y-old children, and adults.

(5) The main difference in approach between the two models is that whereas the *ICRP Publication 30* model calculates only the average dose to the lungs, the new model calculates the dose to each respiratory tract region separately. The equivalent doses to the lungs and extrathoracic airways are obtained from the sums of the regional doses, weighted according to their estimated radiosensitivities.

(6) In the new model, the respiratory tract is represented by five regions (Fig. 1).

(7) Breathing parameters determine the amounts of radionuclides inhaled and depend on age, body size, and level of physical activity (exercise). This is the aspect of the model for which variation with age is greatest, and also the one for which there are comprehensive data relating to women and children.

(8) The deposition model evaluates the fraction of the inhaled particles deposited in each region, for aerosol sizes of practical interest (0.6 nm–100 μm). Values of regional deposition

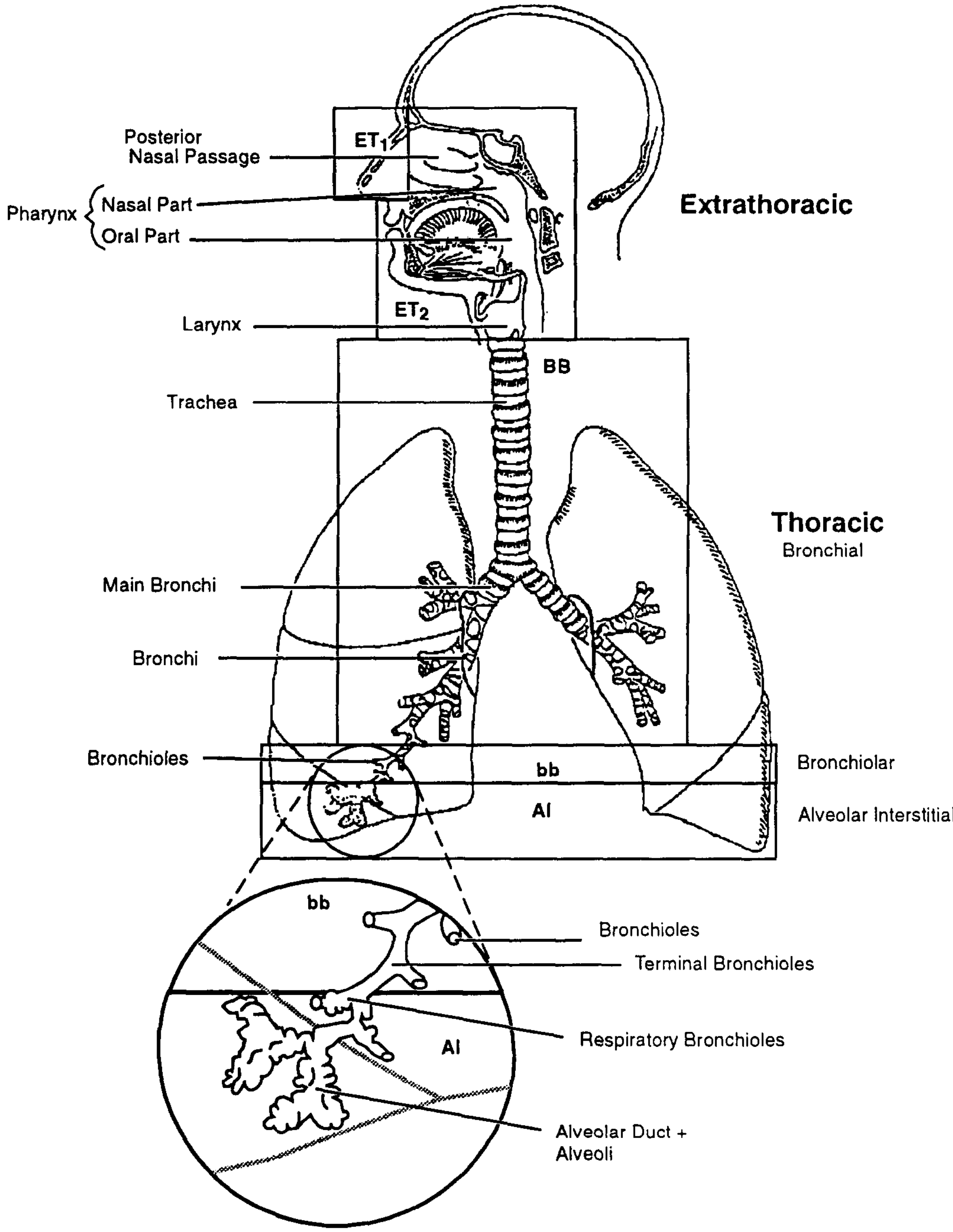

Fig. 1. Respiratory tract regions defined in the new ICRP model (*ICRP Publication 66*, 1994a). The extrathoracic (ET) airways are divided into ET_1, the anterior nasal passage, and ET_2, which consists of the posterior nasal and oral passages, the pharynx and larynx. The thoracic regions are bronchial (BB: trachea, generation 0, and bronchi, airway generations 1–8), bronchiolar (bb: airway generations 9–15), and alveolar–interstitial (AI: the gas exchange region, airway generations 16 and beyond). Lymphatic tissue is associated with the extrathoracic and thoracic airways (LN_{ET} and LN_{TH}, respectively).

are given in this report for each age group, based on inhalation of a 1 μm Activity Median Aerodynamic Diameter (AMAD) aerosol, and reference values of hours per day spent at four levels of exercise: sleep, sitting, light exercise and heavy exercise.

(9) Unlike deposition of particles, that of gases and vapours depends on chemical form, and hence the extent to which the molecules dissolve in or react with the surface lining of the respiratory tract. For important gas and vapour compounds of the elements covered in this report, an estimate is given of the fraction of inhaled material deposited in the respiratory tract, which is assumed to be independent of age and sex.

(10) The model quantifies retention of deposited activity in the respiratory tract regions and clearance to other organs by representing three clearance processes. It is assumed that clearance from the anterior nose (ET_1) is extrinsic (e.g. nose-blowing), and that elsewhere it results from competition between particle transport to the gastrointestinal (GI) tract and lymph nodes, and absorption of material into body fluids. It is assumed, by default, that particle transport rates are the same for all materials, and that the absorption rates are the same in all regions. It is recommended that material-specific rates of absorption should be used whenever reliable human or animal experimental data exist. For other compounds, default values are recommended for use according to whether the absorption is considered to be fast (Type F), moderate (M) or slow (S) (corresponding broadly to inhalation Classes D, W and Y in the *ICRP Publication 30* model). In *ICRP Publication 68*, as an interim measure to expedite the publication of inhalation dose coefficients for workers, compounds for which clearance was given as Class D, W or Y in *ICRP Publication 30* were assigned to Type F, M or S, respectively. For each of the elements covered in this report guidance is given on the choice of absorption Type, according to the information available. A default Type is recommended for use in the absence of specific information. It is assumed that clearance rates by all three processes, nose-blowing, particle transport and absorption, are independent of age and sex.

(11) For the calculation of radiation doses to the respiratory system, target cells are identified in the epithelium of each region representing the conducting airways; the dose to the tissue containing these cells is taken to be the dose to the region. The equivalent dose to the extrathoracic or thoracic airways is obtained from the sum of the doses to each region, weighted by a factor representing the region's estimated radiosensitivity. The values of these factors are taken to be independent of age and sex.

(12) For the calculation of inhalation dose coefficients, allowance has to be made for the absorption of material passing through the GI tract after clearance from the respiratory system. The model used here to describe the behaviour of radionuclides in the GI tract, and for the calculation of doses from radionuclides in the lumen of the gut, is that described in *ICRP Publication 30* (ICRP, 1979). In the 1990 recommendations (ICRP, 1991a) the oesophagus and colon are given explicit tissue weighting factors, w_T (see Table 1). The oesophagus is not addressed specifically in the *ICRP Publication 30* model. In the absence of a dosimetric model for the oesophagus, the specific absorbed fraction for the thymus is taken as an approximation to that for the oesophagus (ICRP, 1991b, 1993). The weighting factor for the colon is applied to the mass average of the equivalent doses to the walls of the upper and lower large intestines of the GI tract (ICRP, 1994b).

(13) The adult f_1 values applied here for inhaled materials passing through the GI tract after clearance from the respiratory system are given in Table 2. In assigning these values, it was considered that for environmental exposure the radionuclides might typically be present as minor constituents of the inhaled particles, and that therefore absorption into body fluids would depend on dissolution of the particle matrix, as well as on the elemental

Table 1. Tissue weighting factors[a]

Organ or tissue (T)	Tissue weighting factor (w_T)	Organ or tissue (T)	Tissue weighting factor (w_T)
Gonads[b]	0.20	Liver	0.05
Bone marrow (red)	0.12	Oesophagus	0.05
Colon[c]	0.12	Thyroid	0.05
Lungs[d]	0.12	Skin	0.01
Stomach	0.12	Bone surface	0.01
Bladder	0.05	Remainder[e,f]	0.05
Breast	0.05		

[a]The values have been developed from a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose they apply to workers, to the whole population, and to either sex (*ICRP Publication 60*, 1991a).

[b]See Paragraph 20.

[c]The colon w_T is applied to the mass average of the equivalent doses H_{ULI}, and H_{LLI}, in the walls of the upper large intestine (ULI) and lower large intestine (LLI) of the GI tract (*ICRP Publication 30*, 1979). Age-specific masses of the walls of the GI tract are given in Table 11. Since the relative masses of the walls of the ULI and LLI are independent of age, the equivalent dose to the colon H_{colon} is given (*ICRP Publication 69*, 1995) as: $H_{colon} = 0.57\ H_{ULI} + 0.43\ H_{LLI}$.

[d]Thoracic airways.

[e]For purposes of calculation, the remainder is composed of the following ten additional tissues and organs: adrenals, brain, extrathoracic airways, small intestine, kidneys, muscle, pancreas, spleen, thymus and uterus. The extrathoracic airways described in the new respiratory tract model (*ICRP Publication 66*) were added to the list of remainder tissues in *ICRP Publication 68*. Their masses are given in Table 11.

[f]Whenever the most exposed remainder tissue or organ receives the highest committed equivalent dose of all organs, a weighting factor of 0.025 (half of remainder) is applied to that tissue or organ and 0.025 (half of remainder) to the mass-averaged committed equivalent dose in the rest of the remainder tissues and organs (ICRP, 1994b). See eqn (11) and Paragraph 77.

form of the radionuclide (see Paragraph 53). Generally, for Type F (rapidly soluble) materials, the greatest f_1 value applied to the element in *ICRP Publication 68* is used here. For barium, an f_1 value of 0.2 is applied as in *ICRP Publication 67*. For Types M and S, default f_1 values of 0.1 and 0.01, respectively, are applied, unless a lower f_1 value for that absorption Type (or for a more soluble Type) was used in *ICRP Publication 68*, in which case that value is applied.

(14) Absorption of radionuclides tends to be greatest in the newborn, but the results of animal studies suggest that uptake from the gut progressively decreases with age, approaching adult values by about the time of weaning in most cases. A similar approach to that described in *ICRP Publications 56, 67* and *69*, has been adopted here. For elements with adult f_1 values of 0.002 or less, a value of 10 times that for the adult is assumed for 3-mo-old infants. (None of the elements covered in this report has an adult f_1 value between 0.002 and 0.01.) For adult f_1 values between 0.01 and 0.5, an increase by a factor of 2 is assumed for 3-mo-old infants. For adult f_1 values greater than 0.5, complete absorption by 3-mo-old infants ($f_1 = 1$) is assumed. For most elements, adult values are applied to 1-, 5-, 10- and 15-y-old children. However, for Type F forms of calcium, iron, cobalt, strontium, barium, lead and radium, intermediate values are used for children following the approach in *ICRP Publications 56* and *67*. For Type M and S forms of these elements, the default adult f_1 values (0.1 and 0.01, respectively) are also applied to children.

(15) Absorption of material from the GI tract is assumed to take place in the small intestine. If complete absorption is indicated in the biokinetic model, then for computational reasons a fraction of 0.99 of the ingested material is taken to be absorbed from the small intestine to the transfer compartment; a fraction of 0.01 of the ingested material enters the lower segments of the GI tract.

Table 2. Adult f_1 values used in this report for inhaled materials passing through the GI tract after clearance from the respiratory system

Section	Element	Type F	Type M	Type S
5.1	Hydrogen	1	0.1	0.01
5.2	Carbon	1	0.1	0.01
5.3	Sulphur	0.8	0.1	0.01
5.4	Calcium	0.3	0.1	0.01
5.5	Iron	0.1	0.1	0.01
5.6	Cobalt	0.1	0.1	0.01
5.7	Nickel	0.05	0.05	0.01
5.8	Zinc	0.5	0.1	0.01
5.9	Selenium	0.8	0.1	0.01
5.10	Strontium	0.3	0.1	0.01
5.11	Zirconium	0.002	0.002	0.002
5.12	Niobium	0.01	0.01	0.01
5.13	Molybdenum	0.8	0.1	0.01
5.14	Technetium	0.8	0.1	0.01
5.15	Ruthenium	0.05	0.05	0.01
5.16	Silver	0.05	0.05	0.01
5.17	Antimony	0.1	0.01	0.01
5.18	Tellurium	0.3	0.1	0.01
5.19	Iodine	1	0.1	0.01
5.20	Caesium	1	0.1	0.01
5.21	Barium	0.2	0.1	0.01
5.22	Cerium	5×10^{-4}	5×10^{-4}	5×10^{-4}
5.23	Lead	0.2	0.1	0.01
5.24	Polonium	0.1	0.1	0.01
5.25	Radium	0.2	0.1	0.01
5.26	Thorium	5×10^{-4}	5×10^{-4}	5×10^{-4}
5.27	Uranium	0.02	0.02	0.002
5.28	Neptunium	5×10^{-4}	5×10^{-4}	5×10^{-4}
5.29	Plutonium	5×10^{-4}	5×10^{-4}	1×10^{-5}
5.30	Americium	5×10^{-4}	5×10^{-4}	5×10^{-4}
5.31	Curium	5×10^{-4}	5×10^{-4}	5×10^{-4}

(16) The age-specific biokinetic models given in *ICRP Publications 56, 67* and *69* are used to describe the tissue distribution, retention and excretion of systemic activity. A model for calcium is described in Annexe A. It is based on the generic model for the alkaline earths given in *ICRP Publication 67*. The model for americium given in *ICRP Publication 67* is used here for curium, since the biokinetic behaviour of the two elements is very similar (Annexe B).

(17) In the 1990 recommendations (ICRP, 1991a), the urinary bladder is given an explicit w_T value. Consequently, a urinary bladder model was formulated for calculating the equivalent dose to the bladder wall from activity in the urine, as described in *ICRP Publications 67* and *69*. The rates at which radionuclides enter the bladder are based on their elimination rates from body tissues and the urinary to faecal excretion ratio given with the biokinetic data. While the urinary to faecal excretion ratio for an element may vary with time, a time-constant value is judged to be adequate for the present dosimetric purposes for many elements. It is not intended that the stated ratios should be used for the interpretation of bioassay measurements where temporal variations in the ratio may be important. To represent the clearance kinetics of the bladder in terms of first order processes, the rate of elimination from the bladder is taken to be twice the number of voids per day (Table 3). For dosimetric purposes, the bladder is taken to be of fixed size, containing a volume that represents the average contents of the bladder during the

Table 3. Parameters of urinary bladder model (*ICRP Publication 67*, 1993)

Age	Number of voids per day	Rate of elimination from bladder (d^{-1})	Bladder contents (ml)
3 mo	20	40	15
1 y	16	32	25
5 y	6	12	65
10 y	6	12	75
15 y	6	12	85
Adult	6	12	115

time period between voids, i.e. one-half of the volume of urine excreted in a single voiding.

(18) Some of the radionuclides considered here decay to nuclides that are themselves radioactive. In this report separate systemic biokinetics have been applied to the parent and its decay products for those elements where this is assumed in *ICRP Publications 67* and *69*. This applies to intakes of lead, radium, tellurium, thorium and uranium. Details of the biokinetic models used for the decay products of these elements are given in Annexe C. For other elements, the treatment of decay products follows that in *ICRP Publication 30*: the usual assumption is that they adopt the biokinetics of their parent, with a few exceptions for intakes of isotopes of iodine, which have decay products that are isotopes of the noble gas xenon. For activity in the respiratory tract prior to systemic uptake: the usual assumption is that the decay products adopt the absorption parameters of their parent, with some exceptions for decay products that are isotopes of noble gases (see Paragraph 75).

(19) Dose coefficients for intakes by 3-mo-old infants, 1-, 5-, 10- and 15-y-old children, and adults are given in this report. In most cases the adult is taken to be aged 20 y. Exceptions are made for the alkaline earth elements, lead, thorium, uranium, neptunium, plutonium, americium and curium (ICRP, 1993, 1995). For these elements, the transfer rates for the adult apply to ages $\geq$25 y, because some of the transfer rates in the biokinetic models are equated with bone formation rates, which are expected to remain elevated up to about aged 25 y. In the calculations of the activity in source regions of the body, following intakes at these ages, continuous changes with age in the transfer rates governing its distribution and retention are obtained by linear interpolation according to age. This also applies to the transfer of activity from the small intestine to body fluids. For application to other ages and protracted intakes, the Task Group considered that tissue doses can be estimated by applying the age-specific dose coefficients to the age ranges given below:

3 mo: from 0 to 12 mo of age
1 y: from 1 y to 2 y
5 y: more than 2 y to 7 y
10 y: more than 7 y to 12 y
15 y: more than 12 y to 17 y
adult: more than 17 y.

As in *ICRP Publications 56, 67* and *69*, a single reference subject is used to represent each age-group. Generally, parameter values for males have been adopted because of the availability of biokinetic data. Where there are known differences between sexes in the biokinetics of an element, this is noted in the relevant section of the biokinetic data in *ICRP Publication 56, 67* or *69*.

(20) The tissue weighting factors, w_T (Table 1), and radiation weighting factors, w_R, used for calculating the effective dose coefficients are those given by ICRP in its 1990 recommendations (ICRP, 1991a). Dose coefficients are given in this report for both the ovaries and testes, the higher of which is multiplied by the gonad tissue weighting factor for the calculation of effective dose.

(21) The dose coefficients calculated in this report, as in *ICRP Publications 56, 67* and *69*, are for acute intakes. For intakes over extended periods, doses per unit intake could be somewhat lower than those calculated here where growth is significant during the period of intake. However, since the age ranges were selected to account for significant changes in growth and biokinetics during life, these coefficients can also be applied to chronic intakes for protection purposes by determining the committed dose for each year's intake and summing for intakes over all years.

(22) The inhalation dose coefficients given here were calculated on the basis of a specified distribution of time spent between different levels of exercise, during which the concentrations of radionuclides in the air are assumed to be constant. The application of these dose coefficients to other situations is discussed in Section 4.

(23) The new biokinetic models, which are based on the underlying physiological processes, offer a number of advantages, particularly in regard to developing age-dependent parameters. They are, however, considerably more complex than those given in *ICRP Publication 30* and more difficult to implement. The Commission has, therefore, attached particular importance to the question of Quality Assurance. The Task Group on Dose Calculations has arranged for the dose coefficients to be calculated independently, using different computer codes, in three of the contributing laboratories. Any discrepancies in these calculations that exceed those caused by rounding errors are investigated and resolved before the results are published.

2. RESPIRATORY TRACT MODEL

(24) The new Human Respiratory Tract Model (ICRP, 1994a) constitutes a general revision and updating of the model used in *ICRP Publication 30* for adult workers. The model is described in full in *ICRP Publication 66*, but a summary of the main features of the model is given here, in particular those relating to age dependence. The new model takes into account extensive data on the behaviour of inhaled materials that have become available since development of the model (TGLD, 1966) on which *ICRP Publication 30* was based. The scope of the model has been extended to apply explicitly to all members of the population, giving parameter values for 3-mo-old infants, 1-, 5-, 10- and 15-y-old children, and adults. In this report, as in *ICRP Publications 56, 67* and *69*, only one reference subject is used to represent each age group. For those ages at which *ICRP Publication 66* provides separate parameter values for males and females (10 y and above), the male values are used here for the reference subject. If inhalation doses specific to females should be required, then data given in *ICRP Publication 66* enable them to be calculated. However, for a given exposure, differences in doses between males and females of the same age are small, because for females both intake and body mass are smaller by about 20%.

(25) The main difference in approach is that whereas the *ICRP Publication 30* model calculates only the average dose to the lungs, the new model calculates doses to specific tissues of the respiratory tract, and takes account of estimated differences in their radiosensitivity. In the new model, the respiratory tract is represented by five regions, based principally on radiobiological considerations, but also taking account of differences in physiology, deposition and clearance (Fig. 1). The extrathoracic (ET) airways are divided into ET_1, the anterior nasal passage, and ET_2, which consists of the posterior nasal and oral passages, the pharynx and larynx. The thoracic regions are bronchial (BB: trachea, generation 0, and bronchi, airway generations 1–8), bronchiolar (bb: airway generations 9–15), and alveolar–interstitial (AI: the gas exchange region, airway generations 16 and beyond). Lymphatic tissue is associated with both the extrathoracic and thoracic airways (LN_{ET} and LN_{TH}, respectively) and is assumed to have a very low radiation detriment.

(26) Values of dimensions of the airways, and scaling factors for subjects of different ages, are specified in *ICRP Publication 66*. In order to apply the model to different age groups, dimensions of conducting and respiratory airways are scaled by body height and Functional Residual Capacity, respectively. It is assumed that the branching structure of the airways (BB and bb) is complete at birth, and that the number of alveoli increases linearly with time, from 40% of the adult total at 3 mo, to 80% at 1 y. The mass of the AI is scaled on the basis of body mass. These dimensions are used with the deposition model to calculate regional deposition, and are also used to derive masses of target tissues (see below).

2.1. Physiology

(27) The *ICRP Publication 66* model enables not only inhalation dose coefficients to be calculated, but also intake per unit exposure (time-integrated activity concentration in air), and hence doses per unit exposure, which are frequently required for environmental dose assessments. Two factors relate intake to exposure: inhalability and ventilation.

(28) Inhalability is the ratio of the particle concentration in the air entering the respiratory tract to that in the ambient air (taken to be 1 for particles with an aerodynamic diameter

smaller than about 1 μm). The inertia of larger particles increases the concentration in the air entering the nose or mouth when facing into a wind, and reduces it otherwise, the average net effect being to reduce it to about half that in the ambient air. Inhalability is assumed to be independent of age and sex.

(29) Ventilation, the breathing frequency and tidal volume, is the main factor in the model that depends on age and level of exercise. This is also the aspect for which there are comprehensive data relating to women and children as well as men. Reference values of the primary quantities, breathing frequency, f_R, (breaths per minute) and ventilation rate, B ($m^3\ h^{-1}$), are given in Table 4 for each age group and for four levels of exercise: sleep, sitting, light exercise and heavy exercise. For 3-mo-old infants, and for 1- and 5-y-old children, the values of f_R and B are the same for males and females. For the other age groups, where there are differences, male values are given (see Paragraph 24). However, the values for 10-y-old males and females differ only for heavy exercise.

(30) The *ICRP Publication 66* model enables deposition fractions to be calculated separately for nose breathing and mouth breathing. Account can therefore be taken of the oro-nasal breathing that takes place in most individuals at heavy exercise, and in habitual mouth-breathers at all levels of exercise. It is assumed (see *ICRP Publication 66*, Paragraph 158 and Table 11) that the fraction of total ventilatory airflow passing through the nose in normal nasal augmenters (nose-breathers) is 100% at sleep, sitting and light exercise, and 50% at heavy exercise. These fractions are taken to be independent of age and sex.

(31) The results of habit surveys are summarized in Annexe B (Respiratory Physiology) of *ICRP Publication 66*. Table 5 gives the distribution of time spent in various activities, taken from Table B.16 of *ICRP Publication 66*, but only for the six reference subjects for which dose coefficients are given here. For 3-mo-old infants and 1-, 5- and 10-y-old children, the time budgets in Table 5 are the same for males and females; for the other age groups, male values are given (see Paragraph 24). These results have been used to provide reference values for the number of hours per day spent at each of the four levels of exercise, which are given in Table 6. For 10-y-old children, the values in Table 6 (and hence the deposition fractions derived from them in Table 7) are the same for males and females, because the time budget for 10-y-old children (Table 5) does not include heavy exercise, the only level at which there are differences in ventilation parameters betweeen males and females (see Paragraph 29).

(32) These parameters can be used to determine intake per unit exposure, and are also used with the deposition model to determine regional deposition.

Table 4. Ventilation parameters for reference subjects[a]

Exercise level		Age					
		3 mo	1 y	5 y	10 y (male)	15 y (male)	Adult (male)
Sleep	f_R min^{-1}	38	34	23	17	14	12
	B $m^3\ h^{-1}$	0.09	0.15	0.24	0.31	0.42	0.45
Sitting	f_R min^{-1}	—	36	25	19	15	12
	B $m^3\ h^{-1}$	—	0.22	0.32	0.38	0.48	0.54
Light exercise	f_R min^{-1}	48	46	39	32	23	20
	B $m^3\ h^{-1}$	0.19	0.35	0.57	1.12	1.38	1.5
Heavy exercise	f_R min^{-1}	—	—	—	44	36	26
	B $m^3\ h^{-1}$	—	—	—	2.22	2.92	3.0

[a] Reference values are given to sufficient precision for calculational purposes and may be more precise than the biological data would support. From *ICRP Publication 66*, Table B15. f_R = frequency, B = ventilation rate. Also, see Paragraph 29.

Table 5. Daily time budget (hours) for reference subjects[a]

Location	Age					
	3 mo	1 y	5 y	10 y	15 y (male)	Adult (male)
Indoors						
At home: Asleep	17	14	12	10	10	8.5
Awake	7[b]	5[c]	6[c]	8[c]	7[d]	7[c]
Elsewhere (e.g. at work)		4[c]	3[c]	3[c]	4[d]	6.5[c]
Outdoors		1[c]	3[c]	3[c]	3[e]	2[f]

[a] From *ICRP Publication 66*, Table B16. Also, see Paragraph 31.
[b] Light exercise.
[c] One-third sitting + two-thirds light exercise.
[d] One-half sitting + one-half light exercise.
[e] Two-thirds light exercise + one-third heavy exercise.
[f] One-half sitting + three-eighths light exercise + one-eighth heavy exercise.

Table 6. Daily time budget[a] and ventilation parameters[b] at each exercise level for members of the public at various ages[c]

Exercise level	3 mo			1 y			5 y		
	h	$m^3 h^{-1}$	m^3	h	$m^3 h^{-1}$	m^3	h	$m^3 h^{-1}$	m^3
Sleep	17.0	0.09	1.53	14.0	0.15	2.10	12.0	0.24	2.88
Sitting				3.33	0.22	0.73	4.0	0.32	1.28
Light exercise	7.0	0.19	1.33	6.67	0.35	2.33	8.0	0.57	4.56
Heavy exercise									
Total			2.86			5.16			8.72

Exercise level	10 y			15 y (male)			Adult (male)		
	h	$m^3 h^{-1}$	m^3	h	$m^3 h^{-1}$	m^3	h	$m^3 h^{-1}$	m^3
Sleep	10.0	0.31	3.10	10.0	0.42	4.20	8.0	0.45	3.60
Sitting	4.67	0.38	1.77	5.5	0.48	2.64	6.0	0.54	3.24
Light exercise	9.33	1.12	10.45	7.5	1.38	10.35	9.75	1.5	14.63
Heavy exercise				1.0	2.92	2.92	0.25	3.0	0.75
Total			15.3			20.1			22.2

[a] The number of hours per day spent at each exercise level given above are reference values (see below). Generally they are based on the distributions of time given in Table 5, and rounded to the nearest 0.01 h. For the adult male, however, the time asleep has been rounded down from 8.5 to 8 h for simplicity and consistency with the reference worker (*ICRP Publication 66*, Table 6). The time spent sitting has been correspondingly increased by 0.5 h.
[b] Ventilation rates ($m^3 h^{-1}$) are reference values (see below) taken from Table 4.
[c] The daily volumes inhaled (m^3) at each exercise level are derived from the reference values of time spent at each activity, and of ventilation rate. See Paragraph 31.
[d] Reference values are given to sufficient precision for calculational purposes and may be more precise than the biological data would support.

2.2. Deposition

(33) Deposition refers to the initial processes that determine how much of the material in the inspired air remains behind after expiration (see Glossary). The deposition model evaluates the fraction of the inhaled particles deposited in each region for aerosol sizes of practical interest (0.6 nm–100 μm). For radionuclides inhaled in particulate form, it is assumed that entry and regional deposition in the respiratory tract of a given subject are governed only by the size distribution of the aerosol particles (as in the *ICRP Publication 30*

Table 7. Deposition of inhaled aerosols in respiratory tract regions and compartments[a]

	Age					
	3 mo	1 y	5 y	10 y	15 y (male)	Adult (male)
Deposition in regions (% of inhaled activity)[b]						
$DE(ET_1)$	20.97	21.07	17.39	17.75	13.91	14.89
$DE(ET_2)$	27.20	27.30	22.32	22.86	18.13	18.97
DE(BB)	1.04	1.04	1.03	1.17	1.69	1.29
DE(bb)	2.05	1.71	1.85	1.70	2.00	1.95
DE(AI)	8.56	9.64	9.85	9.51	10.65	11.48
Total	59.82	60.76	52.44	52.99	46.38	48.58
Fraction of deposits in ET_2, BB and bb regions assigned to compartments[b,c]						
$f_{seq}(ET_2)$	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
$f_{seq}(BB)$, $f_{seq}(bb)$	0.007	0.007	0.007	0.007	0.007	0.007
$f_s(BB)$	0.4839	0.4820	0.4745	0.4748	0.4583	0.4645
$f_s(bb)$	0.4964	0.4957	0.4920	0.4902	0.4848	0.4866
Deposition in compartments (% of inhaled activity)[d]						
$DE(ET'_2)=(1-f_{seq}(ET_2))\ DE(ET_2)$	27	27	22	23	18	19
$DE(ET_{seq})=f_{seq}(ET_2)\ DE(ET_2)$	0.014	0.014	0.011	0.011	0.0091	0.0095
$DE(BB_1)=(1-f_s(BB)-f_{seq}(BB))\ DE(BB)$	0.53	0.53	0.53	0.61	0.90	0.68
$DE(BB_2)=f_s(BB)\ DE(BB)$	0.50	0.50	0.49	0.56	0.77	0.60
$DE(BB_{seq})=f_{seq}(BB)\ DE(BB)$	0.0073	0.0073	0.0072	0.0082	0.012	0.0090
$DE(bb_1)=(1-f_s(bb)-f_{seq}(bb))\ DE(bb)$	1.0	0.85	0.93	0.86	1.0	0.99
$DE(bb_2)=f_s(bb)\ DE(bb)$	1.0	0.85	0.91	0.83	0.97	0.95
$DE(bb_{seq})=f_{seq}(bb)\ DE(bb)$	0.014	0.012	0.013	0.012	0.014	0.014
$DE(AI_1)=0.3\ DE(AI)$	2.6	2.9	3.0	2.9	3.2	3.4
$DE(AI_2)=0.6\ (DE(AI)$	5.1	5.8	5.9	5.7	6.4	6.9
$DE(AI_3)=0.1\ DE(AI)$	0.86	0.96	0.99	0.95	1.1	1.1

[a]The particles are assumed to have density 3.00 g cm^{-3}, and shape factor 1.5 (*ICRP Publication 66*, Paragraph 181). The aerosols are assumed to be log-normally distributed with AMAD 1 μm and σ_g approximately 2.5 (*ICRP Publication 66*, Paragraph 170). The distribution of time spent at each of the four reference exercise levels are as given in Table 6. The deposition fractions are volume-weighted average values for deposition at the four exercise levels. Deposition fractions for each individual exercise level are given (to two significant figures) in *ICRP Publication 66*, Annexe F, Tables F3 (sleep); F4 (sitting); F5 (light exercise); F6 (heavy exercise). Also, see Paragraph 31.

[b]Reference values are given to sufficient precision for calculational purposes and may be more precise than the biological data would support.

[c]It is assumed that a fraction $f_{seq}(ET_2)$ (0.0005, independent of size) of the deposit in region ET_2 is retained in the airway wall (compartment ET_{seq} in Fig. 3) (*ICRP Publication 66*, Paragraph 244). The deposition in compartment ET'_2 is correspondingly reduced. It is assumed that a fraction, $f_{seq}(BB)$, $f_{seq}(bb)$, (0.007, independent of size), of the deposits in BB and bb is retained in the airway wall (compartments BB_{seq} and bb_{seq} in Fig. 3) (*ICRP Publication 66*, Paragraph 250). The fractions of the deposits in BB and bb, $f_s(BB)$ and $f_s(bb)$, that clear slowly (compartments BB_2 and bb_2 in Fig. 3) are related to particle diameter and therefore depend on the size distributions of the particles deposited in the two regions (*ICRP Publication 66*, Paragraph 248). The fractions of the deposition in the AI region assigned to compartments AI_1, AI_2 and AI_3 are 0.3, 0.6 and 0.1, respectively (*ICRP Publication 66*, Table 17), and are assumed to be independent of particle size.

[d]Values of deposition in compartments are derived as shown from reference values, and rounded to two figures.

model). (Deposition fractions of gases and vapours are determined by their chemical form: see Section 2.4). Since a single default particle size distribution is adopted here, a single set of regional deposition fractions (Table 7) applies to inhaled particulate forms of all radionuclides.

(34) Deposition in the ET regions was determined empirically. Deposition measurements in men have been related to characteristic parameters of particle size and airflow. The resulting deposition efficiencies are scaled by anatomical dimensions to predict deposition in

women and children. For the thoracic airways, a theoretical model of gas transport and particle deposition is used to calculate activity deposition in each of the BB, bb, and AI regions, and to quantify the effects of the subject's lung size and breathing rate. Regional deposition fractions are calculated for aerosols having log-normal particle size distributions, with geometric standard deviations (σ_g) taken to be a function of the median particle diameter, increasing from a value of 1.0 at 0.6 nm to a value of 2.5 above about 1 μm (*ICRP Publication 66*, Paragraph 170). Values of the deposition fractions are given in *ICRP Publication 66* as functions of particle size, for each age of subject, for sleep, sitting, light exercise and heavy exercise.

(35) To calculate dose coefficients for inhalation of radionuclides by members of the public, the subjects are taken to be normal nose-breathers whose time is spent according to the distributions given in Table 6. For environmental exposure, the default Activity Median Aerodynamic Diameter (AMAD) is taken to be 1 μm (see *ICRP Publication 66*, Paragraph 181; Dorrian, 1996). Table 7 gives values of fractional deposition in each region of the respiratory tract of the subjects under these conditions. Generally, these deposition fractions do not vary markedly with age. The relatively high deposition in the BB region of the 15-y-old arises from the 1 h per day of heavy exercise, which is more than at other ages, and which involves oro-nasal breathing. Since deposition in the mouth is smaller than in the nose, there is greater penetration to, and hence deposition in, the BB region.

2.3. Clearance

(36) The model describes several routes of clearance from the respiratory tract (Fig. 2), which involve three general processes. Material deposited in ET_1 is removed by extrinsic means, such as nose-blowing. In other regions clearance is competitive between the movement of particles towards the GI tract and lymph nodes (particle transport), and absorption into body fluids of material from the particles in the respiratory tract.

(37) The rate of absorption of a radionuclide, and hence overall clearance from the respiratory tract, is determined by its chemical form. It is assumed that all the clearance rates are independent of age and sex.

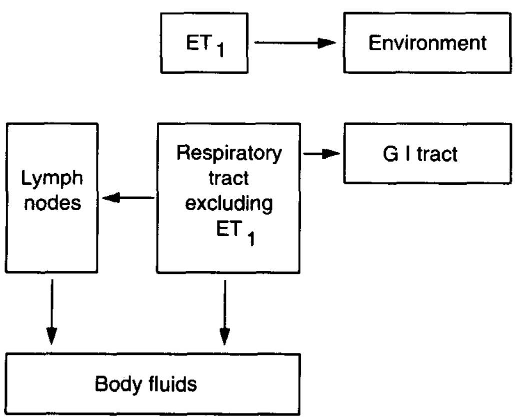

Fig. 2. Routes of clearance from the respiratory tract.

(38) Clearance kinetics are expressed in terms of fractional clearance rates, i.e.:

$$\frac{dR_i(t)}{dt} = -\lambda_i(t)R_i(t) + m_{ji}(t)R_j(t) \tag{1}$$

where $R_i(t)$ is the amount of material retained in region i (ET_2, BB, bb or AI) at time t after intake, $\lambda_i(t)$ is the overall instantaneous rate of clearance of material from region i, and $m_{ji}(t)$ is the rate of clearance of material from any region j into region i. Note, however, that as described below, $\lambda_i(t)$ is not a fixed function for the region, but depends on the initial pattern of respiratory tract deposition and the time course of intake.

(39) It is assumed that the clearance rates due to particle transport and absorption to body fluids are independent. Thus the overall rate of clearance from a region is the sum of the rates due to the individual processes:

$$\begin{aligned} \lambda_i(t) &= m_i(t) + s_i(t) \\ &= g_i(t) + l_i(t) + s_i(t) \end{aligned} \tag{2}$$

where $m_i(t)$ and $s_i(t)$ are the clearance rates from region i due to particle transport and absorption, respectively; $g_i(t)$ and $l_i(t)$ are particle transport rates towards the GI tract and regional lymph nodes.

(40) In general, the rates of clearance from each region, by each route, will change with time after intake, and will be different for material deposited directly in the region during inhalation, and for material cleared into a region following deposition in another region. Indeed, for the latter, the rate of particle transport out of region i depends on the time elapsed since the material was transported into the region, but its rate of absorption to body fluids depends on the time elapsed since the material was originally deposited in the respiratory tract. Thus, $\lambda_i(t)$ and its components in the equations above are themselves dependent on the initial pattern of deposition, the time course of intake and the time course of transport from other regions into region i. To take account of this and to simplify calculations, clearance from each region is represented in the model by a combination of compartments. Each compartment clears at a constant fractional rate, such that the overall clearance approximates the required time-dependent behaviour.

(41) It is assumed by default that particle transport rates are the same for all materials. A single compartment model is therefore provided to describe particle transport of all materials (Fig. 3). Values of rate constants were derived, so far as possible, from human studies, since particle transport rates are known to vary greatly between mammalian species. Figure 3 as it stands would describe the retention and clearance of a completely insoluble material. However, as noted above, there is in general simultaneous absorption to body fluids of material from all the compartments except ET_1, where it is assumed that none occurs.

(42) Absorption into body fluids depends on the physical and chemical form of the deposited material. It is assumed, by default, to occur at the same rate in all regions (including the lymph nodes) except ET_1. Absorption is a two-stage process: dissociation of the particles into material that can be absorbed into body fluids (dissolution); and absorption into body fluids of soluble material and of material dissociated from particles (uptake). The clearance rates associated with both stages can be time-dependent.

(43) The simplest compartment model representation of time-dependent *dissolution* is to assume that a fraction of the deposited material dissolves relatively rapidly, and the rest dissolves more slowly. The *ICRP Publication 66* model uses the system shown in Fig. 4 to represent this. In the model, the material deposited in the respiratory tract is assigned to

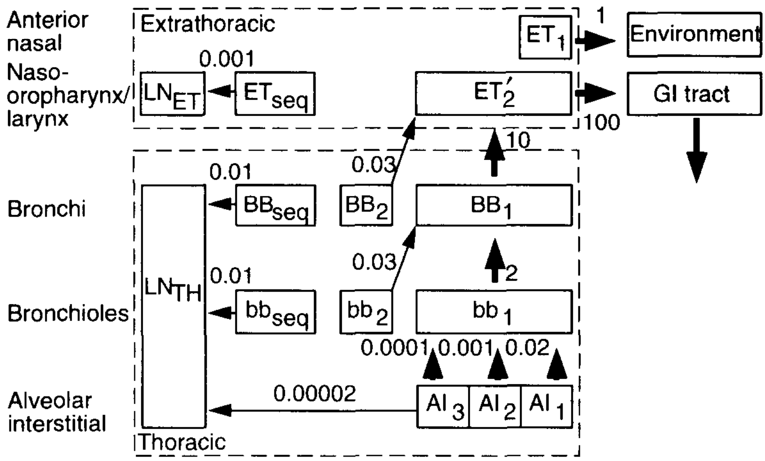

Fig. 3. Compartment model representing time-dependent particle transport from each respiratory tract region. Rates shown alongside arrows are reference values in units of d^{-1} *ICRP Publication 66*, Table 17. It is assumed that (i) the AI deposit is divided between AI_1, AI_2 and AI_3 in the ratio 0.3 : 0.6 : 1; (ii) the fraction of the deposit in BB and bb that is cleared slowly (BB_2 and bb_2) is 50% for particles of physical size <2.5 μm and decreases with diameter >2.5 μm, and the fraction retained in the airway wall (BB_{seq} and bb_{seq}) is 0.7% at all sizes; (iii) 0.05% of material deposited in region ET_2 is retained in its wall (ET_{seq}) and the rest in compartment ET_2', which clears rapidly to the GI tract. The model as shown above would describe the retention and clearance of a completely insoluble material. However, there is in general simultaneous absorption to body fluids of material from all the compartments except ET_1 (see text and Figs 4–6).

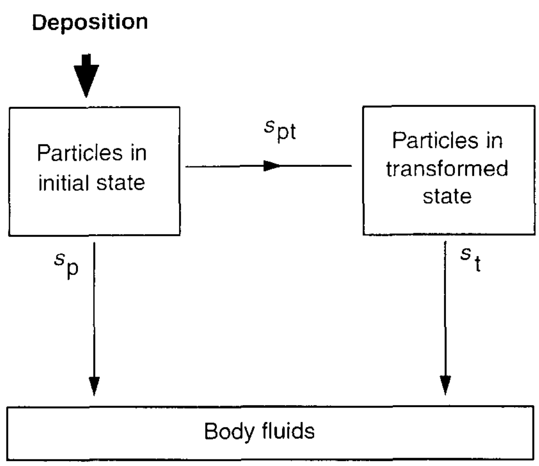

Fig. 4. Compartment model representing time-dependent dissolution, followed by instantaneous uptake to body fluids. All the deposit is initially assigned to the compartment labelled "Particles in initial state". For definition of symbols, see text.

compartments labelled "Particles in initial state", in which it dissolves at a constant rate s_p. Material is simultaneously transferred (at a constant rate s_{pt}) to a corresponding compartment labelled "Particles in transformed state", in which it has a different dissolution rate, s_t. The ratio of s_p to s_{pt} approximates to the fraction that dissolves rapidly. In different situations, the "Particles in transformed state" may represent the residual material following dissolution of a relatively soluble component or surface layer, or material taken up by macrophages. The essential feature is that it remains subject to particle transport. Activity retained in the respiratory tract that is not subject to particle transport is represented by "bound" material compartments (see below).

(44) The system shown in Fig. 4 applies to each of the compartments in the particle transport compartment model shown in Fig. 3 (except ET_1). Thus from each of the 13 compartments containing "Particles in initial state", material moves at a rate s_{pt} to a corresponding compartment containing "Particles in transformed state". The "Particles in transformed state" are cleared by particle transport at the same rates as "Particles in initial state". Thus if $m_{j,k}$ is the rate of particle transport from compartment j to compartment k containing "Particles in initial state" and $m_{jT,kT}$ is the corresponding particle transport rate for "Particles in transformed state", then $m_{j,k} = m_{jT,kT}$ for all j and k.

(45) Consider, for example, a compartment k, into which material moves by particle transport from compartment j at a rate $m_{j,k}$, and from which material moves by particle transport to compartment l at a rate $m_{k,l}$ (Fig. 5). The amount of material present in "Particles in initial state", $I_k(t)$ at time t after intake, is described by:

$$\frac{dI_k(t)}{dt} = m_{j,k}I_j(t) - (m_{k,l} + s_p + s_{pt})I_k(t) \tag{3}$$

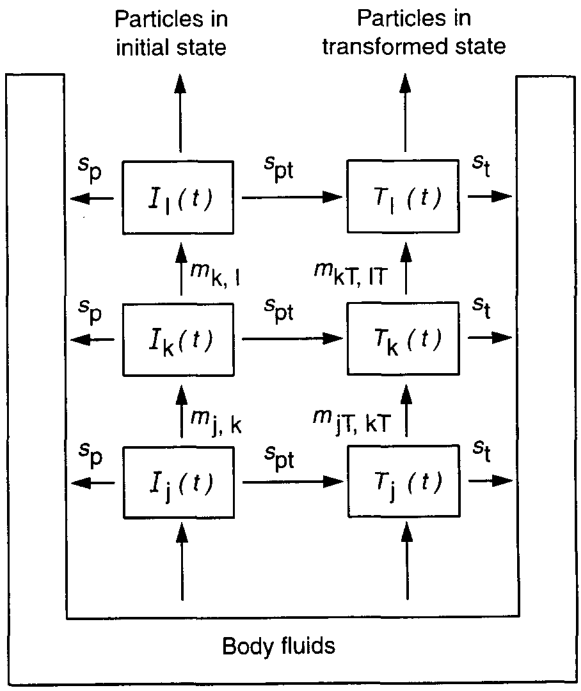

Fig. 5. Compartment model representing time-dependent particle transport and dissolution, followed by instantaneous uptake to body fluids. Material moves into compartment k by particle transport from compartment j at a rate $m_{j,k}$, and from it by particle transport to compartment l at a rate $m_{k,l}$. $I_k(t)$ and $T_k(t)$ are the amounts of material present at time t in compartments representing "Particles in initial state" and "Particles in transformed state", respectively.

Similarly, the amount of material present in "Particles in transformed state", $T_k(t)$ is described by:

$$\frac{dT_k(t)}{dt} = m_{jT,kT}T_j(t) + s_{pt}I_k(t) - (m_{kT,lT} + s_t)T_k(t)$$
$$= m_{j,k}T_j(t) + s_{pt}I_k(t) - (m_{k,l} + s_t)T_k(t) \quad (4)$$

(46) For some compartments, such as bb_1 (Fig. 3), material enters by particle transport from more than one compartment, and in the case of compartment AI_3, material is cleared by particle transport to two compartments. Additional components are required in the equations above to take account of this. In some cases, there is no compartment supplying material by particle transport (e.g. AI_1, AI_2, AI_3), and in others there is no particle transport out of the compartment (e.g. LN_{TH}, LN_{ET}) and correspondingly fewer components are required.

(47) *Uptake* to body fluids of dissociated material can usually be treated as instantaneous, but in some situations a significant fraction of the dissociated material is absorbed slowly into body fluids as a result of binding to respiratory tract components. To represent time-dependent *uptake*, it is assumed that a fraction (f_b) of the dissolved material is retained in a "bound" state (Fig. 6), from which it goes into body fluids at a rate s_b, while the remaining fraction ($1-f_b$) goes to body fluids instantaneously. In the model, material in the "bound" state is *not* cleared by particle transport processes, but only by uptake to body fluids. Thus, only one "bound" compartment is required for each region.

(48) It is recommended that material-specific rates of absorption should be used in the model for compounds for which reliable human or animal experimental data exist. For other compounds, default values of parameters are recommended, according to whether the absorption is considered to be fast (Type F), moderate (M) or slow (S) (corresponding broadly to inhalation Classes D, W and Y in the *ICRP Publication 30* system). Reference values for each are specified in terms of the parameters s_p, s_{pt} and s_t, and are given in

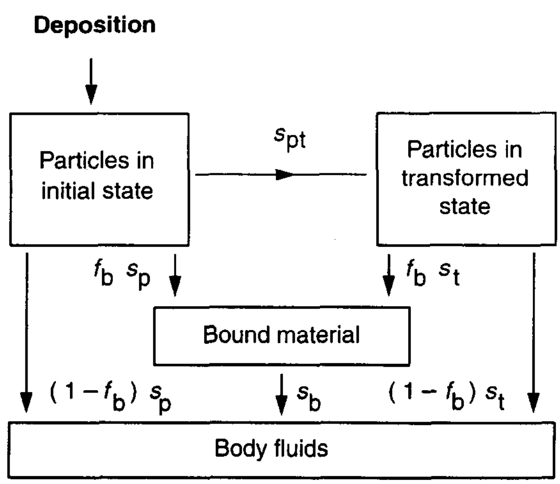

Fig. 6. Compartment model representing time-dependent absorption to body fluids (dissolution and uptake). Material in the compartment labelled "Particles in transformed state" is subject to particle transport at the same rate as material in the compartment labelled "Particles in initial state". Material in the compartment labelled "Bound material" is not subject to particle transport at all. It is cleared only by uptake into body fluids. For definition of symbols, see text.

Table 8. The "bound" state is not invoked for the default values, i.e. $f_b = 0$ for all three Types.

(49) These absorption rates, expressed as *approximate* half-times, and the corresponding amounts of material deposited in each region *that reach body fluids* can be summarized as follows:

Type F: 100% absorbed with a half-time of 10 min. There is rapid absorption of almost all material deposited in BB, bb, and AI, and 50% of material deposited in ET_2. The other 50% of material deposited in ET_2 is cleared to the GI tract by particle transport.

Type M: 10% absorbed with a half-time of 10 min and 90% with a half-time of 140 d. There is rapid absorption of about 10% of the deposit in BB and bb; and 5% of material deposited in ET_2. About 70% of the deposit in AI eventually reaches body fluids.

Type S: 0.1% absorbed with a half-time of 10 min and 99.9% with a half-time of 7000 d. There is little absorption from ET, BB or bb, and about 10% of the deposit in AI eventually reaches body fluids.

For all three absorption Types, all the material deposited in ET_1 is removed by extrinsic means. Most of the deposited material that is not absorbed is cleared to the GI tract by particle transport. The small amounts transferred to lymph nodes continue to be absorbed into body fluids at the same rate as in the respiratory tract.

(50) As an alternative to any of the three default Types defined in *ICRP Publication 66*, instantaneous uptake to body fluids (Type V) may be recommended. This was employed for several compounds in *ICRP Publication 68*, following the descriptions of behaviour given in *ICRP Publication 30*. Although consideration has to be given to the total respiratory tract deposition, regional deposition does not need to be assessed for such materials, since for the purposes of dose calculation they can be treated as if they were injected directly into body fluids.

(51) It is intended that in the revision of *ICRP Publication 30*, information relating to absorption in the respiratory tract of each element having isotopes of radiological importance will be reviewed. Where possible, absorption rates for important compounds will be recommended, and other compounds will be assigned to the three absorption Types. In *ICRP Publication 68*, giving inhalation dose coefficients for workers, compounds for which clearance was previously given as Class D, W or Y in *ICRP Publication 30*, were generally assigned to the new Types F, M or S, respectively.

(52) In this report, guidance is given for each element on which of the default absorption Types should be chosen for environmental exposure, according to the information available. For environmental exposure, the physico-chemical form of the radionuclides inhaled is

Table 8. Default absorption rates for Type F, M and S materials (*ICRP Publication 66*, 1994a)[a]

Type	F (fast)	M (moderate)	S (slow)
Model parameters (d^{-1})			
s_p	100	10	0.1
s_{pt}	0	90	100
s_t	—	0.005	0.0001

[a]The parameter values in this table are reference values, i.e. the recommended default values for use in the model. No "bound" state is assumed for default Types.

generally less well defined than in the case of workplace exposure, and there have been relatively few studies of respiratory tract clearance of radionuclides administered in forms likely to be representative of environmental exposure. Thus it is not feasible to specify absorption parameters for all the chemical forms likely to be encountered in the environment.

(53) Often the radioactive element will be present as a minor constituent of the inhaled particles. Absorption of the radionuclide to body fluids may well then be controlled by dissolution of the particle matrix, rather than by the elemental form of the radionuclide, and so may be different from that generally associated with simple compounds of the element. In particular, this may give rise to Type M or S forms of radionuclides, for which most common simple compounds are Type F. Such particle matrices might be soil minerals, particularly clays, condensates or ash formed in fires or high temperature industrial processes, or mixtures of stable and radioactive elements. Following an accidental release from a nuclear reactor, fission and activation products may be present in fragments of irradiated fuel, of which the matrix is predominantly uranium oxide (Devell, 1988; Toivonen *et al.*, 1992). When elements such as caesium, which are generally very readily absorbed from the lungs to body fluids, are incorporated into fused clay particles, which are highly insoluble, only a small fraction may be absorbed rapidly. The rest is retained within the particles and thus absorbed slowly, at a rate of the order of 0.001 d^{-1} (Snipes *et al.*, 1983). *In vitro* dissolution studies of coal fly ash have shown that lead, polonium and radium are similarly retained in the particles (Kalkwarf *et al.*, 1984). Fission products could also be present in such insoluble matrices in nuclear weapons fallout (Norman and Winchell, 1970). Conversely, in some circumstances, the absorption rate of a relatively insoluble compound can be faster when it is present as a minor component of a more soluble matrix. In particular, absorption of plutonium is much more rapid from oxides in which it is mixed with metals such as sodium or magnesium, than from pure PuO_2 (Stather *et al.*, 1979; Métivier *et al.*, 1980).

(54) Section 5 consists of sub-sections on each of the elements covered, giving respiratory tract biokinetic data and inhalation dose coefficients. A brief review is given of available information on the absorption from the respiratory tract to body fluids following deposition of various compounds of the element. Previous ICRP guidance, generally from the report of the Task Group on Lung Dynamics, (TGLD, 1966), and *ICRP Publication 30* is outlined. For a number of elements it is stated that, by default, unspecified compounds were assigned by the TGLD to inhalation Class D. This is based on the statement in *ICRP Publication 19* (ICRP, 1972, p. 6): "Compounds not specified as Class Y or Class W according to the Task Group on Lung Dynamics are to be considered as Class D (retained for days)." More recent information is then summarized in the order: gases and vapours (see below); particulate materials exhibiting Types F, M and S behaviour, respectively. Emphasis is placed on any information specifically relevant to environmental exposure.

(55) *ICRP Publication 66* does not give criteria for assigning compounds to absorption Types on the basis of experimental results, since it was considered that where such information is available it should be used to determine values of the absorption parameters. Since that approach could not be applied here, such criteria were developed.

(56) Quantitative criteria are given in Annexe D to assign specific materials to Types F, M and S. So that they can be applied uniformly to different mammalian species and different initial patterns of deposition throughout the respiratory tract, as well as to *in vitro* studies, they are defined in terms of the fraction of the deposit absorbed into body fluids in a given time, from a material with a specified constant rate of absorption.

(57) In setting the criterion for assigning a material to Type F, it was considered that there should be no "significant" component of "long-term" lung retention: more than about 90%

of the deposit in the alveolar region in man would be absorbed into body fluids within a month. For assigning a material to Type S, it was considered that in man there should be "significant" lung retention for "years" after intake: less than about 10% of the deposit in the alveolar region would be absorbed into body fluids within 6 months. Further details of the derivation and application of these criteria are given in Annexe D.

(58) In general, for important radionuclides, inhalation dose coefficients for Type M materials are intermediate between those for Types F and S. Therefore, if information is lacking, selection of Type M is least likely to lead to a large overestimate or underestimate of committed effective dose. It is therefore recommended here that for most elements, in the absence of more specific information on absorption characteristics, Type M behaviour is assumed as a default for environmental exposure of members of the public to radioisotopes in particulate form. Exceptions are made in those cases (such as caesium, iodine and thorium) where experimental data indicate that many of the principal forms of the element likely to be encountered exhibit behaviour characteristic of Types F or S.

(59) For each element inhaled in particulate form, dose coefficients are given for absorption Types F, M and S. A summary table gives the values of fractional GI tract absorption, f_1 (see Paragraphs 13 and 14) adopted for each absorption Type.

2.4. Gases and Vapours

(60) For radionuclides inhaled in particulate form it is assumed that entry and regional deposition in the respiratory tract are governed only by the size distribution of the aerosol particles. The situation is different for gases and vapours, for which respiratory tract deposition is material-specific. (In the context of the *ICRP Publication 66* respiratory tract model, *deposition* refers to the initial process, determining how much of the material in the inspired air remains behind after exhalation.) Almost all inhaled gas molecules contact airway surfaces, but usually return to the air unless they dissolve in, or react with, the surface lining. The fraction of an inhaled gas or vapour that is deposited in each region thus depends on its solubility and reactivity. Generally, however, the regional deposition of a gas or vapour cannot be predicted on a mechanistic basis, from knowledge of its physical and chemical properties, but has to be obtained from an *in vivo* experimental study.

(61) As a general default approach, the *ICRP Publication 66* model assigns gases and vapours to three classes, on the basis of the initial pattern of respiratory tract deposition:

- Class SR-0 insoluble and non-reactive: negligible deposition in the respiratory tract.
- Class SR-1 soluble or reactive: deposition may occur throughout the respiratory tract.
- Class SR-2 highly soluble or reactive: total deposition in the extrathoracic airways (ET_2).

Subsequent retention in the respiratory tract and absorption to body fluids are determined by the chemical properties of the specific gas or vapour.

(62) In this report, the approach taken to giving guidance on the deposition and clearance of gases and vapours is similar to that taken on the respiratory tract clearance of radionuclides inhaled in particulate form. For those elements for which inhalation of radionuclides in gas or vapour form is potentially important (see Preface to Section 5), defaults are recommended for the SR class (which determines deposition), and corresponding absorption Type (which determines clearance, and may be V or F), to be used for gases and vapours in the absence of further information. More specific guidance is given in summary tables. Since this report is concerned with environmental exposure, consideration is given only to the behaviour at low mass concentrations.

(63) *Class SR-0.* The elements considered in this report do not include any of the noble gases, and no compounds of the elements covered here are assigned to SR-0.

(64) *Class SR-1.* Soluble or reactive gases and vapours may be deposited throughout the respiratory tract. They may irradiate all airways, but generally exposure is dominated by activity absorbed into body fluids. They require individual evaluation, and some guidance is given in *ICRP Publication 66*. It is recommended (*ICRP Publication 66*, Paragraph 221) that in the absence of information 100% deposition is assumed, with the following distribution: 10% ET_1, 20% ET_2, 10% BB, 20% bb, and 40% AI. It is recommended in *ICRP Publication 68*, Paragraph A2, that if total deposition is known to be different from 100%, then regional deposits should, by default, be distributed in the same proportions, and that the distribution of the deposit in BB (and bb) between the three compartments (BB_1, BB_2 and BB_{seq}, Fig. 3) should be 0.493:0.5:0.007. These recommendations are followed in this report. As noted above, however, generally for SR-1 compounds exposure is dominated by activity absorbed into body fluids. The key parameter is therefore the total fraction of inhaled material deposited in region ET_2 and the lungs (it is assumed that there is no absorption to body fluids from ET_1). Regional deposition is of secondary importance, as, to some extent, is the rate of absorption to body fluids, unless this is low compared to the rate of nuclear transformation.

(65) *Class SR-2.* Highly soluble or reactive gases and vapours as defined in *ICRP Publication 66* are taken to be completely deposited in ET_2. In *ICRP Publication 30* there are a number of compounds for which it is assumed that all the inhaled material is completely and instantaneously translocated to "body fluids" or to the "transfer compartment" without changing its chemical form (Type V). These are therefore classed as SR-2 in *ICRP Publication 68*. As noted below, the assumption of instantaneous uptake leads to simplifications in treatment, and, in view of the convenience this brings, in this report compounds are assigned to Class SR-2 on the basis of 100% deposition and instantaneous absorption to body fluids.

2.5. Respiratory Tract Dosimetry

(66) The dose to the cells at risk in each respiratory tract region is given by the average dose to the target tissue in that region. The target cells identified in both extrathoracic regions, the bronchial and bronchiolar regions, and dimensions that define the mass of tissue containing target cells in each region for dose calculations are given in Table 9. These ranges of depths of target tissues are assumed to be independent of age and sex. The masses of tissue containing target cells in each region, for each age, for use in dose calculations are given in Table 10.

(67) In each respiratory tract region there are also several possible sources. In bb, for example, activity in the fast phase of clearance (bb_1, Fig. 3) is taken to be in the mucus layer above the cilia; activity in the slow phase of clearance (bb_2) is taken to be in the fluid between the cilia; particles retained in the airway wall (bb_{seq}) are taken to be in a macrophage layer at a depth of 20–25 μm (i.e. below the target cells); activity "bound" to the epithelium is uniformly distributed in it; and account also has to be taken of irradiation from activity present in the alveolar region. For each source/target combination, *ICRP Publication 66* provides absorbed fractions for non-penetrating radiations: (α, β and electrons) in each case as a function of energy. To obtain these absorbed fractions, a single cylindrical geometry was used to represent each region of the conducting airways (the anterior nose, ET_1; the posterior passages, mouth, pharynx and larynx, ET_2; the bronchial region, BB; and the bronchiolar region, bb): the representative bronchus for BB is 5 mm in diameter and the representative bronchiole for bb is 1 mm in diameter (*ICRP Publication 66*, Paragraphs 48 and 54).

Table 9. Target tissues of the respiratory tract (*ICRP Publication 66*, 1994a)

Organ	Region	Target cells	Mucus thickness (μm)	Epithelial thickness (μm)	Depth of target cell nuclei[a] (μm)	Assigned fraction[a] (A_i) of w_T
Extrathoracic airways	ET_1 (anterior nose)	Basal	—	50	40–50	0.001
	ET_2 (posterior nose, mouth, pharynx, larynx)	Basal	15	50	40–50	0.998
	LN_{ET} (lymphatics)		—	—	[c]	0.001
Thoracic airways (lungs)	BB (bronchial)	Secretory (BB_{sec})	5	55	10–40	0.333[b]
		Basal (BB_{bas})	5	55	35–50	
	bb (bronchiolar)	Secretory	2	15	4–12	0.333
	AI (alveolar–interstitial)		—	—	[c]	0.333
	LN_{TH} (lymphatics)		—	—	[c]	0.001

[a] Reference values, i.e. the recommended default values for use in the model, independent of age and sex. The extrathoracic airways were formally included in the list of remainder tissues and organs in *ICRP Publication 68*. Whenever the committed equivalent dose to the extrathoracic airways, H_{ET} (calculated according to eqn (5)) is the highest of all organ doses, a weighting factor of 0.025 (half of remainder) is applied to it, and 0.025 (half of remainder) to the mass-averaged committed equivalent dose in the rest of the remainder tissues and organs (ICRP, 1994b). The tissue weighting factor, w_T of 0.12 specified for lung in *ICRP Publication 60* is applied to the equivalent dose to the thoracic airways, H_{TH}, calculated according to eqn (6).
[b] The dose to BB, H_{bb}, is calculated as the arithmetic mean of the doses to BB_{sec} and BB_{bas}.
[c] Average dose to region calculated.

Table 10. Masses of target tissues in the respiratory tract in different subjects (*ICRP Publication 66*, 1994a)[a]

Region	Mass (g)					
	Age 3 mo	1 y	5 y	10 y	15 y (male)	Adult (male)
ET_1	0.002792	0.004133	0.008284	0.01263	0.01852	0.02000
ET_2	0.0628	0.0930	0.1864	0.2843	0.4166	0.4500
LN_{ET}[b]	1.23	2.05	4.11	6.78	11.7	15.0
BB_{sec}[c]	0.2531	0.3105	0.4695	0.6220	0.8169	0.8648
BB_{bas}[c]	0.1266	0.1553	0.2348	0.3110	0.4085	0.4324
bb	0.5014	0.5967	0.9469	1.305	1.768	1.949
AI[d]	90.4	151	301	497	859	1100
LN_{TH}	1.23	2.05	4.11	6.78	11.7	15.0

[a] Reference values. The values are given to sufficient precision for calculational purposes. This may be more precise than the biological data would support. These values are given to two significant figures in *ICRP Publication 66*, Table 5. Also see Paragraphs 29 and 31.
[b] Mass of lymphatic tissue is assumed to be the same in extrathoracic and thoracic regions.
[c] Masses for BB_{sec} and BB_{bas} are the masses of bronchial epithelium through which the nuclei of secretory cells and basal cells respectively are distributed and are based on reference values of airway dimensions.
[d] The mass of AI includes blood, but excludes lymph nodes.

(68) To take account of differences in sensitivity between tissues, the equivalent dose H_i to each region i is multiplied by a factor, A_i, representing the region's estimated radiosensitivity relative to that of the whole organ. The recommended values of A_i are also given in Table 9, and are assumed to be independent of age and sex. The weighted sum is the equivalent dose

to the extrathoracic airways or thoracic airways (given as "lungs" in the tables of dose coefficients) respectively:

$$H_{\mathrm{ET}} = H_{\mathrm{ET}_1} A_{\mathrm{ET}_1} + H_{\mathrm{ET}_2} A_{\mathrm{ET}_2} + H_{\mathrm{LN}_{\mathrm{ET}}} A_{\mathrm{LN}_{\mathrm{ET}}} \tag{5}$$

$$H_{\mathrm{TH}} = H_{\mathrm{BB}} A_{\mathrm{BB}} + H_{\mathrm{bb}} A_{\mathrm{bb}} + H_{\mathrm{AI}} A_{\mathrm{AI}} + H_{\mathrm{LN}_{\mathrm{TH}}} A_{\mathrm{LN}_{\mathrm{TH}}} \tag{6}$$

The tissue weighting factor, w_{T}, of 0.12 specified for lungs in *ICRP Publication 60* is applied to the equivalent dose to the thoracic airways, H_{TH}, to calculate the contribution to effective dose. The extrathoracic airways were formally included in the list of remainder tissues and organs in *ICRP Publication 68* (Table 1).

(69) In calculating the equivalent dose to the extrathoracic airways and thoracic airways, irradiation from the activity distributed in the remainder of the body is taken into account using photon absorbed fractions (AF) taken from Cristy and Eckerman (1987, 1993). For the extrathoracic regions, the specific absorbed fraction (SAF, i.e. the AF per unit mass of target tissue) for the thyroid is used as a surrogate. For all the thoracic regions the SAFs are taken to be the same as that for the whole lungs.

3. COMPUTATION OF AGE-DEPENDENT EFFECTIVE DOSE COEFFICIENTS

(70) The Commission defines effective dose, E, as:

$$E = \sum_{\mathrm{T}} w_{\mathrm{T}} H_{\mathrm{T}}$$

where w_{T} is the tissue weighting factor (Table 1) and H_{T} is the equivalent dose for tissue or organ T.

(71) Several subsidiary dosimetric quantities have proved useful for the dosimetry of incorporated radionuclides. Following an intake to the body of a radioactive material, there is a period during which the material gives rise to equivalent doses in the tissues of the body at varying rates. The time integral of the equivalent dose rate is called the committed equivalent dose, $H_{\mathrm{T}}(\tau)$ where τ is the integration time (in years) following intake. If τ is not specified, it is implied that the value is 50 y for adults and from intake to age 70 y for infants and children. In most cases the integration time for adults is from 20 to 70 y, but for a number of elements some of the transfer rates are related to bone formation rates, which remain age-specific until an age of about 25 y (Paragraph 19). For these, the integration time for adults is from 25 to 75 y. The committed effective dose over τ, $E(\tau)$, is obtained as the sum of the weighted committed equivalent doses to organs or tissues, $H_{\mathrm{T}}(\tau)$.

(72) *ICRP Publication 56* (ICRP, 1989) outlined the computational formulations of the age-dependent dosimetric quantities. Some additional discussion was necessary in *ICRP Publications 67* and *69* (ICRP 1993, 1995) in implementing, in an age-dependent manner, the effective dose quantity defined in the 1990 recommendations (ICRP, 1991a).

(73) The equivalent dose rate at age t in target organ or tissue T due to an acute intake of a radionuclide by an individual of age t_0 at the time of intake, $\dot{H}_{\mathrm{T}}(t,t_0)$, is expressed as:

$$\dot{H}_{\mathrm{T}}(t, t_0) = \sum_{\mathrm{S}} q_{\mathrm{s}}(t, t_0)\ \mathrm{SEE}(T \leftarrow S; t) \qquad (7)$$

where

$q_{\mathrm{s}}(t, t_0)$ = the activity of the radionuclide in source region S at age t after intake at age t_0, Bq

$\mathrm{SEE}(T \leftarrow S;\ t)$ = Specific Effective Energy, equivalent dose in T per nuclear transformation in S at age t, Sv (Bq s)$^{-1}$

$$\mathrm{SEE}(T \leftarrow S; t) = \sum_{\mathrm{R}} \frac{Y_{\mathrm{R}} E_{\mathrm{R}} w_{\mathrm{R}} \mathrm{AF}(T \leftarrow S; t)_{\mathrm{R}}}{m_{\mathrm{T}}(t)} \qquad (8)$$

Y_{R} = yield of radiation R per nuclear transformation, (Bq s)$^{-1}$

E_{R} = energy of radiation R, J

w_{R} = radiation weighting factor for radiation R

$\mathrm{AF}(T \leftarrow S;\ t)_{\mathrm{R}}$ = absorbed fraction in T per transformation in S for radiation R at age t.

$m_{\mathrm{T}}(t)$ = mass of target tissue, T at age t, kg

Specific absorbed fractions (SAFs) at six standard ages have been published (Cristy and Eckerman, 1987, 1993). Values of SEE at intermediate ages are obtained by linear interpolation based on inverse total body mass.

(74) The committed equivalent dose in T accumulated by age 70 y due to the intake at age t_0, $H_T(70-t_0)$, is:

$$H_T(70 - t_0) = \int_{t_0}^{70} \dot{H}_T(t, t_0)\,dt = \int_{t_0}^{70} \sum q_s(t, t_0)\ \mathrm{SEE}(T \leftarrow S; t)\,dt \tag{9}$$

When a radionuclide decays to a decay product, which is itself radioactive, an equivalent set of equations applies to doses from the decay product(s). The identity of decay products, information on the Types of radiations emitted by the radionuclide (i.e. energies and intensities), and the half-lives of the radionuclides used in this report are those given in *ICRP Publication 38* (ICRP, 1983).

(75) The usual assumption in *ICRP Publications 30* and *56* was that these radioactive decay products adopted the biokinetics of their parent; there were a few exceptions in *ICRP Publication 30* for decay products that were isotopes of iodine or noble gases. The new ICRP model of the respiratory tract proposes that the rate at which the particle dissociates is determined by its matrix but the behaviour of dissociated material in the lung would be expected to depend on its elemental form. This consideration would also be relevant to decay products entering the systemic circulation. For the present implementation of the respiratory tract model the escape from the body of radon formed as a decay product within the respiratory tract is included. For calculational purposes a rate of 100 d^{-1} is assumed for this process, in addition to the other routes of removal. This extends the approach adopted for ^{222}Rn following intakes of ^{226}Ra in *ICRP Publication 30*, Part 1. Radioisotopes of xenon formed from the decay of iodine are assumed to escape from the body without decay, as in *ICRP Publication 30*, Part 1. In other cases, the absorption parameters of the parent are applied to all members of the decay chain. In this report separate systemic biokinetics have been applied to the parent and its decay products for those elements where this is assumed in *ICRP Publications 67* and *69*. This applies to intakes of lead, radium, tellurium, thorium and uranium (as described in Annexe C). For other elements, the treatment of decay products follows that in *ICRP Publication 30*.

(76) The committed effective dose accumulated by age 70 y due to the intake at age t_0, $E(70-t_0)$, is:

$$E(70 - t_0) = \sum_{T=1}^{T=12} w_T H_T(70 - t_0) + w_{\mathrm{remainder}} H_{\mathrm{remainder}}(70 - t_0) \tag{10}$$

where the summation extends over the twelve organs and tissues in Table 1 assigned explicit weighting factors, $w_{\mathrm{remainder}}$ is the weighting factor for the remainder tissues, and $H_{\mathrm{remainder}}(70-t_0)$ is the committed equivalent dose accumulated by age 70 y in remainder tissues. The treatment of the remainder dose is explained below. The equivalent dose in the remainder, $H_{\mathrm{remainder}}(70-t_0)$, is formulated in terms of the average equivalent dose in the tissues comprising the remainder (ICRP, 1991a). For the adult, $H_{\mathrm{remainder}}(70-t_0)$ can be evaluated directly from the equivalent dose in these tissues, since their masses are independent of age; see Paragraphs 6 and 7 of *ICRP Publication 61* (ICRP, 1991b). For children, however, the evaluation of $H_{\mathrm{remainder}}(70-t_0)$ must reflect the age-dependence of the organ masses.

(77) The computational form of the equivalent dose rate in the remainder depends upon whether any organ or tissue of the remainder experiences a committed equivalent dose in excess of the committed equivalent dose in organs and tissues given explicit weighting factors

(ICRP, 1991a,b). Let H_{max} denote the maximum committed equivalent dose among all organs with explicit weighting factors and $H_{T'}$, the maximum committed equivalent dose among organs of the remainder. The equivalent dose rate in the remainder tissues, $\dot{H}_{remainder}(t, t_0)$ is then:

$$\dot{H}_{remainder}(t, t_0) = \begin{cases} \dfrac{\sum\limits_{T=1}^{T=10} m_T(t)\dot{H}_T(t, t_0)}{\sum\limits_{T=1}^{T=10} m_T(t)}, & \text{if } H_{T'} \leq H_{max} \\ 0.5\left[\dfrac{\sum\limits_{T=1(T\neq T')}^{T=10} m_T(t)\dot{H}_T(t, t_0)}{\sum\limits_{T=1(T\neq T')}^{T=10} m_T(t)} + \dot{H}_{T'}(t, t_0)\right], & \text{if } H_{T'} > H_{max} \end{cases} \tag{11}$$

where the summation extends over the ten individual organs and tissues of the remainder. In implementing the above equation, the organ masses, $m_T(t)$, are obtained by linear interpolation with time of the data in Table 11. The committed equivalent dose accumulated by age 70 y in the remainder tissue due to an intake at age t_0 is:

$$H_{remainder}(70 - t_0) = \int_{t_0}^{70} \dot{H}_{remainder}(t, t_0)\,\mathrm{d}t \tag{12}$$

(78) In the case of the adult, the organ masses are assumed to be independent of age and thus the formulation is identical to that in *ICRP Publication 61* (ICRP, 1991b).

(79) The dose coefficient is the committed tissue equivalent dose per unit intake at age t_0, $h_T(\tau)$, or committed effective dose per unit intake, $e(\tau)$, where τ is the time period in years over which the dose is calculated, i.e. 50 y for adults and $(70 - t_0)$ y for children. Thus $h_T(\tau)$ and $e(\tau)$ in Sv Bq^{-1} correspond, respectively, to $H_T(\tau)$ and $E(\tau)$ (given for children in eqns (9) and (10)) resulting from the intake of 1 Bq.

Table 11. Reference organ masses and total body (g) used for calculating SEE[a]

Organ	Newborn	1 y	5 y	10 y	15 y	Adult[b]
Adrenals	5.83	3.52	5.27	7.22	10.5	14.0
Brain	352	884	1 260	1 360	1 410	1 400
Breasts	0.107	0.732	1.51	2.60	360	360
Extrathoracic airways	1.30	2.15	4.30	7.08	12.1	15.5
Gall bladder wall	0.408	0.910	3.73	7.28	9.27	10.0
GI tract						
LLI[c] wall	7.96	20.6	41.4	70.0	127	160
SI[c] wall	32.6	84.9	169	286	516	640
stomach wall	6.41	21.8	49.1	85.1	118	150
ULI[c] wall	10.5	27.8	55.2	93.4	168	210
Heart wall	25.4	50.6	92.8	151	241	330
Kidneys	22.9	62.9	116	173	248	310
Liver	121	292	584	887	1 400	1 800
Lungs[d]	50.6	143	290	453	651	1 000
Muscle	760	2 500	5 000	11 000	22 000	28 000
Ovaries	0.328	0.714	1.73	3.13	11.0	11.0
Pancreas	2.80	10.3	23.6	30.0	64.9	100
Skeleton						
Active marrow	47	150	320	610	1 050	1 500
Endosteal tissue	15.0	26.0	37.0	68.0	120	120
Bone volume	140	499	1 094	1 980	4 030	5 000
Skin	118	271	538	888	2 150	2 600
Spleen	9.11	25.5	48.3	77.4	123	180
Testes	0.843	1.21	1.63	1.89	15.5	35.0
Thymus	11.3	22.9	29.6	31.4	28.4	20.0
Thyroid	1.29	1.78	3.45	7.93	12.4	20.0
Urinary bladder wall	2.88	7.70	14.5	23.2	35.9	45.0
Uterus	3.85	1.45	2.70	4.16	80.0	80.0
Total body mass[e]	3 536	9 543	19 458	32 620	55 825	68 831

[a] Values for extrathoracic airways are based on those given in Table 10; values for muscle for the 3-mo-old and the adult are from *ICRP Publication 23*; values for other organs are from *ICRP Publication 56*, Table 1-1. The values are given to sufficient precision for calculational purposes. This may be more precise than the biological data would support.

[b] According to *ICRP Publication 23*.

[c] LLI, lower large intestine; ULI, upper large intestine; SI, small intestine.

[d] Thoracic airways. Masses used only for calculating cross fire from other source regions.

[e] The mass of the whole body minus the contents of the GI tract, urinary bladder and gall bladder.

4. APPLICATION OF THE DOSE COEFFICIENTS

(80) The inhalation dose coefficients calculated in this report are intended to be general purpose reference values. They are derived using single values of many parameters, which have been chosen to be representative but which are recognized to vary according to both the exposure conditions and the subject, for example:

- Activity Median Aerodynamic Diameter,
- Default absorption Type parameters,
- Partition of exposure conditions (e.g. time spent indoors and outdoors),
- Sex,
- Distribution of time between levels of exercise.

(81) In *ICRP Publications 30* and *68* it was pointed out that if the behaviour of any specific material is expected to differ significantly from that of the biokinetic model employed, then the model parameters should be modified to take account of the data available. The new respiratory tract model is designed to facilitate application of material-specific parameter values for inhaled compounds. Similarly, *ICRP Publication 66* contains subject-specific parameter values, which enable more accurate assessments of doses to be made to particular subgroups of the population. The advice to use material- and subject-specific parameter values for absorption rates from both the respiratory system and the GI tract is reinforced here, since the default values chosen were selected to be representative, rather than conservative. This applies particularly to interpretation of urine samples, since excretion rates can be much more sensitive than doses to assumed rates of absorption, either from the respiratory tract or GI tract. Where additional information is available, more accurate assessments of doses can be made by applying the methodology used here.

(82) As noted in Section 2.1, doses per unit exposure (time-integrated activity concentration in air) are frequently required for environmental dose assessments. It may be necessary to consider a group of the population for which the distribution of time spent between exercise levels is different from that for which the reference deposition fractions are given in Table 7, and on which the dose coefficients are based. In general, however, the main effect of exercise level on dose per unit exposure is to change the ventilation rate and hence the volume inhaled, to which the intake is directly proportional. The regional deposition fractions, and hence the dose coefficients, are relatively insensitive to changes in exercise level. Thus for most purposes it would be reasonable to use the dose coefficients given here with other combinations of exercise level, and simply adjust the volume inhaled. The errors introduced are likely to be negligible compared to other uncertainties in the assessment.

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5. RESPIRATORY TRACT BIOKINETIC DATA AND INHALATION DOSE COEFFICIENTS

Preface

(84) This report provides inhalation dose coefficients for all the radionuclides for which ingestion dose coefficients were provided in *ICRP Publications 56, 67* and *69*, and for some additional radionuclides with shorter physical half-lives, marked with an asterisk below. Dose coefficients are also given for isotopes of calcium and caesium. Dose coefficients are given for Type F, M and S particulate forms of all elements, and for gas and vapour forms of those elements indicated below.

Section	Element	Gases and vapours	Radionuclides
5.1	Hydrogen	+	^{3}H
5.2	Carbon	+	^{14}C
5.3	Sulphur	+	^{35}S
5.4	Calcium		^{45}Ca, ^{47}Ca
5.5	Iron		^{55}Fe, ^{59}Fe
5.6	Cobalt		^{57}Co, ^{58}Co, ^{60}Co
5.7	Nickel	+	^{59}Ni, ^{63}Ni
5.8	Zinc		^{65}Zn
5.9	Selenium		^{75}Se, ^{79}Se
5.10	Strontium		^{89}Sr, ^{90}Sr
5.11	Zirconium		^{95}Zr
5.12	Niobium		^{94}Nb*, ^{95}Nb
5.13	Molybdenum		^{99}Mo
5.14	Technetium		^{99}Tc, ^{99m}Tc
5.15	Ruthenium	+	^{103}Ru, ^{106}Ru
5.16	Silver		^{108m}Ag, ^{110m}Ag
5.17	Antimony		^{124}Sb, ^{125}Sb, ^{126}Sb, ^{127}Sb*
5.18	Tellurium	+	^{127m}Te, ^{129m}Te, ^{131m}Te, ^{132}Te
5.19	Iodine	+	^{125}I, ^{129}I, ^{131}I, ^{132}I, ^{133}I*, ^{134}I*, ^{135}I*
5.20	Caesium		^{134}Cs, ^{136}Cs, ^{137}Cs
5.21	Barium		^{133}Ba, ^{140}Ba
5.22	Cerium		^{141}Ce, ^{144}Ce
5.23	Lead		^{210}Pb
5.24	Polonium		^{210}Po
5.25	Radium		^{224}Ra, ^{226}Ra, ^{228}Ra
5.26	Thorium		^{228}Th, ^{230}Th, ^{232}Th, ^{234}Th
5.27	Uranium		^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U
5.28	Neptunium		^{237}Np, ^{239}Np
5.29	Plutonium		^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu
5.30	Americium		^{241}Am, ^{243}Am*
5.31	Curium		^{242}Cm, ^{244}Cm

5.1. Hydrogen

(85) *ICRP Publication 30*, Part 1 (ICRP, 1979) considered inhalation of three forms of tritium: elemental tritium (HT), tritiated water (HTO) and organic compounds (organically bound tritium, OBT). It was assessed that, because of its low solubility, exposure to HT gas was limited by direct irradiation from the gas within the lungs. It was, however, emphasized that in practice exposure to HTO would usually be the limiting factor, because the exposure

Table 5.6.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-58 (T½ = 70.8 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	5.2E-09	4.2E-09	2.5E-09	1.5E-09	1.1E-09	9.2E-10
Bladder Wall	1.7E-09	1.1E-09	6.3E-10	4.0E-10	2.4E-10	2.1E-10
Bone Surface	2.8E-09	2.1E-09	1.1E-09	7.1E-10	5.1E-10	4.5E-10
Brain	1.1E-09	7.0E-10	3.9E-10	2.5E-10	1.6E-10	1.5E-10
Breast	4.1E-09	3.5E-09	2.4E-09	1.6E-09	1.0E-09	9.2E-10
GI-Tract						
Oesophagus	4.4E-09	3.7E-09	2.4E-09	1.6E-09	1.2E-09	1.1E-09
St Wall	3.4E-09	2.6E-09	1.5E-09	9.6E-10	7.6E-10	5.8E-10
SI Wall	3.3E-09	2.5E-09	1.3E-09	8.1E-10	4.8E-10	4.0E-10
ULI Wall	5.5E-09	4.1E-09	2.0E-09	1.3E-09	7.3E-10	6.2E-10
LLI Wall	9.7E-09	7.2E-09	3.4E-09	2.2E-09	1.2E-09	1.0E-09
Colon	7.3E-09	5.5E-09	2.6E-09	1.7E-09	9.3E-10	7.9E-10
Kidneys	2.8E-09	2.1E-09	1.1E-09	7.2E-10	5.0E-10	4.1E-10
Liver	4.9E-09	3.8E-09	2.2E-09	1.5E-09	1.1E-09	9.1E-10
Muscle	2.7E-09	2.1E-09	1.1E-09	7.4E-10	5.5E-10	4.6E-10
Ovaries	3.0E-09	2.3E-09	1.2E-09	7.6E-10	4.7E-10	3.8E-10
Pancreas	4.4E-09	3.4E-09	2.0E-09	1.2E-09	9.4E-10	7.2E-10
Red Marrow	2.2E-09	1.7E-09	1.1E-09	7.7E-10	6.1E-10	5.7E-10
Respiratory Tract						
ET Airways	3.3E-08	3.0E-08	1.6E-08	9.2E-09	5.5E-09	4.3E-09
Lungs	3.4E-08	2.8E-08	1.8E-08	1.2E-08	1.1E-08	8.9E-09
Skin	1.6E-09	1.1E-09	6.4E-10	4.0E-10	2.9E-10	2.5E-10
Spleen	4.0E-09	3.2E-09	1.7E-09	1.1E-09	8.5E-10	6.9E-10
Testes	1.1E-09	7.3E-10	3.6E-10	2.3E-10	1.4E-10	1.2E-10
Thymus	4.4E-09	3.7E-09	2.4E-09	1.6E-09	1.2E-09	1.1E-09
Thyroid	2.8E-09	2.1E-09	1.2E-09	7.5E-10	5.0E-10	4.3E-10
Uterus	2.2E-09	1.6E-09	8.1E-10	5.0E-10	3.0E-10	2.5E-10
Remainder	2.4E-09	1.6E-08	1.1E-09	7.0E-10	5.3E-10	4.5E-10
Effective Dose	7.3E-09	6.5E-09	3.5E-09	2.4E-09	2.0E-09	1.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-58 (T½ = 70.8 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	6.3E-09	5.4E-09	3.3E-09	2.0E-09	1.5E-09	1.2E-09
Bladder Wall	1.2E-09	9.0E-10	4.3E-10	2.8E-10	1.4E-10	1.1E-10
Bone Surface	2.9E-09	2.5E-09	1.3E-09	8.1E-10	6.0E-10	5.2E-10
Brain	5.2E-10	4.2E-10	2.5E-10	1.6E-10	1.2E-10	1.0E-10
Breast	5.2E-09	4.8E-09	3.4E-09	2.3E-09	1.4E-09	1.3E-09
GI-Tract						
Oesophagus	5.3E-09	4.7E-09	3.3E-09	2.2E-09	1.7E-09	1.5E-09
St Wall	3.7E-09	3.1E-09	1.8E-09	1.2E-09	9.7E-10	7.1E-10
SI Wall	3.1E-09	2.4E-09	1.2E-09	7.8E-10	4.5E-10	3.7E-10
ULI Wall	5.9E-09	4.4E-09	2.1E-09	1.4E-09	7.6E-10	6.3E-10
LLI Wall	1.1E-08	7.9E-09	3.7E-09	2.4E-09	1.3E-09	1.1E-09
Colon	8.2E-09	5.9E-09	2.8E-09	1.8E-09	9.9E-10	8.1E-10
Kidneys	2.8E-09	2.4E-09	1.3E-09	7.8E-10	5.6E-10	4.5E-10
Liver	4.8E-09	4.2E-09	2.5E-09	1.6E-09	1.3E-09	1.0E-09
Muscle	2.8E-09	2.4E-09	1.3E-09	8.7E-10	6.7E-10	5.5E-10
Ovaries	2.8E-09	2.1E-09	1.1E-09	6.9E-10	4.2E-10	3.2E-10
Pancreas	4.9E-09	4.1E-09	2.5E-09	1.5E-09	1.2E-09	9.1E-10
Red Marrow	2.2E-09	1.9E-09	1.2E-09	9.0E-10	7.5E-10	7.0E-10
Respiratory Tract						
ET Airways	3.5E-08	3.2E-08	1.7E-08	9.8E-09	5.9E-09	4.6E-09
Lungs	4.7E-08	3.9E-08	2.5E-08	1.8E-08	1.6E-08	1.3E-08
Skin	1.5E-09	1.2E-09	7.1E-10	4.5E-10	3.3E-10	2.9E-10
Spleen	4.6E-09	4.1E-09	2.2E-09	1.5E-09	1.1E-09	8.9E-10
Testes	5.7E-10	4.2E-10	1.8E-10	1.1E-10	5.4E-11	4.0E-11
Thymus	5.3E-09	4.7E-09	3.3E-09	2.2E-09	1.7E-09	1.5E-09
Thyroid	2.8E-09	2.4E-09	1.4E-09	8.8E-10	6.0E-10	5.1E-10
Uterus	1.7E-09	1.3E-09	6.6E-10	3.8E-10	2.1E-10	1.7E-10
Remainder	2.4E-09	2.1E-09	1.2E-09	8.1E-10	6.4E-10	5.3E-10
Effective Dose	9.0E-09	7.5E-09	4.5E-09	3.1E-09	2.6E-09	2.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-60 (T½ = 5.27 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.1
Adrenals	3.2E-08	2.4E-08	1.4E-08	9.9E-09	6.8E-09	5.8E-09
Bladder Wall	2.5E-08	1.9E-08	1.2E-08	6.9E-09	5.0E-09	4.8E-09
Bone Surface	2.6E-08	2.0E-08	1.2E-08	7.8E-09	5.4E-09	4.7E-09
Brain	2.3E-08	1.7E-08	9.8E-09	6.1E-09	4.0E-09	3.4E-09
Breast	1.9E-08	1.4E-08	8.2E-09	5.5E-09	3.9E-09	3.3E-09
GI-Tract						
Oesophagus	2.6E-08	2.0E-08	1.1E-08	7.5E-09	5.1E-09	4.3E-09
St Wall	2.7E-08	2.0E-08	1.2E-08	7.5E-09	5.5E-09	4.6E-09
SI Wall	3.1E-08	2.4E-08	1.4E-08	9.2E-09	6.2E-09	5.3E-09
ULI Wall	3.2E-08	2.5E-08	1.4E-08	9.4E-09	6.2E-09	5.5E-09
LLI Wall	3.3E-08	2.7E-08	1.5E-08	9.6E-09	6.2E-09	6.0E-09
Colon	3.2E-08	2.6E-08	1.5E-08	9.5E-09	6.2E-09	5.7E-09
Kidneys	2.9E-08	2.2E-08	1.3E-08	8.9E-09	6.1E-09	5.2E-09
Liver	5.5E-08	4.2E-08	2.5E-08	1.8E-08	1.3E-08	1.1E-08
Muscle	2.5E-08	1.9E-08	1.1E-08	7.0E-09	4.8E-09	4.2E-09
Ovaries	3.0E-08	2.3E-08	1.4E-08	9.0E-09	6.2E-09	5.3E-09
Pancreas	3.4E-08	2.6E-08	1.5E-08	1.0E-08	6.9E-09	5.8E-09
Red Marrow	2.3E-08	1.7E-08	1.1E-08	7.4E-09	5.1E-09	4.4E-09
Respiratory Tract						
ET Airways	9.5E-08	8.3E-08	4.5E-08	2.7E-08	1.6E-08	1.3E-08
Lungs	2.5E-08	1.9E-08	1.1E-08	7.5E-09	5.3E-09	4.4E-09
Skin	1.8E-08	1.4E-08	7.5E-09	4.9E-09	3.4E-09	3.0E-09
Spleen	2.8E-08	2.1E-08	1.2E-08	8.1E-09	5.5E-09	4.7E-09
Testes	2.3E-08	1.7E-08	9.9E-09	6.6E-09	4.6E-09	4.0E-09
Thymus	2.6E-08	2.0E-08	1.1E-08	7.5E-09	5.1E-09	4.3E-09
Thyroid	2.8E-08	2.1E-08	1.2E-08	7.7E-09	5.0E-09	4.3E-09
Uterus	3.0E-08	2.3E-08	1.3E-08	9.0E-09	6.1E-09	5.3E-09
Remainder	6.0E-08	5.1E-08	2.8E-08	1.7E-08	1.1E-08	8.5E-09
Effective Dose	3.0E-08	2.3E-08	1.4E-08	8.9E-09	6.1E-09	5.2E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-60 (T½ = 5.27 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	3.2E-08	2.7E-08	1.7E-08	1.0E-08	7.8E-09	6.8E-09
Bladder Wall	1.2E-08	9.2E-09	5.6E-09	3.3E-09	2.4E-09	2.5E-09
Bone Surface	2.0E-08	1.5E-08	9.0E-09	5.7E-09	4.3E-09	3.9E-09
Brain	1.1E-08	7.7E-09	4.6E-09	2.9E-09	2.1E-09	1.9E-09
Breast	2.5E-08	2.1E-08	1.5E-08	1.0E-08	6.6E-09	6.1E-09
GI-Tract						
Oesophagus	2.7E-08	2.3E-08	1.5E-08	1.0E-08	8.1E-09	7.3E-09
St Wall	2.2E-08	1.7E-08	1.1E-08	6.5E-09	5.5E-09	4.5E-09
SI Wall	1.9E-08	1.5E-08	8.4E-09	5.4E-09	3.7E-09	3.3E-09
ULI Wall	2.5E-08	1.9E-08	1.1E-08	6.6E-09	4.4E-09	3.9E-09
LLI Wall	3.5E-08	2.6E-08	1.4E-08	8.6E-09	5.3E-09	4.8E-09
Colon	2.9E-08	2.2E-08	1.2E-08	7.5E-09	4.8E-09	4.3E-09
Kidneys	2.0E-08	1.6E-08	9.5E-09	6.0E-09	4.4E-09	4.0E-09
Liver	3.7E-08	2.9E-08	1.8E-08	1.2E-08	9.7E-09	8.5E-09
Muscle	1.8E-08	1.4E-08	8.5E-09	5.5E-09	4.3E-09	3.8E-09
Ovaries	1.8E-08	1.3E-08	7.8E-09	5.0E-09	3.5E-09	3.1E-09
Pancreas	2.9E-08	2.3E-08	1.4E-08	9.1E-09	6.9E-09	5.7E-09
Red Marrow	1.6E-08	1.3E-08	8.2E-09	5.8E-09	4.6E-09	4.4E-09
Respiratory Tract						
ET Airways	1.2E-07	1.0E-07	5.4E-08	3.2E-08	2.0E-08	1.6E-08
Lungs	1.9E-07	1.6E-07	1.0E-07	7.3E-08	6.5E-08	5.2E-08
Skin	1.2E-08	9.0E-09	5.3E-09	3.5E-09	2.5E-09	2.4E-09
Spleen	2.5E-08	2.1E-08	1.2E-08	8.0E-09	6.1E-09	5.3E-09
Testes	1.0E-08	7.3E-09	4.3E-09	2.8E-09	2.1E-09	1.9E-09
Thymus	2.7E-08	2.3E-08	1.5E-08	1.0E-08	8.1E-09	7.3E-09
Thyroid	2.0E-08	1.6E-08	9.7E-09	6.0E-09	4.2E-09	3.8E-09
Uterus	1.6E-08	1.2E-08	6.8E-09	4.3E-09	3.1E-09	2.8E-09
Remainder	1.7E-08	1.3E-08	8.1E-09	5.3E-09	4.1E-09	3.7E-09
Effective Dose	4.2E-08	3.4E-08	2.1E-08	1.5E-08	1.2E-08	1.0E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-60 (T½ = 5.27 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	7.7E-08	7.5E-08	5.1E-08	3.1E-08	2.4E-08	2.2E-08
Bladder Wall	7.6E-09	6.5E-09	3.6E-09	2.0E-09	1.2E-09	1.0E-09
Bone Surface	3.4E-08	3.2E-08	2.0E-08	1.2E-08	9.9E-09	9.3E-09
Brain	6.6E-09	6.1E-09	4.1E-09	2.8E-09	2.2E-09	2.1E-09
Breast	7.1E-08	7.1E-08	5.3E-08	3.5E-08	2.5E-08	2.5E-08
GI-Tract						
Oesophagus	6.8E-08	6.8E-08	5.0E-08	3.5E-08	3.0E-08	2.8E-08
St Wall	4.0E-08	3.9E-08	2.6E-08	1.7E-08	1.5E-08	1.2E-08
SI Wall	2.0E-08	1.7E-08	9.7E-09	5.7E-09	4.0E-09	3.5E-09
ULI Wall	2.8E-08	2.3E-08	1.3E-08	7.6E-09	5.2E-09	4.5E-09
LLI Wall	3.8E-08	2.8E-08	1.4E-08	8.8E-09	5.3E-09	4.4E-09
Colon	3.2E-08	2.5E-08	1.4E-08	8.1E-09	5.2E-09	4.5E-09
Kidneys	3.3E-08	3.1E-08	1.9E-08	1.2E-08	9.3E-09	8.5E-09
Liver	5.9E-08	5.7E-08	3.8E-08	2.6E-08	2.2E-08	2.0E-08
Muscle	3.2E-08	3.0E-08	2.0E-08	1.3E-08	1.1E-08	9.8E-09
Ovaries	1.4E-08	1.2E-08	7.1E-09	4.1E-09	2.7E-09	2.3E-09
Pancreas	5.9E-08	5.6E-08	3.7E-08	2.4E-08	1.9E-08	1.6E-08
Red Marrow	2.7E-08	2.6E-08	1.9E-08	1.4E-08	1.2E-08	1.2E-08
Respiratory Tract						
ET Airways	2.4E-07	2.2E-07	1.2E-07	7.5E-08	4.7E-08	4.3E-08
Lungs	5.3E-07	4.9E-07	3.4E-07	2.4E-07	2.1E-07	1.8E-07
Skin	1.7E-08	1.6E-08	1.1E-08	7.3E-09	5.6E-09	5.5E-09
Spleen	5.5E-08	5.3E-08	3.5E-08	2.3E-08	1.9E-08	1.7E-08
Testes	4.0E-09	3.3E-09	1.8E-09	1.1E-09	6.2E-10	5.1E-10
Thymus	6.8E-08	6.8E-08	5.0E-08	3.5E-08	3.0E-08	2.8E-08
Thyroid	3.7E-08	3.5E-08	2.3E-08	1.4E-08	1.0E-08	9.8E-09
Uterus	1.1E-08	9.8E-09	5.3E-09	2.8E-09	1.9E-09	1.6E-09
Remainder	2.7E-08	2.6E-08	1.8E-08	1.2E-08	1.0E-08	9.4E-09
Effective Dose	9.2E-08	8.6E-08	5.9E-08	4.0E-08	3.4E-08	3.1E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.7. Nickel

(127) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides, halides, carbides and nitrates of nickel (Ni) to inhalation Class W and all other compounds of the element to Class D. In *ICRP Publication 30*, Part 3 (ICRP, 1981), hydroxides and carbides of nickel were assigned to Class W. All other commonly occurring nickel compounds were assigned to Class D, except nickel carbonyl, which was treated as a vapour (see below).

(128) A dosimetric model for extrapolating results of rat nickel inhalation studies to humans has been presented by Oberdörster (1989).

Absorption Types

(a) *Gases and vapours*

(129) *Nickel carbonyl.* Little new information was found regarding the inhalation of nickel carbonyl beyond that quoted in *ICRP Publication 30*, Part 3 (Tedeschi and Sunderman, 1957; Sunderman and Selin, 1968; Committee on Medical and Biological Effects of Environmental Pollutants, 1975). It is assumed in *ICRP Publication 30* that all nickel entering the respiratory system as nickel carbonyl is deposited there and then translocated to the transfer compartment with a half-time of 0.1 d. Following the treatment of nickel carbonyl in *ICRP Publication 68* (ICRP, 1994), the initial deposition is here taken to be 30% ET_2, 10% BB, 20% bb, 40% AI. The deposited material is instantaneously transferred to the "bound" compartments in ET, BB, bb and AI respectively ($s_p = \infty$; $s_{pt} = 0$; $f_b = 1$, Fig. 6). To give subsequent transfer to blood with a half-time of 0.1 d, s_b is set to $\ln 2/(0.1\ d) = 7\ d^{-1}$.

(b) *Particulate aerosols*

(130) Following inhalation of ^{63}Ni-labelled nickel sulphate by rats, the nickel was cleared from the lung with a half-time of 0.7–1.7 d, independent of the initial lung deposit of nickel, and with faeces the dominant route of excretion (Benson *et al.*, 1991). Following inhalation of $NiSO_4 \cdot 6H_2O$ by cynomolgus monkeys, nickel cleared rapidly from the body, with approximately 96% of the initial body content clearing with a half-time of 5 h, and the remaining 4% with a half-time of approximately 10 d (Benson *et al.*, 1993). Clearance of nickel sulphate is thus consistent with Type F.

(131) ^{63}Ni-labelled nickel subsulphide (Ni_3S_2) inhaled by rats cleared rapidly from the lung with a half-time of approximately 4 d (Benson *et al.*, 1994). Nickel was detected in several extra-respiratory tract tissues within a few hours after the end of the exposure and was detected in lung and kidneys up to 16 d post-exposure. Nickel was excreted in both urine and faeces throughout the first week after exposure, after which excretion in urine predominated. Following inhalation of Ni_3S_2 by cynomolgus monkeys, the pulmonary clearance half-time was 4 d (Benson *et al.*, 1993). Nickel was excreted in both urine and faeces. The results indicate either Type F or M behaviour, but do not enable the two to be distinguished.

(132) The fate of inhaled ^{63}Ni-labelled nickel oxide (NiO, "green" oxide, calcined at 1 200°C) has been studied in cynomolgus monkeys and in rats (Benson *et al.*, 1993, 1994). In the monkeys, nickel cleared rapidly from the upper respiratory tract, but little clearance occurred from the lung over a 200 d period after the exposure, and the lung retention half-time was estimated at >200 d. In rats, inhaled NiO was cleared from the lung with a half-time of 120 d. Other studies on NiO in rats indicated a half-time for pulmonary clearance of NiO of 33 d (Benson *et al.*, 1992). The reason for this difference is not known. Following the NiO exposures, the nickel was not distributed systemically and was excreted only in faeces during the first few days after the exposure. Tanaka and co-workers (1985) also investigated the

pulmonary clearance and tissue distribution of inhaled NiO in rats. The clearance half-times for nickel of 11.5–21 months were estimated based on the assumption that the amount of clearance was proportional to the amount deposited. Overall the results indicate Type S behaviour for NiO.

Dose coefficients

(133) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.7.2 and 5.7.3) were derived for the gases and vapours given in Table 5.7.1a, and for particulate aerosols using the f_1 values given in Table 5.7.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.7.1a. Classification and absorption Types for gas and vapour compounds of nickel

Chemical form/origin	Deposition: Vapour Class	Deposition: Fraction deposited (%)	Absorption: Type	Absorption: f_1
Carbonyl	SR-1	100[a]	[b]	[c]

[a] 30% ET_2, 10% BB, 20% bb, 40% AI.
[b] The deposited material is instantaneously transferred to the "bound" compartments in ET, BB, bb and AI respectively ($s_p = \infty$; $s_{pt} = 0$; $f_b = 1$, Fig. 6). To give subsequent transfer to blood with a half-time of 0.1 d, s_b is set to $\ln 2/(0.1\ \mathrm{d}) = 7\ \mathrm{d}^{-1}$.
[c] Not applicable since all material deposited in the respiratory tract is absorbed to body fluids.

Table 5.7.1b. Values of f_1 for inhaled particulate compounds of nickel

Absorption Type	f_1[a]: 3 mo	f_1[a]: 1 y–adult
F	0.1	0.05
M[b]	0.1	0.05
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[b] Default Type M is recommended for use in the absence of specific information.

Table 5.7.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-59 (T½ = 7.50E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Bladder Wall	9.4E-10	8.0E-10	4.5E-10	2.8E-10	2.0E-10	1.9E-10
Bone Surface	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Brain	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Breast	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
GI-Tract						
Oesophagus	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
St Wall	9.3E-10	7.9E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
SI Wall	9.5E-10	8.0E-10	4.5E-10	2.8E-10	1.9E-10	1.8E-10
ULI Wall	1.1E-09	9.2E-10	4.9E-10	3.0E-10	2.1E-10	1.9E-10
LLI Wall	1.5E-09	1.2E-09	5.9E-10	3.6E-10	2.3E-10	2.2E-10
Colon	1.3E-09	1.0E-09	5.4E-10	3.3E-10	2.2E-10	2.0E-10
Kidneys	9.6E-10	8.5E-10	4.7E-10	2.9E-10	1.9E-10	1.8E-10
Liver	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Muscle	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Ovaries	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Pancreas	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Red Marrow	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Respiratory Tract						
ET Airways	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Lungs	9.2E-10	7.9E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Skin	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Spleen	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Testes	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Thymus	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Thyroid	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Uterus	9.2E-10	7.8E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Remainder	9.2E-10	7.9E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Effective Dose	9.6E-10	8.1E-10	4.5E-10	2.8E-10	1.9E-10	1.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-59 (T½ = 7.50E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Bladder Wall	3.7E-10	2.9E-10	1.8E-10	1.1E-10	8.4E-11	8.1E-11
Bone Surface	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Brain	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Breast	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
GI-Tract						
Oesophagus	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
St Wall	3.9E-10	3.0E-10	1.8E-10	1.1E-10	8.3E-11	8.0E-11
SI Wall	4.3E-10	3.3E-10	1.9E-10	1.2E-10	8.6E-11	8.3E-11
ULI Wall	7.6E-10	5.6E-10	2.9E-10	1.8E-10	1.1E-10	1.1E-10
LLI Wall	1.5E-09	1.1E-09	5.1E-10	3.1E-10	1.8E-10	1.6E-10
Colon	1.1E-09	7.8E-10	3.9E-10	2.3E-10	1.4E-10	1.3E-10
Kidneys	3.8E-10	3.1E-10	1.8E-10	1.1E-10	7.9E-11	7.8E-11
Liver	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Muscle	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Ovaries	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Pancreas	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Red Marrow	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Respiratory Tract						
ET Airways	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Lungs	3.1E-09	2.5E-09	1.4E-09	8.1E-10	5.5E-10	4.7E-10
Skin	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Spleen	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Testes	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Thymus	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Thyroid	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Uterus	3.6E-10	2.9E-10	1.7E-10	1.0E-10	8.0E-11	7.8E-11
Remainder	3.6E-10	2.9E-10	1.7E-10	1.1E-10	8.0E-11	7.8E-11
Effective Dose	7.9E-10	6.2E-10	3.4E-10	2.1E-10	1.4E-10	1.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-59 (T½ = 7.50E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Bladder Wall	4.4E-11	3.1E-11	2.1E-11	1.4E-11	1.2E-11	1.2E-11
Bone Surface	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Brain	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Breast	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
GI-Tract						
Oesophagus	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
St Wall	7.9E-11	5.1E-11	2.9E-11	1.8E-11	1.5E-11	1.4E-11
SI Wall	1.2E-10	8.5E-11	4.4E-11	2.8E-11	1.9E-11	1.8E-11
ULI Wall	5.4E-10	3.7E-10	1.7E-10	1.0E-10	5.8E-11	5.1E-11
LLI Wall	1.5E-09	9.8E-10	4.5E-10	2.7E-10	1.5E-10	1.3E-10
Colon	9.3E-10	6.3E-10	2.9E-10	1.7E-10	9.6E-11	8.3E-11
Kidneys	4.6E-11	3.3E-11	2.1E-11	1.4E-11	1.1E-11	1.2E-11
Liver	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Muscle	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Ovaries	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Pancreas	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Red Marrow	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Respiratory Tract						
ET Airways	5.7E-11	4.3E-11	2.8E-11	2.0E-11	1.6E-11	1.6E-11
Lungs	1.3E-08	1.2E-08	7.5E-09	4.6E-09	3.7E-09	3.5E-09
Skin	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Spleen	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Testes	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Thymus	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Thyroid	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Uterus	4.3E-11	3.1E-11	2.0E-11	1.3E-11	1.2E-11	1.2E-11
Remainder	4.5E-11	3.2E-11	2.0E-11	1.4E-11	1.2E-11	1.2E-11
Effective Dose	1.7E-09	1.5E-09	9.5E-10	5.9E-10	4.6E-10	4.4E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-59 (T½ = 7.50E+04 y).

Nickel Carbonyl Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Bladder Wall	3.5E-09	3.0E-09	1.9E-09	1.2E-09	8.4E-10	7.6E-10
Bone Surface	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Brain	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Breast	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
GI-Tract						
Oesophagus	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
St Wall	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
SI Wall	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
ULI Wall	3.5E-09	3.0E-09	1.8E-09	1.1E-09	8.1E-10	7.4E-10
LLI Wall	3.6E-09	3.0E-09	1.9E-09	1.1E-09	8.2E-10	7.5E-10
Colon	3.6E-09	3.0E-09	1.8E-09	1.1E-09	8.1E-10	7.4E-10
Kidneys	3.6E-09	3.2E-09	1.9E-09	1.2E-09	7.9E-10	7.3E-10
Liver	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Muscle	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Ovaries	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Pancreas	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Red Marrow	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Respiratory Tract						
ET Airways	1.5E-08	1.1E-08	5.8E-09	3.7E-09	2.6E-09	2.4E-09
Lungs	5.1E-09	4.3E-09	2.7E-09	1.8E-09	1.3E-09	1.2E-09
Skin	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Spleen	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Testes	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Thymus	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Thyroid	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Uterus	3.5E-09	2.9E-09	1.8E-09	1.1E-09	8.0E-10	7.3E-10
Remainder	9.4E-09	7.0E-09	3.8E-09	2.4E-09	1.7E-09	1.6E-09
Effective Dose	4.0E-09	3.3E-09	2.0E-09	1.3E-09	9.1E-10	8.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-63 (T½ = 96.0 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Bladder Wall	2.3E-09	1.9E-09	1.1E-09	6.8E-10	4.8E-10	4.5E-10
Bone Surface	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Brain	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Breast	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
GI-Tract						
Oesophagus	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
St Wall	2.3E-09	1.9E-09	1.1E-09	6.6E-10	4.6E-10	4.3E-10
SI Wall	2.3E-09	1.9E-09	1.1E-09	6.6E-10	4.6E-10	4.3E-10
ULI Wall	2.7E-09	2.2E-09	1.2E-09	7.3E-10	4.9E-10	4.6E-10
LLI Wall	3.6E-09	2.8E-09	1.4E-09	8.8E-10	5.6E-10	5.2E-10
Colon	3.1E-09	2.5E-09	1.3E-09	8.0E-10	5.2E-10	4.8E-10
Kidneys	2.3E-09	2.0E-09	1.1E-09	7.1E-10	4.5E-10	4.3E-10
Liver	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Muscle	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Ovaries	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Pancreas	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Red Marrow	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Respiratory Tract						
ET Airways	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.6E-10	4.3E-10
Lungs	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.6E-10	4.3E-10
Skin	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Spleen	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Testes	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Thymus	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Thyroid	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Uterus	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Remainder	2.2E-09	1.9E-09	1.1E-09	6.5E-10	4.5E-10	4.3E-10
Effective Dose	2.3E-09	2.0E-09	1.1E-09	6.7E-10	4.6E-10	4.4E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-63 ($T\frac{1}{2}$ = 96.0 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Bladder Wall	8.8E-10	7.0E-10	4.2E-10	2.6E-10	2.0E-10	1.9E-10
Bone Surface	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Brain	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Breast	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
GI-Tract						
Oesophagus	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
St Wall	9.4E-10	7.3E-10	4.3E-10	2.6E-10	2.0E-10	1.9E-10
SI Wall	1.0E-09	7.9E-10	4.6E-10	2.8E-10	2.0E-10	2.0E-10
ULI Wall	1.9E-09	1.4E-09	7.0E-10	4.3E-10	2.8E-10	2.6E-10
LLI Wall	3.7E-09	2.6E-09	1.2E-09	7.5E-10	4.4E-10	3.9E-10
Colon	2.6E-09	1.9E-09	9.4E-10	5.7E-10	3.5E-10	3.1E-10
Kidneys	9.1E-10	7.4E-10	4.4E-10	2.7E-10	1.9E-10	1.8E-10
Liver	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Muscle	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Ovaries	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Pancreas	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Red Marrow	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Respiratory Tract						
ET Airways	3.8E-09	3.0E-09	1.4E-09	9.2E-10	5.6E-10	5.4E-10
Lungs	1.3E-08	9.9E-09	5.9E-09	3.7E-09	2.9E-09	2.5E-09
Skin	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Spleen	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Testes	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Thymus	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Thyroid	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Uterus	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Remainder	8.7E-10	6.9E-10	4.1E-10	2.5E-10	1.9E-10	1.9E-10
Effective Dose	2.5E-09	1.9E-09	1.1E-09	7.0E-10	5.3E-10	4.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-63 (T½ = 96.0 y).

Particulate Aerosol: AMAD ≈ 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Bladder Wall	1.1E-10	7.4E-11	4.8E-11	3.2E-11	2.8E-11	2.8E-11
Bone Surface	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Brain	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Breast	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
GI-Tract						
Oesophagus	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
St Wall	1.9E-10	1.2E-10	6.8E-11	4.3E-11	3.4E-11	3.3E-11
SI Wall	3.0E-10	2.1E-10	1.1E-10	6.6E-11	4.5E-11	4.2E-11
ULI Wall	1.3E-09	9.0E-10	4.1E-10	2.5E-10	1.4E-10	1.2E-10
LLI Wall	3.6E-09	2.4E-09	1.1E-09	6.6E-10	3.6E-10	3.1E-10
Colon	2.3E-09	1.6E-09	7.1E-10	4.3E-10	2.3E-10	2.0E-10
Kidneys	1.1E-10	7.8E-11	4.9E-11	3.2E-11	2.6E-11	2.7E-11
Liver	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Muscle	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Ovaries	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Pancreas	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Red Marrow	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Respiratory Tract						
ET Airways	1.2E-08	1.0E-08	5.2E-09	3.6E-09	2.2E-09	2.2E-09
Lungs	3.7E-08	3.3E-08	2.1E-08	1.3E-08	1.1E-08	1.0E-08
Skin	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Spleen	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Testes	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Thymus	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Thyroid	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Uterus	1.0E-10	7.2E-11	4.6E-11	3.1E-11	2.6E-11	2.7E-11
Remainder	1.1E-10	7.9E-11	5.0E-11	3.3E-11	2.8E-11	2.8E-11
Effective Dose	4.8E-09	4.3E-09	2.7E-09	1.7E-09	1.3E-09	1.3E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.7.3(d).
Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ni-63 (T½ = 96.0 y).

Nickel Carbonyl Vapour Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Bladder Wall	8.5E-09	7.2E-09	4.5E-09	2.8E-09	2.0E-09	1.8E-09
Bone Surface	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Brain	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Breast	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
GI-Tract						
Oesophagus	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
St Wall	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
SI Wall	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
ULI Wall	8.5E-09	7.2E-09	4.4E-09	2.7E-09	1.9E-09	1.8E-09
LLI Wall	8.7E-09	7.3E-09	4.5E-09	2.8E-09	2.0E-09	1.8E-09
Colon	8.6E-09	7.2E-09	4.4E-09	2.7E-09	1.9E-09	1.8E-09
Kidneys	8.7E-09	7.6E-09	4.6E-09	2.9E-09	1.9E-09	1.7E-09
Liver	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Muscle	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Ovaries	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Pancreas	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Red Marrow	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Respiratory Tract						
ET Airways	3.6E-08	2.6E-08	1.4E-08	8.8E-09	6.1E-09	5.6E-09
Lungs	1.2E-08	1.0E-08	6.4E-09	4.2E-09	3.1E-09	2.8E-09
Skin	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Spleen	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Testes	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Thymus	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Thyroid	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Uterus	8.3E-09	7.1E-09	4.3E-09	2.7E-09	1.9E-09	1.7E-09
Remainder	2.2E-08	1.6E-08	9.0E-09	5.7E-09	4.0E-09	3.7E-09
Effective Dose	9.5E-09	8.0E-09	4.8E-09	3.0E-09	2.2E-09	2.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.8. Zinc

(134) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides and hydroxides of zinc (Zn) to inhalation Class Y, halides, phosphates and sulphides to Class W, and sulphates to Class D. By default, other unspecified compounds were assigned to Class D. *ICRP Publication 30*, Part 2 (ICRP, 1980), assigned all commonly occurring compounds to Class Y, citing experiments on dogs and rats (Morrow *et al.*, 1968), which suggested that $Zn(NO_3)_2$ and $Zn_3(PO_4)_2$ should be assigned to Class Y.

Absorption Types

(135) In man, very little information on inhaled zinc is available. In one case of accidental exposure, ^{65}Zn was rapidly cleared from the lungs except for a small component, which was retained for a period of several months. However, in this case the zinc compound or compounds involved are not known (Newton and Holmes, 1966).

(136) Lung retention of zinc oxide by rats was studied following inhalation (Oberdörster and Hochrainer, 1979) and instillation (Rosaminth and Breining, 1974; Hirano *et al.*, 1989). The results of all three studies are consistent with assignment to Type F.

(137) Retention following instillation of zinc chromate into rats indicates Type M behaviour (Bragt and Dura, 1983). The results of experiments on dogs and rats with $Zn(NO_3)_2$ and $Zn_3(PO_4)$ (Morrow *et al.*, 1968) are consistent with assignment to Type M.

(138) Measurements following instillation into rats of corrosion products from a water-cooled reactor indicate Type S behaviour for the ^{65}Zn present (Collier *et al.*, 1994).

Dose coefficients

(139) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Table 5.8.2) were derived using the f_1 values given in Table 5.8.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.8.1. Values of f_1 for inhaled particulate compounds of zinc

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	1	0.5
M[b]	0.2	0.1
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.8.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Zn-65 (T½ = 244 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.5	0.5	0.5	0.5	0.5
Adrenals	1.7E-08	1.2E-08	6.4E-09	4.3E-09	2.8E-09	2.5E-09
Bladder Wall	1.2E-08	8.5E-09	5.3E-09	2.9E-09	1.9E-09	2.0E-09
Bone Surface	2.0E-08	1.4E-08	7.8E-09	5.2E-09	3.4E-09	3.1E-09
Brain	1.3E-08	9.2E-09	5.1E-09	3.3E-09	2.0E-09	1.8E-09
Breast	9.6E-09	6.6E-09	3.5E-09	2.3E-09	1.6E-09	1.4E-09
GI-Tract						
Oesophagus	1.3E-08	9.3E-09	5.0E-09	3.3E-09	2.2E-09	1.9E-09
St Wall	1.2E-08	8.4E-09	4.9E-09	3.0E-09	2.2E-09	1.9E-09
SI Wall	1.5E-08	1.1E-08	5.9E-09	4.0E-09	2.6E-09	2.3E-09
ULI Wall	1.4E-08	1.0E-08	5.6E-09	3.7E-09	2.5E-09	2.2E-09
LLI Wall	1.6E-08	1.1E-08	6.4E-09	4.2E-09	2.6E-09	2.6E-09
Colon	1.5E-08	1.1E-08	5.9E-09	3.9E-09	2.5E-09	2.4E-09
Kidneys	1.5E-08	1.0E-08	5.7E-09	3.8E-09	2.5E-09	2.2E-09
Liver	1.4E-08	9.9E-09	5.4E-09	3.6E-09	2.3E-09	2.1E-09
Muscle	1.3E-08	9.2E-09	4.9E-09	3.3E-09	2.1E-09	1.9E-09
Ovaries	1.6E-08	1.1E-08	6.2E-09	4.2E-09	2.8E-09	2.5E-09
Pancreas	1.6E-08	1.1E-08	5.9E-09	4.0E-09	2.7E-09	2.4E-09
Red Marrow	1.7E-08	1.2E-08	6.5E-09	4.6E-09	3.1E-09	2.7E-09
Respiratory Tract						
ET Airways	2.9E-08	2.4E-08	1.3E-08	7.9E-09	4.8E-09	4.0E-09
Lungs	1.3E-08	9.1E-09	4.8E-09	3.2E-09	2.2E-09	1.9E-09
Skin	9.8E-09	6.7E-09	3.5E-09	2.3E-09	1.5E-09	1.3E-09
Spleen	1.4E-08	1.0E-08	5.4E-09	3.6E-09	2.4E-09	2.1E-09
Testes	1.2E-08	8.1E-09	4.5E-09	2.9E-09	2.0E-09	1.8E-09
Thymus	1.3E-08	9.3E-09	5.0E-09	3.3E-09	2.2E-09	1.9E-09
Thyroid	1.5E-08	1.0E-08	5.6E-09	3.6E-09	2.3E-09	2.0E-09
Uterus	1.5E-08	1.1E-08	5.9E-09	4.0E-09	2.6E-09	2.4E-09
Remainder	2.1E-08	1.7E-08	9.0E-09	5.6E-09	3.5E-09	2.9E-09
Effective Dose	1.5E-08	1.0E-08	5.7E-09	3.8E-09	2.5E-09	2.2E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.8.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Zn-65 (T½ = 244 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	8.9E-09	6.7E-09	4.0E-09	2.5E-09	1.8E-09	1.6E-09
Bladder Wall	4.4E-09	3.0E-09	1.9E-09	1.0E-09	7.1E-10	7.3E-10
Bone Surface	8.0E-09	5.6E-09	3.2E-09	2.1E-09	1.5E-09	1.4E-09
Brain	4.4E-09	2.9E-09	1.7E-09	1.1E-09	7.4E-10	6.8E-10
Breast	6.1E-09	4.8E-09	3.1E-09	2.1E-09	1.4E-09	1.3E-09
GI-Tract						
Oesophagus	7.2E-09	5.6E-09	3.5E-09	2.4E-09	1.8E-09	1.6E-09
St Wall	5.8E-09	4.3E-09	2.6E-09	1.6E-09	1.3E-09	1.1E-09
SI Wall	6.2E-09	4.4E-09	2.5E-09	1.6E-09	1.1E-09	9.7E-10
ULI Wall	6.7E-09	4.7E-09	2.6E-09	1.7E-09	1.1E-09	1.0E-09
LLI Wall	8.4E-09	6.0E-09	3.3E-09	2.1E-09	1.3E-09	1.3E-09
Colon	7.4E-09	5.3E-09	2.9E-09	1.9E-09	1.2E-09	1.1E-09
Kidneys	6.3E-09	4.5E-09	2.5E-09	1.6E-09	1.2E-09	1.0E-09
Liver	7.2E-09	5.4E-09	3.2E-09	2.1E-09	1.6E-09	1.3E-09
Muscle	5.7E-09	4.1E-09	2.3E-09	1.5E-09	1.1E-09	9.8E-10
Ovaries	6.2E-09	4.3E-09	2.5E-09	1.6E-09	1.1E-09	9.8E-10
Pancreas	7.8E-09	5.7E-09	3.3E-09	2.2E-09	1.6E-09	1.3E-09
Red Marrow	6.4E-09	4.5E-09	2.8E-09	1.9E-09	1.5E-09	1.3E-09
Respiratory Tract						
ET Airways	2.2E-08	1.9E-08	1.1E-08	6.3E-09	3.9E-09	3.1E-09
Lungs	2.1E-08	1.7E-08	1.1E-08	7.5E-09	6.4E-09	5.1E-09
Skin	3.9E-09	2.7E-09	1.5E-09	9.8E-10	6.9E-10	6.3E-10
Spleen	7.2E-09	5.3E-09	3.0E-09	2.0E-09	1.5E-09	1.3E-09
Testes	3.9E-09	2.6E-09	1.5E-09	9.6E-10	6.9E-10	6.2E-10
Thymus	7.2E-09	5.6E-09	3.5E-09	2.4E-09	1.8E-09	1.6E-09
Thyroid	6.3E-09	4.5E-09	2.6E-09	1.7E-09	1.1E-09	1.0E-09
Uterus	5.6E-09	3.8E-09	2.2E-09	1.4E-09	9.8E-10	8.8E-10
Remainder	1.4E-08	1.2E-08	2.3E-09	1.5E-09	1.1E-09	9.7E-10
Effective Dose	8.5E-09	6.5E-09	3.7E-09	2.4E-09	1.9E-09	1.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.8.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Zn-65 (T½ = 244 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	8.1E-09	7.3E-09	4.8E-09	2.8E-09	2.1E-09	1.8E-09
Bladder Wall	1.2E-09	9.2E-10	4.7E-10	2.8E-10	1.6E-10	1.3E-10
Bone Surface	4.0E-09	3.4E-09	1.9E-09	1.2E-09	8.8E-10	7.8E-10
Brain	8.8E-10	6.9E-10	4.2E-10	2.9E-10	2.0E-10	1.8E-10
Breast	7.1E-09	6.6E-09	4.8E-09	3.2E-09	2.1E-09	1.9E-09
GI-Tract						
Oesophagus	6.9E-09	6.5E-09	4.6E-09	3.1E-09	2.5E-09	2.2E-09
St Wall	4.4E-09	3.9E-09	2.4E-09	1.5E-09	1.3E-09	1.0E-09
SI Wall	2.8E-09	2.2E-09	1.2E-09	7.2E-10	4.5E-10	3.8E-10
ULI Wall	3.8E-09	3.0E-09	1.6E-09	9.7E-10	6.1E-10	5.1E-10
LLI Wall	5.5E-09	4.0E-09	2.0E-09	1.3E-09	7.4E-10	6.1E-10
Colon	4.5E-09	3.4E-09	1.8E-09	1.1E-09	6.7E-10	5.5E-10
Kidneys	3.7E-09	3.3E-09	1.8E-09	1.1E-09	8.2E-10	7.0E-10
Liver	6.2E-09	5.6E-09	3.5E-09	2.3E-09	1.9E-09	1.6E-09
Muscle	3.6E-09	3.1E-09	1.9E-09	1.2E-09	9.6E-10	8.1E-10
Ovaries	2.4E-09	1.8E-09	9.9E-10	6.0E-10	3.8E-10	3.0E-10
Pancreas	6.3E-09	5.6E-09	3.5E-09	2.2E-09	1.7E-09	1.3E-09
Red Marrow	3.0E-09	2.6E-09	1.8E-09	1.3E-09	1.1E-09	1.0E-09
Respiratory Tract						
ET Airways	2.2E-08	2.1E-08	1.1E-08	6.6E-09	4.1E-09	3.2E-09
Lungs	3.5E-08	3.2E-08	2.1E-08	1.5E-08	1.3E-08	1.0E-08
Skin	2.0E-09	1.7E-09	1.0E-09	6.8E-10	4.8E-10	4.5E-10
Spleen	6.0E-09	5.4E-09	3.2E-09	2.1E-09	1.6E-09	1.3E-09
Testes	7.0E-10	4.9E-10	2.4E-10	1.5E-10	8.6E-11	6.8E-11
Thymus	6.9E-09	6.5E-09	4.6E-09	3.1E-09	2.5E-09	2.2E-09
Thyroid	3.9E-09	3.5E-09	2.1E-09	1.3E-09	9.0E-10	7.9E-10
Uterus	1.8E-09	1.4E-09	6.9E-10	3.9E-10	2.4E-10	1.9E-10
Remainder	3.1E-09	2.7E-09	1.7E-09	1.1E-09	9.1E-10	7.7E-10
Effective Dose	7.6E-09	6.7E-09	4.4E-09	2.9E-09	2.4E-09	2.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.9. Selenium

(140) The ICRP Task Group on Lung Dynamics (1966) assigned oxides, hydroxides and carbides of selenium (Se) to inhalation Class W and all other commonly occurring inorganic compounds of the element to Class D. In *ICRP Publication 30*, Part 3 (ICRP, 1981), this classification was adopted for inorganic compounds of selenium, and elemental selenium was assigned to inhalation Class W.

Absorption Types

(141) The biological behaviour of selenium has been reported by several authors. The main studies focused on the lung clearance of selenium dioxide (SeO_2), selenious acid (H_2SeO_3) and elemental selenium.

(142) Selenious acid forms from selenium dioxide reacting with water vapour. The absorption of these two compounds from the lungs is very rapid. Approximately 95% of inhaled selenium oxide or selenious acid was absorbed from the lungs of dogs in a few hours (Heisler Weissman *et al.*, 1977). All the experiments, performed either *in vivo* with rats and dogs or by *in vitro* investigations, confirm this result (Burkstaller *et al.*, 1977; Burkstaller and Cuddihy, 1979; Medinsky *et al.*, 1981). These observations are consistent with assignment of selenium dioxide and selenious acid to Type F. Measurements following intratracheal instillation of sodium selenate and selenite into rats are also consistent with assignment to Type F (Rhoads and Sanders, 1985).

(143) The elemental form of selenium was studied *in vivo* in rats and dogs. Clearance from the lung is very rapid: 75% is absorbed within 2 h and 98% in 2 d following inhalation exposure of dogs (Weissman *et al.*, 1983). These results are consistent with those obtained with rats (Burkstaller and Cuddihy, 1979; Medinsky *et al.*, 1981), and consistent with assignment of the elemental form of selenium to Type F.

Dose coefficients

(144) Dose coefficients (given in Tables 5.9.2 and 5.9.3) were derived using the f_1 values given in Table 5.9.1 and the biokinetic data given in *ICRP Publication 69* (ICRP, 1995). For completeness, dose coefficients are given for particulate materials of all three absorption Types, although no experimental data were found indicating Type M or S behaviour for any form of selenium.

Table 5.9.1. Values of f_1 for inhaled particulate compounds of selenium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F[b]	1	0.8
M	0.2	0.1
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type F is recommended for use in the absence of specific information.

Table 5.9.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Se-75 (T½ = 120 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	9.7E-09	7.4E-09	4.1E-09	2.9E-09	1.8E-09	1.6E-09
Bladder Wall	4.1E-09	3.1E-09	1.7E-09	1.1E-09	7.0E-10	5.9E-10
Bone Surface	6.0E-09	4.5E-09	2.3E-09	1.6E-09	1.0E-09	8.9E-10
Brain	3.3E-09	2.5E-09	1.3E-09	8.0E-10	4.6E-10	4.1E-10
Breast	3.5E-09	2.6E-09	1.3E-09	8.3E-10	5.2E-10	4.5E-10
GI-Tract						
Oesophagus	4.3E-09	3.2E-09	1.6E-09	1.1E-09	6.8E-10	5.7E-10
St Wall	6.6E-09	5.0E-09	2.6E-09	1.8E-09	1.0E-09	8.9E-10
SI Wall	6.5E-09	5.0E-09	2.6E-09	1.7E-09	1.0E-09	8.7E-10
ULI Wall	7.2E-09	5.5E-09	2.9E-09	1.8E-09	1.1E-09	9.5E-10
LLI Wall	5.6E-09	4.4E-09	2.2E-09	1.5E-09	8.5E-10	7.6E-10
Colon	6.5E-09	5.0E-09	2.6E-09	1.7E-09	9.9E-10	8.7E-10
Kidneys	3.3E-08	2.4E-08	1.3E-08	9.2E-09	6.3E-09	5.4E-09
Liver	2.4E-08	1.8E-08	9.6E-09	6.9E-09	4.5E-09	3.9E-09
Muscle	4.5E-09	3.3E-09	1.7E-09	1.1E-09	7.0E-10	6.1E-10
Ovaries	7.4E-09	5.6E-09	2.7E-09	1.7E-09	8.9E-10	7.9E-10
Pancreas	1.6E-08	1.1E-08	5.6E-09	4.1E-09	2.3E-09	1.9E-09
Red Marrow	4.0E-09	3.0E-09	1.7E-09	1.2E-09	7.9E-10	7.1E-10
Respiratory Tract						
ET Airways	2.1E-08	1.9E-08	9.4E-09	5.3E-09	3.0E-09	2.3E-09
Lungs	5.4E-09	4.1E-09	2.1E-09	1.4E-09	9.4E-10	7.7E-10
Skin	2.9E-09	2.1E-09	1.1E-09	6.8E-10	4.2E-10	3.8E-10
Spleen	1.2E-08	9.2E-09	4.9E-09	3.4E-09	2.1E-09	1.7E-09
Testes	1.0E-08	8.6E-09	5.6E-09	4.6E-09	9.9E-10	6.6E-10
Thymus	4.3E-09	3.2E-09	1.6E-09	1.1E-09	6.8E-10	5.7E-10
Thyroid	4.3E-09	3.2E-09	1.6E-09	1.0E-09	6.1E-10	5.2E-10
Uterus	5.3E-09	4.0E-09	2.1E-09	1.3E-09	8.1E-10	7.1E-10
Remainder	1.9E-08	1.4E-08	7.3E-09	5.2E-09	3.5E-09	3.0E-09
Effective Dose	7.8E-09	6.0E-09	3.4E-09	2.5E-09	1.2E-09	1.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.9.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Se-75 ($T\frac{1}{2}$ = 120 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	5.0E-09	3.7E-09	2.2E-09	1.4E-09	1.0E-09	8.8E-10
Bladder Wall	1.5E-09	1.0E-09	5.6E-10	3.5E-10	2.3E-10	1.9E-10
Bone Surface	3.0E-09	2.2E-09	1.2E-09	7.6E-10	5.6E-10	4.9E-10
Brain	1.1E-09	6.8E-10	3.8E-10	2.4E-10	1.5E-10	1.3E-10
Breast	2.8E-09	2.2E-09	1.5E-09	9.8E-10	6.1E-10	5.7E-10
GI-Tract						
Oesophagus	3.0E-09	2.4E-09	1.6E-09	1.1E-09	8.1E-10	7.1E-10
St Wall	3.2E-09	2.3E-09	1.3E-09	8.8E-10	6.2E-10	4.9E-10
SI Wall	2.9E-09	2.0E-09	1.1E-09	6.9E-10	4.2E-10	3.6E-10
ULI Wall	4.0E-09	2.8E-09	1.5E-09	9.3E-10	5.5E-10	4.7E-10
LLI Wall	5.3E-09	3.9E-09	1.9E-09	1.2E-09	6.7E-10	5.8E-10
Colon	4.6E-09	3.3E-09	1.6E-09	1.0E-09	6.0E-10	5.1E-10
Kidneys	1.0E-08	6.4E-09	3.7E-09	2.5E-09	1.9E-09	1.6E-09
Liver	8.4E-09	5.7E-09	3.3E-09	2.3E-09	1.7E-09	1.4E-09
Muscle	2.2E-09	1.6E-09	8.9E-10	5.8E-10	4.3E-10	3.6E-10
Ovaries	3.0E-09	2.1E-09	1.0E-09	6.6E-10	3.7E-10	3.2E-10
Pancreas	6.3E-09	4.2E-09	2.3E-09	1.6E-09	1.1E-09	8.4E-10
Red Marrow	1.9E-09	1.4E-09	8.4E-10	6.1E-10	4.7E-10	4.3E-10
Respiratory Tract						
ET Airways	2.1E-08	1.9E-08	9.6E-09	5.3E-09	3.1E-09	2.4E-09
Lungs	2.1E-08	1.7E-08	1.1E-08	7.5E-09	6.6E-09	5.2E-09
Skin	1.3E-09	8.8E-10	4.9E-10	3.0E-10	2.1E-10	1.9E-10
Spleen	5.2E-09	3.6E-09	2.1E-09	1.4E-09	9.7E-10	7.7E-10
Testes	3.1E-09	2.2E-09	1.4E-09	1.1E-09	2.7E-10	1.9E-10
Thymus	3.0E-09	2.4E-09	1.6E-09	1.1E-09	8.1E-10	7.1E-10
Thyroid	2.2E-09	1.7E-09	9.5E-10	5.7E-10	3.7E-10	3.2E-10
Uterus	2.1E-09	1.4E-09	7.4E-10	4.6E-10	2.9E-10	2.4E-10
Remainder	2.2E-09	1.0E-08	8.7E-10	5.8E-10	4.3E-10	3.7E-10
Effective Dose	5.4E-09	4.5E-09	2.5E-09	1.7E-09	1.3E-09	1.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.9.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Se-75 (T½ = 120 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.0E-09	3.4E-09	2.1E-09	1.3E-09	1.0E-09	8.5E-10
Bladder Wall	6.1E-10	4.5E-10	2.2E-10	1.3E-10	6.9E-11	5.5E-11
Bone Surface	2.3E-09	1.9E-09	1.1E-09	6.9E-10	5.4E-10	4.6E-10
Brain	2.7E-10	2.1E-10	1.3E-10	7.8E-11	5.6E-11	4.7E-11
Breast	3.1E-09	2.9E-09	2.0E-09	1.4E-09	8.5E-10	8.3E-10
GI-Tract						
Oesophagus	3.1E-09	2.9E-09	2.1E-09	1.5E-09	1.1E-09	1.0E-09
St Wall	2.3E-09	1.9E-09	1.2E-09	7.8E-10	6.1E-10	4.5E-10
SI Wall	1.6E-09	1.2E-09	6.4E-10	4.0E-10	2.3E-10	1.8E-10
ULI Wall	2.9E-09	2.1E-09	1.1E-09	6.7E-10	3.7E-10	3.0E-10
LLI Wall	5.2E-09	3.6E-09	1.7E-09	1.1E-09	5.8E-10	4.8E-10
Colon	3.9E-09	2.8E-09	1.3E-09	8.4E-10	4.6E-10	3.8E-10
Kidneys	2.2E-09	1.6E-09	9.4E-10	5.8E-10	4.3E-10	3.3E-10
Liver	3.2E-09	2.7E-09	1.7E-09	1.1E-09	9.1E-10	7.5E-10
Muscle	1.7E-09	1.5E-09	8.4E-10	5.4E-10	4.3E-10	3.6E-10
Ovaries	1.4E-09	1.1E-09	5.3E-10	3.4E-10	2.0E-10	1.5E-10
Pancreas	3.3E-09	2.8E-09	1.7E-09	1.1E-09	8.0E-10	6.3E-10
Red Marrow	1.3E-09	1.2E-09	7.6E-10	5.6E-10	4.8E-10	4.4E-10
Respiratory Tract						
ET Airways	2.3E-08	2.0E-08	1.0E-08	5.8E-09	3.4E-09	2.6E-09
Lungs	3.1E-08	2.7E-08	1.7E-08	1.2E-08	1.0E-08	8.1E-09
Skin	8.2E-10	6.8E-10	4.1E-10	2.5E-10	1.8E-10	1.6E-10
Spleen	3.0E-09	2.6E-09	1.6E-09	9.9E-10	7.5E-10	6.0E-10
Testes	4.4E-10	2.9E-10	1.4E-10	1.0E-10	3.2E-11	2.2E-11
Thymus	3.1E-09	2.9E-09	2.1E-09	1.5E-09	1.1E-09	1.0E-09
Thyroid	1.8E-09	1.6E-09	9.9E-10	5.8E-10	3.8E-10	3.2E-10
Uterus	8.9E-10	6.8E-10	3.4E-10	2.0E-10	1.1E-10	8.4E-11
Remainder	1.5E-09	1.3E-09	7.5E-10	5.0E-10	4.1E-10	3.4E-10
Effective Dose	5.6E-09	4.7E-09	2.9E-09	2.0E-09	1.6E-09	1.3E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.9.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Se-79 (T½ = 6.50E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Bladder Wall	4.0E-09	2.9E-09	1.4E-09	8.8E-10	5.2E-10	4.4E-10
Bone Surface	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Brain	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Breast	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
GI-Tract						
Oesophagus	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
St Wall	4.0E-09	2.9E-09	1.4E-09	8.1E-10	4.5E-10	3.9E-10
SI Wall	3.9E-09	2.8E-09	1.3E-09	8.0E-10	4.5E-10	3.9E-10
ULI Wall	5.2E-09	3.9E-09	1.8E-09	1.1E-09	5.9E-10	5.0E-10
LLI Wall	7.4E-09	5.8E-09	2.7E-09	1.6E-09	8.7E-10	7.4E-10
Colon	6.1E-09	4.7E-09	2.2E-09	1.3E-09	7.1E-10	6.1E-10
Kidneys	9.0E-08	6.5E-08	3.4E-08	2.3E-08	1.5E-08	1.3E-08
Liver	4.6E-08	3.5E-08	1.7E-08	1.1E-08	6.7E-09	5.5E-09
Muscle	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Ovaries	1.5E-08	1.1E-08	4.5E-09	2.4E-09	7.0E-10	7.2E-10
Pancreas	3.0E-08	1.9E-08	8.5E-09	6.4E-09	2.8E-09	2.0E-09
Red Marrow	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Respiratory Tract						
ET Airways	7.5E-09	5.2E-09	2.3E-09	1.5E-09	8.0E-10	7.4E-10
Lungs	4.0E-09	2.8E-09	1.4E-09	8.1E-10	4.6E-10	3.9E-10
Skin	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Spleen	2.2E-08	1.6E-08	8.1E-09	5.1E-09	3.0E-09	2.2E-09
Testes	4.1E-08	3.6E-08	2.5E-08	1.9E-08	2.3E-09	1.1E-09
Thymus	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Thyroid	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Uterus	3.9E-09	2.8E-09	1.3E-09	7.9E-10	4.5E-10	3.8E-10
Remainder	4.7E-08	3.4E-08	1.8E-08	1.2E-08	7.8E-09	6.6E-09
Effective Dose	1.6E-08	1.3E-08	7.7E-09	5.6E-09	1.5E-09	1.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.9.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Se-79 (T½ = 6.50E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Bladder Wall	1.4E-09	8.8E-10	4.8E-10	2.9E-10	1.9E-10	1.6E-10
Bone Surface	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Brain	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Breast	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
GI-Tract						
Oesophagus	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
St Wall	1.6E-09	9.8E-10	5.0E-10	2.9E-10	1.8E-10	1.6E-10
SI Wall	1.8E-09	1.2E-09	5.9E-10	3.4E-10	2.0E-10	1.8E-10
ULI Wall	4.6E-09	3.2E-09	1.5E-09	8.7E-10	4.7E-10	3.9E-10
LLI Wall	1.1E-08	7.5E-09	3.3E-09	2.0E-09	1.0E-09	8.8E-10
Colon	7.2E-09	5.0E-09	2.3E-09	1.4E-09	7.2E-10	6.0E-10
Kidneys	3.1E-08	2.0E-08	1.1E-08	7.5E-09	5.5E-09	4.8E-09
Liver	1.6E-08	1.0E-08	5.6E-09	3.6E-09	2.4E-09	2.1E-09
Muscle	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Ovaries	5.0E-09	3.3E-09	1.5E-09	7.6E-10	2.6E-10	2.7E-10
Pancreas	9.9E-09	5.8E-09	2.8E-09	2.1E-09	1.0E-09	7.4E-10
Red Marrow	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Respiratory Tract						
ET Airways	2.5E-08	1.9E-08	8.1E-09	5.4E-09	3.0E-09	2.9E-09
Lungs	7.5E-08	5.9E-08	3.7E-08	2.6E-08	2.4E-08	1.9E-08
Skin	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Spleen	7.6E-09	4.8E-09	2.7E-09	1.6E-09	1.1E-09	8.3E-10
Testes	1.5E-08	1.1E-08	8.3E-09	6.1E-09	8.3E-10	4.3E-10
Thymus	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Thyroid	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Uterus	1.3E-09	8.5E-10	4.4E-10	2.6E-10	1.6E-10	1.4E-10
Remainder	1.8E-09	1.1E-09	6.0E-10	3.6E-10	2.3E-10	2.0E-10
Effective Dose	1.4E-08	1.1E-08	6.9E-09	4.9E-09	3.3E-09	2.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.9.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Se-79 (T½ = 6.50E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Bladder Wall	1.2E-10	7.8E-11	4.7E-11	3.0E-11	2.3E-11	2.2E-11
Bone Surface	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Brain	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Breast	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
GI-Tract						
Oesophagus	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
St Wall	4.0E-10	2.4E-10	1.1E-10	6.7E-11	4.5E-11	4.0E-11
SI Wall	7.7E-10	5.1E-10	2.4E-10	1.4E-10	8.1E-11	7.1E-11
ULI Wall	4.1E-09	2.8E-09	1.3E-09	7.5E-10	4.0E-10	3.4E-10
LLI Wall	1.2E-08	7.8E-09	3.5E-09	2.1E-09	1.1E-09	9.5E-10
Colon	7.3E-09	4.9E-09	2.2E-09	1.3E-09	7.1E-10	6.0E-10
Kidneys	2.8E-09	1.8E-09	1.2E-09	8.2E-10	6.8E-10	6.5E-10
Liver	1.4E-09	9.3E-10	5.7E-10	3.8E-10	3.0E-10	2.8E-10
Muscle	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Ovaries	4.3E-10	2.7E-10	1.3E-10	6.7E-11	3.5E-11	3.7E-11
Pancreas	8.5E-10	5.0E-10	2.9E-10	1.9E-10	1.2E-10	1.0E-10
Red Marrow	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Respiratory Tract						
ET Airways	8.5E-08	7.1E-08	3.5E-08	2.4E-08	1.5E-08	1.5E-08
Lungs	1.8E-07	1.6E-07	1.0E-07	7.0E-08	6.2E-08	5.6E-08
Skin	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Spleen	6.7E-10	4.3E-10	2.7E-10	1.7E-10	1.3E-10	1.1E-10
Testes	1.4E-09	1.1E-09	7.9E-10	4.5E-10	8.4E-11	5.8E-11
Thymus	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Thyroid	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Uterus	1.2E-10	7.4E-11	4.3E-11	2.7E-11	2.0E-11	1.9E-11
Remainder	2.1E-10	1.4E-10	7.8E-11	5.0E-11	3.6E-11	3.5E-11
Effective Dose	2.3E-08	2.0E-08	1.3E-08	8.7E-09	7.6E-09	6.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.10. Strontium

(145) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned strontium phosphate to inhalation Class D and the other compounds of strontium (Sr) listed to Class W. *ICRP Publication 30*, Part 1 (ICRP, 1979), assigned "soluble" compounds of strontium to Class D, referring to a study by Morrow *et al.* (1968), which showed that $SrCl_2$ is rapidly cleared from lungs. Strontium titanate ($SrTiO_3$) was shown to be much more tenaciously retained (Fish *et al.*, 1967) and was assigned to Class Y.

Absorption Types

(146) Measurements following accidental inhalation by humans of strontium carbonate ($SrCO_3$) and strontium chloride ($SrCl_2$) indicate Type F behaviour (Rundo and Williams, 1961; Petkau and Pleskach, 1971). Animal experiments have shown that with simple ionic compounds (chloride and sulphate) most of the strontium is rapidly cleared, consistent with assignment to Type F (Bair, 1961; Boecker *et al.*, 1967; Cuddihy and Ozog, 1973; Naményi *et al.*, 1986).

(147) Environmental strontium could well be inhaled in particles in which it is a minor constituent. For example, after an accidental release it could be present in fragments of irradiated fuel. Measurements following the accidental inhalation of a mixture of fresh fission products, indicate Type M behaviour of the strontium present (Johnson *et al.*, 1983). Results of an *in vitro* study on airborne fission products from the Three Mile Island reactor accident are consistent with assignment to Type F (Kanapilly *et al.*, 1980). An *in vitro* study on aerosols generated during transfer, cutting, storage and shipment of nuclear reactor fuel is consistent with assignment of the strontium present to Type M (Dua *et al.*, 1987).

(148) It has also been demonstrated that when strontium is incorporated into a matrix such as fused aluminosilicate particles (Sr-FAP), only a small fraction may be rapidly absorbed, while the remainder is retained within the particles and absorbed slowly. Estimates of the rate of dissolution of Sr-FAP were in the range 0.0005–0.002 d^{-1} (Snipes *et al.*, 1972; Kanapilly and Goh, 1973; Bailey *et al.*, 1985a, 1985b), and indicate Type S behaviour.

Dose coefficients

(149) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.10.2 and 5.10.3) were derived using the f_1 values given in Table 5.10.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.10.1. Values of f_1 for inhaled particulate compounds of strontium

	f_1[a]					
Absorption Type	3 mo	1 y	5 y	10 y	15 y	Adult
F	0.6	0.4	0.4	0.4	0.4	0.3
M[b]	0.2	0.1	0.1	0.1	0.1	0.1
S	0.02	0.01	0.01	0.01	0.01	0.01

[a] f_1 values for the adult are taken from Table 2. Those for children are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.10.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sr-89 (T½ = 50.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.4	0.4	0.4	0.4	0.3
Adrenals	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Bladder Wall	2.2E-09	2.0E-09	1.3E-09	8.1E-10	4.1E-10	6.0E-10
Bone Surface	9.1E-08	3.9E-08	2.2E-08	1.8E-08	1.5E-08	5.4E-09
Brain	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Breast	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
GI-Tract						
Oesophagus	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
St Wall	2.8E-09	2.0E-09	8.6E-10	4.6E-10	2.2E-10	2.4E-10
SI Wall	2.7E-09	2.4E-09	1.0E-09	5.8E-10	2.6E-10	2.9E-10
ULI Wall	1.1E-08	1.1E-08	4.8E-09	2.7E-09	1.1E-09	1.3E-09
LLI Wall	2.9E-08	2.9E-08	1.3E-08	6.9E-09	2.9E-09	3.5E-09
Colon	1.9E-08	1.9E-08	8.2E-09	4.5E-09	1.9E-09	2.2E-09
Kidneys	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Liver	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Muscle	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Ovaries	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Pancreas	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Red Marrow	9.1E-08	3.0E-08	1.2E-08	1.1E-08	9.7E-09	4.3E-09
Respiratory Tract						
ET Airways	1.1E-08	8.0E-09	3.3E-09	2.1E-09	1.1E-09	1.1E-09
Lungs	1.7E-09	1.4E-09	6.5E-10	3.5E-10	1.8E-10	2.0E-10
Skin	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Spleen	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Testes	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Thymus	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Thyroid	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Uterus	1.6E-09	1.3E-09	6.1E-10	3.2E-10	1.5E-10	1.8E-10
Remainder	1.7E-09	1.3E-09	6.2E-10	3.2E-10	1.5E-10	1.8E-10
Effective Dose	1.5E-08	7.3E-09	3.2E-09	2.3E-09	1.7E-09	1.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Sr parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.10.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sr-89 (T½ = 50.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Bladder Wall	6.6E-10	4.9E-10	3.2E-10	2.0E-10	1.0E-10	1.6E-10
Bone Surface	2.7E-08	9.3E-09	5.3E-09	4.4E-09	3.6E-09	1.4E-09
Brain	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Breast	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
GI-Tract						
Oesophagus	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
St Wall	3.0E-09	1.7E-09	7.1E-10	4.0E-10	2.2E-10	2.0E-10
SI Wall	5.1E-09	3.7E-09	1.6E-09	9.3E-10	4.4E-10	3.8E-10
ULI Wall	2.9E-08	2.2E-08	9.1E-09	5.5E-09	2.6E-09	2.2E-09
LLI Wall	8.2E-08	6.0E-08	2.5E-08	1.5E-08	7.3E-09	6.2E-09
Colon	5.2E-08	3.8E-08	1.6E-08	9.6E-09	4.6E-09	3.9E-09
Kidneys	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Liver	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Muscle	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Ovaries	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Pancreas	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Red Marrow	2.7E-08	7.1E-09	3.0E-09	2.7E-09	2.4E-09	1.1E-09
Respiratory Tract						
ET Airways	2.3E-08	1.6E-08	6.6E-09	4.4E-09	2.4E-09	2.4E-09
Lungs	1.9E-07	1.5E-07	9.0E-08	6.3E-08	5.3E-08	4.5E-08
Skin	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Spleen	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Testes	4.9E-10	3.2E-10	1.5E-10	7.7E-11	3.7E-11	4.6E-11
Thymus	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Thyroid	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Uterus	4.9E-10	3.2E-10	1.5E-10	7.8E-11	3.7E-11	4.6E-11
Remainder	5.9E-10	3.8E-10	1.8E-10	9.6E-11	4.7E-11	5.4E-11
Effective Dose	3.3E-08	2.4E-08	1.3E-08	9.1E-09	7.3E-09	6.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Sr parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.10.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sr-89 (T½ = 50.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.5E-11	1.7E-11	7.7E-12	4.1E-12	1.8E-12	2.3E-12
Bladder Wall	4.5E-11	2.6E-11	1.6E-11	1.0E-11	5.0E-12	7.5E-12
Bone Surface	1.9E-09	4.9E-10	2.7E-10	2.3E-10	1.7E-10	6.6E-11
Brain	3.4E-11	1.7E-11	7.5E-12	4.0E-12	1.8E-12	2.2E-12
Breast	3.5E-11	1.7E-11	7.7E-12	4.1E-12	1.8E-12	2.3E-12
GI-Tract						
Oesophagus	3.5E-11	1.7E-11	7.7E-12	4.1E-12	1.9E-12	2.3E-12
St Wall	2.7E-09	1.5E-09	6.1E-10	3.5E-10	2.0E-10	1.6E-10
SI Wall	6.1E-09	4.0E-09	1.7E-09	1.0E-09	4.9E-10	4.0E-10
ULI Wall	3.7E-08	2.4E-08	1.0E-08	6.2E-09	2.9E-09	2.4E-09
LLI Wall	1.0E-07	6.7E-08	2.9E-08	1.7E-08	8.4E-09	7.0E-09
Colon	6.6E-08	4.3E-08	1.8E-08	1.1E-08	5.3E-09	4.4E-09
Kidneys	3.4E-11	1.7E-11	7.6E-12	4.0E-12	1.8E-12	2.2E-12
Liver	3.4E-11	1.7E-11	7.7E-12	4.1E-12	1.8E-12	2.2E-12
Muscle	3.4E-11	1.7E-11	7.6E-12	4.0E-12	1.8E-12	2.2E-12
Ovaries	3.4E-11	1.7E-11	7.6E-12	4.0E-12	1.8E-12	2.2E-12
Pancreas	3.4E-11	1.7E-11	7.7E-12	4.1E-12	1.8E-12	2.2E-12
Red Marrow	1.9E-09	3.7E-10	1.5E-10	1.4E-10	1.2E-10	5.3E-11
Respiratory Tract						
ET Airways	2.7E-08	2.0E-08	8.1E-09	5.4E-09	3.0E-09	2.9E-09
Lungs	2.6E-07	2.1E-07	1.2E-07	8.6E-08	7.2E-08	6.2E-08
Skin	3.4E-11	1.7E-11	7.6E-12	4.0E-12	1.8E-12	2.2E-12
Spleen	3.4E-11	1.7E-11	7.7E-12	4.1E-12	1.8E-12	2.2E-12
Testes	3.4E-11	1.7E-11	7.5E-12	4.0E-12	1.7E-12	2.2E-12
Thymus	3.5E-11	1.7E-11	7.7E-12	4.1E-12	1.9E-12	2.3E-12
Thyroid	3.4E-11	1.7E-11	7.6E-12	4.0E-12	1.8E-12	2.2E-12
Uterus	3.4E-11	1.7E-11	7.6E-12	4.0E-12	1.8E-12	2.2E-12
Remainder	1.6E-10	9.2E-11	4.2E-11	2.6E-11	1.4E-11	1.2E-11
Effective Dose	3.9E-08	3.0E-08	1.7E-08	1.2E-08	9.3E-09	7.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Sr parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.10.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sr-90 (T½ = 29.1 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.4	0.4	0.4	0.4	0.3
Adrenals	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Bladder Wall	8.8E-09	5.9E-09	3.5E-09	2.5E-09	1.8E-09	1.3E-09
Bone Surface	1.3E-06	5.8E-07	4.5E-07	7.4E-07	1.2E-06	3.7E-07
Brain	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Breast	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
GI-Tract						
Oesophagus	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
St Wall	7.0E-09	4.5E-09	2.1E-09	1.3E-09	7.9E-10	6.2E-10
SI Wall	7.0E-09	4.7E-09	2.2E-09	1.3E-09	8.1E-10	6.4E-10
ULI Wall	2.2E-08	1.6E-08	7.1E-09	4.2E-09	2.3E-09	1.8E-09
LLI Wall	5.6E-08	4.3E-08	1.9E-08	1.1E-08	5.8E-09	5.0E-09
Colon	3.7E-08	2.8E-08	1.2E-08	7.2E-09	3.8E-09	3.2E-09
Kidneys	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Liver	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Muscle	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Ovaries	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Pancreas	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Red Marrow	8.6E-07	3.3E-07	1.9E-07	2.6E-07	3.3E-07	1.6E-07
Respiratory Tract						
ET Airways	1.8E-08	1.2E-08	5.1E-09	3.3E-09	1.9E-09	1.7E-09
Lungs	6.7E-09	4.3E-09	2.1E-09	1.3E-09	8.0E-10	6.1E-10
Skin	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Spleen	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Testes	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Thymus	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Thyroid	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Uterus	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Remainder	6.6E-09	4.3E-09	2.0E-09	1.2E-09	7.7E-10	5.9E-10
Effective Dose	1.3E-07	5.2E-08	3.1E-08	4.1E-08	5.3E-08	2.4E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Sr parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.10.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sr-90 ($T½$ = 29.1 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Bladder Wall	3.6E-09	2.3E-09	1.5E-09	1.1E-09	7.9E-10	6.9E-10
Bone Surface	4.8E-07	2.1E-07	1.8E-07	2.9E-07	5.0E-07	1.6E-07
Brain	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Breast	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
GI-Tract						
Oesophagus	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
St Wall	4.0E-09	2.4E-09	1.2E-09	6.9E-10	4.6E-10	3.8E-10
SI Wall	5.4E-09	3.7E-09	1.8E-09	1.1E-09	6.4E-10	5.3E-10
ULI Wall	3.0E-08	2.1E-08	9.8E-09	5.8E-09	3.1E-09	2.6E-09
LLI Wall	1.0E-07	7.3E-08	3.3E-08	1.9E-08	1.0E-08	8.7E-09
Colon	6.0E-08	4.4E-08	2.0E-08	1.2E-08	6.2E-09	5.2E-09
Kidneys	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Liver	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Muscle	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Ovaries	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Pancreas	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Red Marrow	3.1E-07	1.2E-07	7.7E-08	1.0E-07	1.3E-07	7.0E-08
Respiratory Tract						
ET Airways	7.5E-08	5.6E-08	2.4E-08	1.6E-08	9.1E-09	8.8E-09
Lungs	8.2E-07	7.0E-07	4.3E-07	2.9E-07	2.3E-07	2.1E-07
Skin	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Spleen	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Testes	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Thymus	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Thyroid	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Uterus	2.7E-09	1.6E-09	8.2E-10	4.9E-10	3.3E-10	2.8E-10
Remainder	2.7E-09	1.7E-09	8.5E-10	5.1E-10	3.4E-10	2.9E-10
Effective Dose	1.5E-07	1.1E-07	6.5E-08	5.1E-08	5.0E-08	3.6E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Sr parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.10.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sr-90 (T½ = 29.1 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Bladder Wall	3.2E-10	2.1E-10	1.5E-10	1.1E-10	9.1E-11	8.8E-11
Bone Surface	4.5E-08	2.6E-08	2.7E-08	3.7E-08	4.7E-08	1.9E-08
Brain	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Breast	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
GI-Tract						
Oesophagus	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
St Wall	2.0E-09	1.3E-09	6.3E-10	3.7E-10	2.7E-10	2.3E-10
SI Wall	4.8E-09	3.5E-09	1.7E-09	1.0E-09	6.2E-10	5.4E-10
ULI Wall	3.5E-08	2.5E-08	1.2E-08	7.2E-09	4.1E-09	3.5E-09
LLI Wall	1.3E-07	8.9E-08	4.2E-08	2.5E-08	1.4E-08	1.2E-08
Colon	7.5E-08	5.3E-08	2.5E-08	1.5E-08	8.4E-09	7.2E-09
Kidneys	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Liver	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Muscle	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Ovaries	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Pancreas	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Red Marrow	2.6E-08	1.2E-08	1.0E-08	1.2E-08	1.3E-08	8.4E-09
Respiratory Tract						
ET Airways	2.6E-07	2.1E-07	1.1E-07	7.2E-08	4.4E-08	4.4E-08
Lungs	3.4E-06	3.2E-06	2.2E-06	1.5E-06	1.3E-06	1.3E-06
Skin	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Spleen	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Testes	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Thymus	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Thyroid	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Uterus	2.3E-10	1.4E-10	7.7E-11	4.8E-11	3.6E-11	3.4E-11
Remainder	4.5E-10	2.8E-10	1.5E-10	1.0E-10	7.0E-11	6.6E-11
Effective Dose	4.2E-07	4.0E-07	2.7E-07	1.8E-07	1.6E-07	1.6E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Sr parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.11. Zirconium

(150) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned zirconium carbide to inhalation Class Y, oxides, hydroxides, halides and nitrates of zirconium (Zr) to Class W, and all other compounds to Class D. This classification was adopted without change in *ICRP Publication 30*, Part 1 (ICRP, 1979), which cited in support experiments on mice with various compounds, including ZrO_2 (Thomas *et al.*, 1971), and experience in man (Cofield, 1963; Waligora, 1971).

(151) A recent review of the literature (Thind, 1995) for human data revealed only papers by Cofield (1963) and Waligora (1971) relating to occupational exposure, and by Wrenn *et al.* (1964) on public exposure from weapons fallout.

Absorption Types

(152) In all the studies noted below the zirconium isotope followed was ^{95}Zr ($t_{1/2}$ 64 d), a high-yield fission product (and a neutron activation product derived from zirconium-based fuel cladding) which decays to niobium-95 (^{95}Nb, $t_{1/2}$ 35 d). In most studies, both radionuclides were deposited in the respiratory tract, and the combined activity of the two radionuclides followed. Thus, in interpreting the results it has to be assumed that their behaviour was similar. Furthermore, the ^{95}Nb measured was partly that which deposited, and partly that formed from the *in situ* decay of ^{95}Zr. Because of the relatively short half-lives of these radionuclides, few studies are of sufficient duration to distinguish Type M and S behaviour.

(153) Measurements of ^{95}Zr–^{95}Nb in the lungs of a subject for 5 mo following an accidental intake of unspecified material indicate Type M or S behaviour (Cofield, 1963).

(154) Measurements of ^{95}Zr in the lungs of guinea-pigs following inhalation of Zr oxalate, either carrier-free or with added $ZrOCl_2$, are consistent with assignment to Type M (Schmidtke *et al.*, 1964; Schiessle *et al.*, 1964).

(155) Thomas *et al.* (1971) studied the biokinetics of ^{95}Zr–^{95}Nb following inhalation by mice of aerosols formed by heating droplets of Zr oxalate solution to various temperatures. *In vitro* dissolution tests were conducted on similar materials by Kanapilly and Goh (1973) and Kanapilly *et al.* (1973). The aerosols formed at 100 and 250°C (both Zr oxalate) gave results indicating Type F behaviour, although at 250°C solid particles were produced, which dissolved more slowly than those formed at 100°C. The aerosols formed at 600°C ($Zr(CO_3)_2$ and $ZrOCO_3$) and at 1100°C (ZrO_2 and $ZrOCO_3$) gave very similar results, which indicate Type S behaviour. Results following inhalation of similar ^{95}Nb-labelled zirconium aerosols (formed at 1000°C) by dogs are consistent with assignment to Type S (Cuddihy, 1978), and measurements following (accidental) inhalation by a human subject indicate Type M or S behaviour (Waligora, 1971).

(156) During the early 1960s, measurements were made of ^{95}Zr–Nb activities in human lungs due to fall-out from atmospheric nuclear weapons tests. Most were made *post mortem* (Schönfeld *et al.*, 1960; Osborne, 1963; Wrenn *et al.*, 1964; Dutailly *et al.*, 1966), but *in vivo* measurements were also made, enabling the variation with time in individual subjects to be determined (Rundo and Newton, 1962, 1965). Several authors compared their measurements with those predicted from measured air concentrations, using a single exponential model (ICRP, 1959). Biological lung retention half-times were estimated to be between about 70 d (Wrenn *et al.*, 1964) and more than 120 d (Rundo and Newton, 1965). Wrenn *et al.* (1964) noted that little ^{95}Zr–^{95}Nb activity

was found in other tissues, and that Wegst *et al.* (1964) had shown that ^{95}Zr–^{95}Nb activity in the lungs was present in particulate form. Overall, this indicates Type M or S behaviour.

(157) Following an accidental release, zirconium could be present in fragments of irradiated fuel, where the matrix is predominantly uranium oxide. The results of one human study following accidental inhalation of irradiated fuel indicate Type M behaviour of the zirconium present (Rundo, 1965). In another, measurements of ^{95}Zr–^{95}Nb made on a worker for 6 months following an accidental intake, probably of irradiated fuel (UO_2), indicate Type S behaviour (Thind, 1995). Results of a study in which irradiated UO_2 powder was administered to rats by intratracheal instillation (Lang *et al.*, 1994) are consistent with assignment of the zirconium present to Type M or S, but were of insufficient duration (3 months) to distinguish between the two. Studies of the *in vitro* dissolution of particles released from the Chernobyl accident (Cuddihy *et al.*, 1989) are consistent with assignment of the zirconium present to Type M.

Dose coefficients

(158) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Table 5.11.2) were derived using the f_1 values given in Table 5.11.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.11.1. Values of f_1 for inhaled particulate compounds of zirconium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.02	0.002
M[b]	0.02	0.002
S	0.02	0.002

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.11.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Zr-95 (T½ = 64.0 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	6.1E-09	6.7E-09	3.9E-09	3.0E-09	2.3E-09	2.1E-09
Bladder Wall	3.3E-09	3.3E-09	2.0E-09	1.5E-09	9.1E-10	8.7E-10
Bone Surface	1.8E-07	2.1E-07	1.4E-07	8.5E-08	5.0E-08	5.3E-08
Brain	4.4E-09	4.5E-09	2.6E-09	1.9E-09	1.4E-09	1.3E-09
Breast	2.8E-09	2.7E-09	1.5E-09	1.1E-09	7.0E-10	6.6E-10
GI-Tract						
Oesophagus	3.4E-09	3.2E-09	1.8E-09	1.3E-09	9.5E-10	8.8E-10
St Wall	3.2E-09	2.9E-09	1.9E-09	1.3E-09	8.7E-10	8.1E-10
SI Wall	4.9E-09	4.7E-09	2.9E-09	2.3E-09	1.6E-09	1.4E-09
ULI Wall	8.3E-09	6.7E-09	3.7E-09	2.6E-09	1.6E-09	1.5E-09
LLI Wall	1.7E-08	1.3E-08	6.5E-09	4.6E-09	2.9E-09	2.4E-09
Colon	1.2E-08	9.4E-09	4.9E-09	3.5E-09	2.2E-09	1.9E-09
Kidneys	4.6E-09	4.8E-09	2.9E-09	2.2E-09	1.6E-09	1.4E-09
Liver	3.4E-09	3.3E-09	1.9E-09	1.4E-09	9.7E-10	8.8E-10
Muscle	4.1E-09	4.1E-09	2.4E-09	1.7E-09	1.2E-09	1.1E-09
Ovaries	4.9E-09	4.9E-09	3.1E-09	2.5E-09	1.8E-09	1.6E-09
Pancreas	3.9E-09	3.9E-09	2.3E-09	1.7E-09	1.3E-09	1.3E-09
Red Marrow	4.9E-08	4.4E-08	2.2E-08	1.4E-08	9.4E-09	7.9E-09
Respiratory Tract						
ET Airways	3.0E-08	2.6E-08	1.4E-08	8.4E-09	5.2E-09	4.3E-09
Lungs	4.1E-09	4.1E-09	2.3E-09	1.7E-09	1.2E-09	1.1E-09
Skin	3.4E-09	3.3E-09	1.8E-09	1.2E-09	7.9E-10	7.1E-10
Spleen	3.8E-09	3.7E-09	2.1E-09	1.5E-09	1.0E-09	9.1E-10
Testes	2.6E-09	2.5E-09	1.4E-09	9.9E-10	6.9E-10	5.5E-10
Thymus	3.4E-09	3.2E-09	1.8E-09	1.3E-09	9.5E-10	8.8E-10
Thyroid	2.9E-09	2.9E-09	1.8E-09	1.3E-09	1.0E-09	9.9E-10
Uterus	3.7E-09	3.6E-09	2.3E-09	1.7E-09	1.3E-09	1.1E-09
Remainder	4.2E-09	4.2E-09	2.4E-09	1.8E-09	1.2E-09	1.1E-09
Effective Dose	1.2E-08	1.1E-08	6.4E-09	4.2E-09	2.8E-09	2.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.11.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Zr-95 (T½ = 64.0 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	6.4E-09	5.7E-09	3.5E-09	2.2E-09	1.7E-09	1.5E-09
Bladder Wall	1.6E-09	1.3E-09	7.5E-10	5.2E-10	3.2E-10	2.9E-10
Bone Surface	4.2E-08	4.4E-08	3.2E-08	1.8E-08	1.2E-08	1.3E-08
Brain	1.4E-09	1.3E-09	7.7E-10	5.4E-10	4.1E-10	3.8E-10
Breast	4.8E-09	4.4E-09	3.0E-09	2.1E-09	1.3E-09	1.2E-09
GI-Tract						
Oesophagus	4.8E-09	4.4E-09	3.0E-09	2.0E-09	1.6E-09	1.4E-09
St Wall	3.9E-09	3.2E-09	1.9E-09	1.2E-09	9.9E-10	7.7E-10
SI Wall	4.1E-09	3.3E-09	1.8E-09	1.2E-09	7.7E-10	6.7E-10
ULI Wall	1.1E-08	7.7E-09	3.7E-09	2.3E-09	1.3E-09	1.1E-09
LLI Wall	2.5E-08	1.7E-08	7.8E-09	5.0E-09	2.7E-09	2.3E-09
Colon	1.7E-08	1.2E-08	5.5E-09	3.5E-09	1.9E-09	1.6E-09
Kidneys	3.2E-09	2.9E-09	1.6E-09	1.1E-09	8.2E-10	6.9E-10
Liver	4.5E-09	4.0E-09	2.4E-09	1.6E-09	1.2E-09	1.0E-09
Muscle	3.1E-09	2.7E-09	1.6E-09	1.1E-09	8.1E-10	6.9E-10
Ovaries	3.0E-09	2.5E-09	1.5E-09	1.0E-09	7.3E-10	6.1E-10
Pancreas	4.7E-09	4.1E-09	2.5E-09	1.6E-09	1.3E-09	1.0E-09
Red Marrow	1.2E-08	1.0E-08	5.7E-09	3.7E-09	2.7E-09	2.4E-09
Respiratory Tract						
ET Airways	4.7E-08	3.9E-08	1.9E-08	1.2E-08	6.9E-09	5.9E-09
Lungs	1.1E-07	9.1E-08	5.7E-08	4.2E-08	3.9E-08	3.1E-08
Skin	1.9E-09	1.7E-09	9.6E-10	6.2E-10	4.4E-10	3.9E-10
Spleen	4.5E-09	4.0E-09	2.2E-09	1.5E-09	1.1E-09	9.3E-10
Testes	9.7E-10	8.1E-10	4.5E-10	2.9E-10	2.0E-10	1.6E-10
Thymus	4.8E-09	4.4E-09	3.0E-09	2.0E-09	1.6E-09	1.4E-09
Thyroid	2.9E-09	2.5E-09	1.5E-09	9.8E-10	7.2E-10	6.4E-10
Uterus	2.0E-09	1.7E-09	9.8E-10	6.4E-10	4.6E-10	3.9E-10
Remainder	2.8E-09	2.5E-09	1.5E-09	1.0E-09	7.9E-10	6.8E-10
Effective Dose	2.0E-08	1.6E-08	9.7E-09	6.8E-09	5.9E-09	4.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.11.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Zr-95 (T½ = 64.0 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	8.1E-09	7.1E-09	4.4E-09	2.6E-09	1.9E-09	1.6E-09
Bladder Wall	1.2E-09	9.0E-10	4.3E-10	2.7E-10	1.4E-10	1.1E-10
Bone Surface	8.9E-09	4.5E-09	2.6E-09	1.6E-09	1.1E-09	1.0E-09
Brain	7.1E-10	5.3E-10	3.2E-10	2.1E-10	1.5E-10	1.3E-10
Breast	6.7E-09	6.2E-09	4.4E-09	3.0E-09	1.9E-09	1.7E-09
GI-Tract						
Oesophagus	6.6E-09	6.0E-09	4.2E-09	2.9E-09	2.3E-09	2.0E-09
St Wall	4.8E-09	4.0E-09	2.4E-09	1.5E-09	1.3E-09	9.2E-10
SI Wall	4.0E-09	3.0E-09	1.5E-09	9.3E-10	5.3E-10	4.4E-10
ULI Wall	1.1E-08	7.9E-09	3.6E-09	2.2E-09	1.2E-09	9.9E-10
LLI Wall	2.6E-08	1.8E-08	7.8E-09	4.8E-09	2.5E-09	2.1E-09
Colon	1.8E-08	1.2E-08	5.5E-09	3.3E-09	1.8E-09	1.5E-09
Kidneys	3.5E-09	3.0E-09	1.6E-09	1.0E-09	7.3E-10	5.9E-10
Liver	6.0E-09	5.4E-09	3.2E-09	2.1E-09	1.7E-09	1.4E-09
Muscle	3.5E-09	3.0E-09	1.7E-09	1.1E-09	8.7E-10	7.1E-10
Ovaries	2.7E-09	2.0E-09	1.1E-09	6.5E-10	4.0E-10	3.1E-10
Pancreas	6.2E-09	5.3E-09	3.2E-09	2.0E-09	1.6E-09	1.2E-09
Red Marrow	4.0E-09	2.7E-09	1.7E-09	1.2E-09	1.0E-09	9.6E-10
Respiratory Tract						
ET Airways	5.8E-08	4.8E-08	2.3E-08	1.4E-08	8.3E-09	7.2E-09
Lungs	1.6E-07	1.3E-07	8.0E-08	5.8E-08	5.3E-08	4.2E-08
Skin	1.9E-09	1.6E-09	9.2E-10	5.8E-10	4.2E-10	3.7E-10
Spleen	5.9E-09	5.2E-09	2.9E-09	1.9E-09	1.5E-09	1.2E-09
Testes	6.0E-10	4.2E-10	1.8E-10	1.1E-10	5.5E-11	4.0E-11
Thymus	6.6E-09	6.0E-09	4.2E-09	2.9E-09	2.3E-09	2.0E-09
Thyroid	3.6E-09	3.2E-09	1.9E-09	1.1E-09	7.8E-10	6.7E-10
Uterus	1.7E-09	1.4E-09	6.7E-10	3.7E-10	2.2E-10	1.7E-10
Remainder	3.0E-09	2.6E-09	1.5E-09	1.0E-09	8.2E-10	6.9E-10
Effective Dose	2.4E-08	1.9E-08	1.2E-08	8.3E-09	7.3E-09	5.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.12. Niobium

(159) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides, halides and nitrates of niobium (Nb) to inhalation Class W, and all other compounds to Class D. *ICRP Publication 30*, Part 1 (ICRP, 1979), assigned oxides, and hydroxides of niobium to Class Y, and all other compounds to Class W. The results of experiments on mice with various compounds, including the oxide (Thomas *et al.*, 1971), and on dogs with the oxalate and oxide (McClellan and Rupprecht, 1968) were cited in support of this classification.

Absorption Types

(160) Cuddihy (1978) reviewed information on the lung clearance of inhaled niobium compounds. In all the studies noted below the niobium isotope followed was ^{95}Nb ($t_{1/2}$ 35 d), which is the decay product of the high yield fission product zirconium-95 (^{95}Zr, $t_{1/2}$ 64 d). In most studies both radionuclides were deposited in the respiratory tract, and thus the ^{95}Nb followed was partly that which deposited, and partly that formed from the *in situ* decay of ^{95}Zr. In most studies the combined activity of the two radionuclides was measured, and thus in interpreting the results it has to be assumed that their behaviour is similar. Furthermore, in only a few studies was the inhaled material a pure niobium compound. Because of the relatively short half-lives of these radionuclides few studies are of sufficient duration to distinguish Type M and S behaviour.

(161) Measurements of ^{95}Nb following inhalation of Nb-oxalate by dogs indicate Type M behaviour (Kanapilly *et al.*, 1969), and by rats indicate Type F behaviour in one study (Moskalev *et al.*, 1964), and in another Type M with greater lung retention when inhaled with added stable niobium than when carrier-free (Thomas *et al.*, 1967). Measurements of ^{95}Nb following inhalation of ^{95}Nb-labelled zirconium oxalate by dogs are consistent with assignment to Type M (Cuddihy, 1978).

(162) Thomas *et al.* (1971) studied the biokinetics of ^{95}Zr–^{95}Nb following inhalation by mice of aerosols formed by heating droplets of zirconium oxalate solution to various temperatures. *In vitro* dissolution tests were conducted on similar materials by Kanapilly and Goh (1973) and Kanapilly *et al.* (1973). The aerosols formed at 100 and 250°C (both zirconium oxalate) gave results indicating Type F behaviour, although at 250°C solid particles were produced, which dissolved more slowly than those formed at 100°C. For both materials niobium was absorbed faster than zirconium, especially for that formed at 100°C. The aerosols formed at 600°C ($Zr(CO_3)_2$ and $ZrOCO_3$) and at 1 100°C (ZrO_2 and $ZrOCO_3$) gave very similar results, with no differential loss of niobium, which indicate Type S behaviour. Results following inhalation by dogs of a similar ^{95}Nb-labelled zirconium aerosol (formed at 1 000°C) are consistent with assignment to Type S (Cuddihy, 1978), and measurements following (accidental) inhalation by a human subject indicate Type M or S behaviour (Waligora, 1971).

(163) During the early 1960s, measurements were made of ^{95}Zr–^{95}Nb activities in human lungs due to fall-out from atmospheric nuclear weapons tests. Most were made *post mortem* (Schönfeld *et al.*, 1960; Osborne, 1963; Wrenn *et al.*, 1964; Dutailly *et al.*, 1966), but *in vivo* measurements were also made, enabling the variation with time in individual subjects to be determined (Rundo and Newton, 1962, 1965). Several authors compared their measurements with those predicted from measured air concentrations, using a single exponential model (ICRP, 1959). Biological lung retention half-times were estimated to be between about 70 d (Wrenn *et al.*, 1964) and more than 120 d (Rundo and Newton, 1965). Wrenn *et al.* (1964)

noted that little ^{95}Zr–^{95}Nb activity was found in other tissues, and that Wegst *et al.* (1964) had shown that ^{95}Zr–^{95}Nb activity in the lungs was present in particulate form. Overall this indicates Type M or S behaviour.

(164) Following an accidental release, niobium could be present in fragments of irradiated fuel, where the matrix is predominantly uranium oxide. The results of one human study following accidental inhalation of irradiated fuel indicate Type M behaviour of the ^{95}Zr–^{95}Nb present (Rundo, 1965). In another, measurements of ^{95}Zr–^{95}Nb made on a worker for 6 months following an accidental intake, probably of irradiated fuel (UO_2), indicate Type S behaviour (Thind, 1995). Results of a study in which irradiated UO_2 powder was administered to rats by intratracheal instillation (Lang *et al.*, 1994) are consistent with assignment of the niobium present to Type M. Studies of the *in vitro* dissolution of particles released from the Chernobyl accident (Cuddihy *et al.*, 1989) are consistent with assignment of the niobium present to Type M.

(165) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.12.2 and 5.12.3) were derived using the f_1 values given in Table 5.12.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.12.1. Values of f_1 for inhaled particulate compounds of niobium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.02	0.01
M[b]	0.02	0.01
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.12.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Nb-94 (T½ = 2.03E+04 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.5E-08	3.1E-08	1.8E-08	1.3E-08	9.0E-09	7.8E-09
Bladder Wall	1.6E-08	1.5E-08	8.7E-09	5.6E-09	3.6E-09	3.5E-09
Bone Surface	7.5E-08	5.8E-08	3.5E-08	1.9E-08	1.2E-08	1.1E-08
Brain	1.8E-08	1.6E-08	9.1E-09	5.9E-09	3.9E-09	3.6E-09
Breast	1.6E-08	1.4E-08	7.6E-09	5.2E-09	3.3E-09	2.9E-09
GI-Tract						
Oesophagus	1.7E-08	1.5E-08	8.4E-09	5.9E-09	4.0E-09	3.5E-09
St Wall	2.2E-08	2.0E-08	1.1E-08	7.3E-09	4.7E-09	4.2E-09
SI Wall	2.4E-08	2.2E-08	1.2E-08	8.5E-09	5.5E-09	4.8E-09
ULI Wall	3.1E-08	2.7E-08	1.5E-08	9.8E-09	6.0E-09	5.4E-09
LLI Wall	4.0E-08	3.1E-08	1.6E-08	1.0E-08	6.3E-09	5.7E-09
Colon	3.5E-08	2.9E-08	1.5E-08	1.0E-08	6.1E-09	5.5E-09
Kidneys	6.7E-08	5.6E-08	3.2E-08	2.9E-08	2.1E-08	1.8E-08
Liver	1.0E-07	9.9E-08	5.5E-08	4.2E-08	2.9E-08	2.5E-08
Muscle	2.0E-08	1.8E-08	9.6E-09	6.6E-09	4.4E-09	3.9E-09
Ovaries	2.2E-08	2.0E-08	1.1E-08	7.6E-09	5.1E-09	4.4E-09
Pancreas	2.9E-08	2.7E-08	1.5E-08	1.1E-08	7.4E-09	6.4E-09
Red Marrow	6.1E-08	4.4E-08	2.4E-08	1.4E-08	9.4E-09	8.2E-09
Respiratory Tract						
ET Airways	6.6E-08	5.9E-08	3.2E-08	1.9E-08	1.2E-08	9.7E-09
Lungs	2.3E-08	2.0E-08	1.1E-08	7.7E-09	5.3E-09	4.5E-09
Skin	1.6E-08	1.4E-08	7.1E-09	4.7E-09	3.1E-09	2.8E-09
Spleen	2.2E-08	2.0E-08	1.1E-08	7.8E-09	5.1E-09	4.3E-09
Testes	1.4E-08	1.2E-08	6.8E-09	4.7E-09	3.2E-09	2.8E-09
Thymus	1.7E-08	1.5E-08	8.4E-09	5.9E-09	4.0E-09	3.5E-09
Thyroid	1.6E-08	1.5E-08	8.4E-09	5.8E-09	3.9E-09	3.5E-09
Uterus	1.9E-08	1.7E-08	9.7E-09	6.8E-09	4.6E-09	3.9E-09
Remainder	2.0E-08	1.8E-08	9.9E-09	6.8E-09	4.6E-09	4.0E-09
Effective Dose	3.1E-08	2.7E-08	1.5E-08	1.0E-08	6.7E-09	5.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.12.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Nb-94 (T½ = 2.03E+04 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.5E-08	2.3E-08	1.4E-08	9.4E-09	7.1E-09	6.1E-09
Bladder Wall	7.0E-09	6.3E-09	3.8E-09	2.4E-09	1.6E-09	1.6E-09
Bone Surface	2.9E-08	2.4E-08	1.5E-08	8.4E-09	6.1E-09	5.8E-09
Brain	6.6E-09	5.9E-09	3.8E-09	2.4E-09	1.8E-09	1.7E-09
Breast	1.7E-08	1.6E-08	1.1E-08	7.3E-09	4.8E-09	4.4E-09
GI-Tract						
Oesophagus	1.7E-08	1.6E-08	1.1E-08	7.4E-09	5.8E-09	5.1E-09
St Wall	1.5E-08	1.4E-08	8.2E-09	5.3E-09	4.1E-09	3.4E-09
SI Wall	1.4E-08	1.2E-08	6.8E-09	4.4E-09	3.0E-09	2.6E-09
ULI Wall	2.5E-08	2.0E-08	1.0E-08	6.5E-09	4.0E-09	3.5E-09
LLI Wall	4.5E-08	3.2E-08	1.6E-08	9.7E-09	5.7E-09	4.9E-09
Colon	3.4E-08	2.5E-08	1.3E-08	7.9E-09	4.7E-09	4.1E-09
Kidneys	2.7E-08	2.3E-08	1.5E-08	1.2E-08	9.4E-09	8.3E-09
Liver	4.3E-08	4.2E-08	2.6E-08	1.9E-08	1.4E-08	1.3E-08
Muscle	1.2E-08	1.1E-08	6.5E-09	4.3E-09	3.3E-09	2.9E-09
Ovaries	1.1E-08	9.7E-09	5.7E-09	3.7E-09	2.6E-09	2.3E-09
Pancreas	2.0E-08	1.8E-08	1.1E-08	7.5E-09	5.8E-09	4.8E-09
Red Marrow	2.3E-08	1.8E-08	1.1E-08	6.9E-09	5.4E-09	4.9E-09
Respiratory Tract						
ET Airways	9.6E-08	8.3E-08	4.3E-08	2.6E-08	1.6E-08	1.3E-08
Lungs	2.2E-07	1.9E-07	1.2E-07	8.4E-08	7.4E-08	6.0E-08
Skin	8.0E-09	7.1E-09	4.2E-09	2.7E-09	2.0E-09	1.8E-09
Spleen	1.7E-08	1.6E-08	9.2E-09	6.2E-09	4.7E-09	3.9E-09
Testes	5.2E-09	4.7E-09	2.7E-09	1.8E-09	1.3E-09	1.2E-09
Thymus	1.7E-08	1.6E-08	1.1E-08	7.4E-09	5.8E-09	5.1E-09
Thyroid	1.1E-08	1.1E-08	6.4E-09	4.1E-09	3.0E-09	2.6E-09
Uterus	8.9E-09	7.9E-09	4.6E-09	3.0E-09	2.1E-09	1.8E-09
Remainder	1.2E-08	1.0E-08	6.3E-09	4.3E-09	3.3E-09	2.9E-09
Effective Dose	4.3E-08	3.7E-08	2.3E-08	1.6E-08	1.3E-08	1.1E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.12.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Nb-94 (T½ = 2.03E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	7.4E-08	7.3E-08	5.1E-08	3.3E-08	2.9E-08	2.7E-08
Bladder Wall	6.1E-09	5.3E-09	3.0E-09	1.7E-09	1.1E-09	9.7E-10
Bone Surface	3.4E-08	3.2E-08	2.1E-08	1.4E-08	1.2E-08	1.2E-08
Brain	6.1E-09	5.8E-09	4.1E-09	2.8E-09	2.3E-09	2.3E-09
Breast	6.8E-08	7.0E-08	5.4E-08	3.6E-08	2.9E-08	2.9E-08
GI-Tract						
Oesophagus	6.6E-08	6.8E-08	5.3E-08	3.8E-08	3.4E-08	3.4E-08
St Wall	3.8E-08	3.7E-08	2.6E-08	1.8E-08	1.6E-08	1.4E-08
SI Wall	1.7E-08	1.5E-08	9.0E-09	5.4E-09	4.0E-09	3.7E-09
ULI Wall	3.0E-08	2.5E-08	1.3E-08	8.2E-09	5.6E-09	5.1E-09
LLI Wall	4.9E-08	3.5E-08	1.7E-08	1.0E-08	6.2E-09	5.3E-09
Colon	3.8E-08	2.9E-08	1.5E-08	9.2E-09	5.9E-09	5.2E-09
Kidneys	3.2E-08	3.0E-08	2.0E-08	1.3E-08	1.1E-08	1.1E-08
Liver	5.9E-08	5.8E-08	4.1E-08	2.9E-08	2.6E-08	2.4E-08
Muscle	3.0E-08	2.9E-08	2.0E-08	1.4E-08	1.2E-08	1.2E-08
Ovaries	1.1E-08	9.9E-09	5.9E-09	3.5E-09	2.5E-09	2.2E-09
Pancreas	5.5E-08	5.4E-08	3.8E-08	2.5E-08	2.2E-08	2.0E-08
Red Marrow	2.8E-08	2.7E-08	2.1E-08	1.6E-08	1.5E-08	1.5E-08
Respiratory Tract						
ET Airways	2.9E-07	2.6E-07	1.5E-07	1.0E-07	7.0E-08	6.7E-08
Lungs	7.9E-07	7.6E-07	5.3E-07	3.8E-07	3.4E-07	3.2E-07
Skin	1.6E-08	1.6E-08	1.1E-08	7.4E-09	6.4E-09	6.2E-09
Spleen	5.2E-08	5.1E-08	3.5E-08	2.4E-08	2.1E-08	2.0E-08
Testes	3.2E-09	2.6E-09	1.4E-09	8.7E-10	5.6E-10	4.8E-10
Thymus	6.6E-08	6.8E-08	5.3E-08	3.8E-08	3.4E-08	3.4E-08
Thyroid	3.3E-08	3.2E-08	2.2E-08	1.4E-08	1.2E-08	1.1E-08
Uterus	9.1E-09	8.1E-09	4.5E-09	2.5E-09	1.8E-09	1.6E-09
Remainder	2.6E-08	2.5E-08	1.8E-08	1.3E-08	1.2E-08	1.1E-08
Effective Dose	1.2E-07	1.2E-07	8.3E-08	5.8E-08	5.2E-08	4.9E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.12.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Nb-95 (T½ = 35.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.4E-09	2.8E-09	1.6E-09	1.2E-09	8.0E-10	6.8E-10
Bladder Wall	1.8E-09	1.4E-09	8.4E-10	5.7E-10	3.6E-10	3.4E-10
Bone Surface	3.1E-08	2.2E-08	1.4E-08	6.2E-09	3.6E-09	3.6E-09
Brain	1.8E-09	1.4E-09	7.2E-10	4.7E-10	3.1E-10	2.7E-10
Breast	1.5E-09	1.2E-09	6.3E-10	4.3E-10	2.7E-10	2.4E-10
GI-Tract						
Oesophagus	1.9E-09	1.5E-09	7.6E-10	5.3E-10	3.5E-10	3.0E-10
St Wall	2.3E-09	2.0E-09	1.0E-09	6.6E-10	4.2E-10	3.7E-10
SI Wall	3.0E-09	2.4E-09	1.3E-09	9.2E-10	5.7E-10	4.9E-10
ULI Wall	4.6E-09	3.6E-09	1.8E-09	1.2E-09	6.9E-10	6.1E-10
LLI Wall	7.4E-09	5.3E-09	2.5E-09	1.7E-09	9.4E-10	8.2E-10
Colon	5.8E-09	4.3E-09	2.1E-09	1.4E-09	8.0E-10	7.0E-10
Kidneys	5.4E-09	4.1E-09	2.3E-09	2.1E-09	1.4E-09	1.2E-09
Liver	7.9E-09	7.2E-09	3.8E-09	3.0E-09	2.0E-09	1.7E-09
Muscle	2.1E-09	1.6E-09	8.5E-10	5.8E-10	3.8E-10	3.2E-10
Ovaries	2.8E-09	2.3E-09	1.2E-09	8.6E-10	5.6E-10	4.7E-10
Pancreas	2.9E-09	2.5E-09	1.3E-09	9.8E-10	6.4E-10	5.5E-10
Red Marrow	9.6E-09	5.7E-09	2.8E-09	1.6E-09	1.1E-09	9.0E-10
Respiratory Tract						
ET Airways	2.3E-08	2.1E-08	1.1E-08	6.6E-09	3.9E-09	3.0E-09
Lungs	2.2E-09	1.8E-09	9.5E-10	6.7E-10	4.6E-10	3.9E-10
Skin	1.6E-09	1.2E-09	5.9E-10	3.8E-10	2.5E-10	2.2E-10
Spleen	2.2E-09	1.8E-09	9.3E-10	6.8E-10	4.4E-10	3.7E-10
Testes	1.3E-09	1.1E-09	5.8E-10	3.9E-10	2.6E-10	2.2E-10
Thymus	1.9E-09	1.5E-09	7.6E-10	5.3E-10	3.5E-10	3.0E-10
Thyroid	1.5E-09	1.3E-09	6.9E-10	4.8E-10	3.2E-10	2.8E-10
Uterus	2.2E-09	1.8E-09	9.7E-10	6.8E-10	4.4E-10	3.7E-10
Remainder	2.1E-09	1.7E-09	8.7E-10	3.6E-09	2.2E-09	3.4E-10
Effective Dose	4.1E-09	3.1E-09	1.6E-09	1.2E-09	7.5E-10	5.7E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

limit on HTO is so much lower. *ICRP Publication 30* assumed that all inhaled HTO is instantaneously distributed uniformly among all the soft tissues of the body. It also noted that exposure to an atmosphere containing HTO also results in the intake of HTO by absorption through intact skin. According to *ICRP Publication 30*: "Many organic compounds of tritium are not very volatile under normal circumstances and the probability of their being inhaled as vapours is, therefore, small. In circumstances where they might be inhaled it would be prudent to assume that once they enter the lungs they are instantaneously and completely translocated to blood without changing their chemical form."

(86) Inhalation of tritium has been the subject of a number of studies recently reviewed by Hill and Johnson (1993). The following summary of information on the inhalation biokinetics of tritium is based predominantly on that review.

Absorption Types

(a) *Gases and vapours*

(87) *Tritium gas.* As noted in *ICRP Publication 66* (ICRP, 1994a), a recent study in which human volunteers inhaled HT (Peterman *et al.*, 1985) indicates that about 0.01% of the HT inhaled is absorbed and converted to HTO. As discussed in *ICRP Publication 68* (ICRP, 1994b), the contribution to effective dose from 0.01% absorption and conversion to HTO exceeds that from direct irradiation of the lungs from HT within the airways, and HT is therefore assigned here to Class SR-1.

(88) *Tritiated water.* In agreement with *ICRP Publication 30*, Hill and Johnson (1993) considered that inhaled HTO can be assumed, in the absence of specific information, to translocate to blood instantaneously and then distribute uniformly throughout the body without changing chemical form. HTO is therefore assigned here to Class SR-2.

(89) *Organic compounds.* Small amounts of volatile and highly soluble organic acids may be released as effluent from tritium facilities (Belot *et al.*, 1993). A recent review of OBT metabolism has been given by Diabaté and Strack (1993). In agreement with *ICRP Publication 30*, Hill and Johnson (1993) considered that inhaled OBT can be assumed, in the absence of specific information, to translocate to blood instantaneously and then distribute uniformly throughout the body without changing chemical form. Tritium in unspecified organic compounds is therefore assigned here to Class SR-2.

(90) *Tritiated methane* $CH_{4-x}T_x$. Tritiated methane may be released from low-level waste disposal sites. The dosimetric consequences of inhaling this gas were examined by Phipps *et al.* (1990) using *ICRP Publication 30* methods. In the absence of other experimental information they assumed that 1% of the methane was metabolized. This is consistent with experimental results for sheep by Dougherty *et al.* (1967), which found that approximately 0.3% of infused methane was converted to carbon dioxide. Tritiated methane is therefore assigned here to Class SR-1.

(b) *Particulate aerosols*

(91) Tritium could be released to the environment in particulate form, and studies of the solubility of solid tritiated compounds have been conducted. For example, the results of an *in vitro* study of the dissolution of 1 μm (count median diameter) titanium tritide powder in serum ultrafiltrate were consistent with assignment to Type M (Cheng *et al.*, 1994). Preliminary results following intratracheal instillation of titanium tritide into rats indicate that the dissolution rate is similar to that observed *in vitro* (Cheng *et al.*, 1995). It is assumed here that for inhalation of inorganic particulate material, the biokinetics of tritium absorbed into body fluids follow that of HTO.

Intake through skin

(92) Both *ICRP Publication 30* and Hill and Johnson (1993) also considered the absorption of HTO through the skin. *ICRP Publication 30* cited work by Osborne (1966) which showed that for an adult at rest, about 1% of the activity in 1 m^3 air is absorbed through the skin per minute, and from this result estimated that, for a sedentary male worker, absorption through the skin contributes approximately one-third of the total HTO intake for a given atmospheric concentration. Similar assessments were made in *ICRP Publication 66* (ICRP, 1994a) and by Myers and Johnson (1991). Estimates of the absorption of HTO through the skin of children would need to take account of skin surface areas at different ages, values of which are given in the Report of the Task Group on Reference Man (ICRP, 1975). According to Hill and Johnson (1993) there is negligible absorption of HT by the skin, and the gas is not readily converted to HTO on the skin. Absorption through skin is not included in the derivation of the dose coefficients for HTO (given in Table 5.1.2).

Dose coefficients

(93) Dose coefficients given in Table 5.1.2 are derived for the gases and vapours given in Table 5.1.1a, the recommended absorption Types given in Table 5.1.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993). Different biokinetic data are given for tritiated water, and for organically bound tritium in *ICRP Publication 67*, Tables C-1.1 and C-2.1, respectively. The biokinetic data chosen here according to the form inhaled are identified in Tables 5.1.1a and 5.1.1b.

Table 5.1.1a. Classification and absorption Types for gas and vapour compounds of hydrogen

	Deposition		Absorption		
Chemical form/origin	Vapour Class	Fraction deposited (%)	Type	f_1	Biokinetic model[a]
Tritiated water	SR-2	100	V	[c]	HTO
Unspecified organic compounds	SR-2	100	V	[c]	OBT
Tritium gas	SR-1	0.01[b]	V	[c]	HTO
Tritiated methane	SR-1	1.0[b]	V	[c]	HTO

[a] HTO = Biokinetic model for tritiated water, *ICRP Publication 67*, Table C-1.1. OBT = Biokinetic model for organically bound tritium, *ICRP Publication 67*, Table C-2.1.
[b] Deposited beyond ET_1, i.e. in ET_2 and the lungs.
[c] Not applicable since all activity deposited in the respiratory tract is instantaneously absorbed (TypeV).

Table 5.1.1b. Values of f_1 for inhaled particulate compounds of hydrogen[a]

	f_1[b]	
Absorption Type	3 mo	1 y–adult
F	1	1
M[c]	0.2	0.1
S	0.02	0.01

[a] Following uptake into body fluids, the biokinetic data for tritiated water are used (*ICRP Publication 67*, Table C-1.1).
[b] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[c] Default Type M is recommended for use in the absence of specific information.

Table 5.1.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 (T½ = 12.3 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Bladder Wall	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Bone Surface	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Brain	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Breast	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
GI-Tract						
Oesophagus	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
St Wall	3.6E-11	2.5E-11	1.3E-11	9.4E-12	6.6E-12	6.8E-12
SI Wall	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.2E-12
ULI Wall	2.6E-11	2.0E-11	1.1E-11	8.2E-12	5.9E-12	6.2E-12
LLI Wall	2.9E-11	2.2E-11	1.2E-11	8.7E-12	6.1E-12	6.4E-12
Colon	2.8E-11	2.1E-11	1.1E-11	8.4E-12	6.0E-12	6.3E-12
Kidneys	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Liver	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Muscle	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Ovaries	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Pancreas	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Red Marrow	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Respiratory Tract						
ET Airways	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Lungs	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.9E-12	6.2E-12
Skin	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Spleen	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Testes	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Thymus	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Thyroid	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Uterus	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Remainder	2.5E-11	1.9E-11	1.1E-11	8.0E-12	5.8E-12	6.1E-12
Effective Dose	2.6E-11	2.0E-11	1.1E-11	8.2E-12	5.9E-12	6.2E-12

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.1.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 (T½ = 12.3 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Bladder Wall	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Bone Surface	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Brain	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Breast	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
GI-Tract						
Oesophagus	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
St Wall	3.4E-11	1.9E-11	9.1E-12	5.7E-12	4.0E-12	3.7E-12
SI Wall	5.5E-11	4.0E-11	1.8E-11	1.1E-11	6.3E-12	5.7E-12
ULI Wall	3.0E-10	2.2E-10	9.3E-11	5.7E-11	2.8E-11	2.4E-11
LLI Wall	8.3E-10	6.0E-10	2.6E-10	1.6E-10	7.8E-11	6.5E-11
Colon	5.3E-10	3.8E-10	1.7E-10	1.0E-10	5.0E-11	4.2E-11
Kidneys	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Liver	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Muscle	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Ovaries	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Pancreas	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Red Marrow	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Respiratory Tract						
ET Airways	8.5E-12	5.5E-12	3.4E-12	2.5E-12	2.0E-12	2.2E-12
Lungs	2.2E-09	1.8E-09	9.7E-10	5.7E-10	3.8E-10	3.2E-10
Skin	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Spleen	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Testes	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Thymus	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Thyroid	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Uterus	8.3E-12	5.4E-12	3.3E-12	2.4E-12	2.0E-12	2.1E-12
Remainder	9.1E-12	6.0E-12	3.6E-12	2.6E-12	2.1E-12	2.2E-12
Effective Dose	3.4E-10	2.7E-10	1.4E-10	8.2E-11	5.3E-11	4.5E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.1.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 (T½ = 12.3 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Bladder Wall	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Bone Surface	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Brain	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Breast	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
GI-Tract						
Oesophagus	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
St Wall	2.9E-11	1.7E-11	7.3E-12	4.3E-12	2.7E-12	2.3E-12
SI Wall	6.6E-11	4.5E-11	2.0E-11	1.2E-11	6.2E-12	5.3E-12
ULI Wall	4.0E-10	2.7E-10	1.2E-10	7.2E-11	3.7E-11	3.1E-11
LLI Wall	1.1E-09	7.7E-10	3.4E-10	2.0E-10	1.1E-10	9.0E-11
Colon	7.2E-10	4.9E-10	2.2E-10	1.3E-10	6.7E-11	5.7E-11
Kidneys	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Liver	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Muscle	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Ovaries	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Pancreas	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Red Marrow	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Respiratory Tract						
ET Airways	6.7E-12	5.9E-12	3.4E-12	2.5E-12	1.8E-12	1.8E-12
Lungs	8.9E-09	8.2E-09	5.0E-09	3.0E-09	2.3E-09	2.1E-09
Skin	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Spleen	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Testes	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Thymus	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Thyroid	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Uterus	7.1E-13	4.5E-13	3.1E-13	2.4E-13	2.1E-13	2.3E-13
Remainder	1.9E-12	1.2E-12	6.7E-13	4.6E-13	3.5E-13	3.4E-13
Effective Dose	1.2E-09	1.0E-09	6.3E-10	3.8E-10	2.8E-10	2.6E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.1.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 (T½ = 12.3 y).

Tritiated Water Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Bladder Wall	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Bone Surface	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Brain	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Breast	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
GI-Tract						
Oesophagus	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
St Wall	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
SI Wall	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
ULI Wall	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
LLI Wall	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Colon	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Kidneys	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Liver	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Muscle	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Ovaries	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Pancreas	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Red Marrow	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Respiratory Tract						
ET Airways	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Lungs	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Skin	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Spleen	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Testes	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Thymus	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Thyroid	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Uterus	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Remainder	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11
Effective Dose	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11	1.8E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.1.2(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 ($T\frac{1}{2}$ = 12.3 y).

Organically Bound Tritium Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Bladder Wall	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Bone Surface	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Brain	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Breast	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
GI-Tract						
Oesophagus	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
St Wall	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
SI Wall	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
ULI Wall	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
LLI Wall	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Colon	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Kidneys	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Liver	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Muscle	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Ovaries	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Pancreas	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Red Marrow	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Respiratory Tract						
ET Airways	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Lungs	1.1E-10	1.1E-10	7.0E-11	5.6E-11	4.1E-11	4.1E-11
Skin	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Spleen	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Testes	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Thymus	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Thyroid	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Uterus	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Remainder	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11
Effective Dose	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11	4.1E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.1.2(f).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 (T½ = 12.3 y).

Tritium Gas Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Bladder Wall	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Bone Surface	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Brain	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Breast	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
GI-Tract						
Oesophagus	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
St Wall	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
SI Wall	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
ULI Wall	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
LLI Wall	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Colon	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Kidneys	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Liver	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Muscle	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Ovaries	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Pancreas	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Red Marrow	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Respiratory Tract						
ET Airways	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Lungs	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Skin	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Spleen	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Testes	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Thymus	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Thyroid	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Uterus	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Remainder	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15
Effective Dose	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15	1.8E-15

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.1.2(g).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for H-3 ($T_{1/2}$ = 12.3 y).

Tritiated Methane Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Bladder Wall	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Bone Surface	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Brain	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Breast	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
GI-Tract						
Oesophagus	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
St Wall	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
SI Wall	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
ULI Wall	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
LLI Wall	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Colon	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Kidneys	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Liver	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Muscle	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Ovaries	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Pancreas	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Red Marrow	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Respiratory Tract						
ET Airways	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Lungs	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Skin	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Spleen	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Testes	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Thymus	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Thyroid	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Uterus	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Remainder	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13
Effective Dose	6.4E-13	4.8E-13	3.1E-13	2.3E-13	1.8E-13	1.8E-13

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.2. Carbon

(94) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides of elements to inhalation Classes D, W and Y according to their positions in the Periodic Table. *ICRP Publication 30*, Part 3 (ICRP, 1981), identified three main classes of carbon (C) compounds that may be inhaled: gases, organic compounds, and aerosols of carbon-containing compounds. The following is mainly based on the discussion in that report.

Absorption Types

(a) *Gases and vapours*

(95) Consideration was given to the inhalation and retention in body tissues of the gases carbon monoxide and carbon dioxide. It was noted that the uptake and retention of other inhaled carbon-containing gases was not considered.

(96) *Carbon monoxide.* The inhalation and retention in body tissues have been extensively studied. Carbon monoxide has a low solubility in tissue water, and its retention is mainly due to binding to haemoglobin. It was assumed that when radioactive carbon monoxide is inhaled, 0.4 is instantaneously bound to haemoglobin and 0.6 exhaled. Carbon monoxide bound to haemoglobin was assumed to be uniformly distributed throughout all organs and tissues of the body and retained with a biological half-time of 200 min. On this basis, carbon monoxide is assigned to Class SR-1 (40% deposition) with Type V clearance.

(97) *Carbon dioxide.* Since carbon dioxide is transferred across the alveolar membrane about 30 times more rapidly than oxygen, because of its higher solubility coefficient in water, it was considered appropriate to assume that all carbon dioxide that enters the respiratory system is translocated to blood. On this basis carbon dioxide is assigned to Class SR-2.

(98) *Organic compounds.* It was noted that "most organic compounds are not very volatile under normal circumstances and the probability of their being inhaled as vapours is, therefore, small. In circumstances where such substances are inhaled it would be prudent, as in the case of tritiated organic compounds, to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form." On this basis, unspecified organic compounds are assigned to Class SR-2.

(b) *Particulate aerosols*

(99) In *ICRP Publication 30*, Part 3 (ICRP, 1981), it was stated that aerosols containing carbon in the form of a carbonate or carbide in combination with a particular element were not considered in the report; however, some insight on their lung retention might be obtained from the metabolic data for the appropriate element, or from the report of the TGLD (1966).

(100) Results of studies in which rats inhaled ^{14}C-labelled diesel exhaust particles indicate Type M behaviour (Chan *et al.*, 1981; Lee *et al.*, 1987). Measurements following intratracheal instillation into rats of a ^{14}C-bearing material obtained from air filters during re-tubing of a CANDU reactor are consistent with assignment to Type S (Johnson, 1989).

Dose coefficients

(101) Dose coefficients (given in Table 5.2.2) were derived for the gases and vapours given in Table 5.2.1a, and for particulate aerosols, using the f_1 values given in Table 5.2.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993), except for the gases carbon monoxide and carbon dioxide. For carbon monoxide a biological half-time of 200 min is used (*ICRP Publication 30*, Part 3) which is assumed to be age-invariant. For carbon dioxide, following *ICRP Publication 30*, Part 3, it is assumed that carbon inhaled as carbon dioxide is

uniformly distributed throughout all organs and tissues of the body, and that its retention is given by:

$$R(t) = 0.18e^{-0.693t/5} + 0.81e^{-0.693t/60} + 0.01e^{-0.693t/t_b}$$

where t is in minutes and t_b is the biological half-time for dietary carbon. Age-specific values of t_b are taken from *ICRP Publication 67*, Table C-3.1, and it is assumed that the other parameter values are age-invariant.

Table 5.2.1a. Classification and absorption Types for gas and vapour compounds of carbon[a]

	Deposition		Absorption	
Chemical form/origin	Vapour Class	Fraction deposited (%)	Type	f_1
Carbon monoxide	SR-1	40[b]	V	[c]
Carbon dioxide; organic compounds	SR-2	100	V	[c]

[a]For carbon in unspecified gas or vapour form, Class SR-2 is recommended.
[b]Deposited beyond ET_1, i.e. in ET_2 and the lungs.
[c]Not applicable, since all activity deposited in the respiratory tract is instantaneously absorbed (Type V).

Table 5.2.1b. Values of f_1 for inhaled particulate compounds of carbon

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	1	1
M[b]	0.2	0.1
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[b]Default Type M is recommended for use in the absence of specific information.

Table 5.2.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for C-14 (T½ = 5.73E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Bladder Wall	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Bone Surface	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Brain	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Breast	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
GI-Tract						
Oesophagus	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
St Wall	6.2E-10	6.7E-10	3.6E-10	2.9E-10	1.9E-10	2.0E-10
SI Wall	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
ULI Wall	5.3E-10	6.3E-10	3.4E-10	2.8E-10	1.9E-10	1.9E-10
LLI Wall	5.6E-10	6.4E-10	3.5E-10	2.8E-10	1.9E-10	2.0E-10
Colon	5.4E-10	6.3E-10	3.5E-10	2.8E-10	1.9E-10	1.9E-10
Kidneys	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Liver	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Muscle	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Ovaries	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Pancreas	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Red Marrow	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Respiratory Tract						
ET Airways	3.2E-09	2.5E-09	1.1E-09	7.8E-10	4.6E-10	4.6E-10
Lungs	5.5E-10	6.4E-10	3.6E-10	2.9E-10	2.0E-10	2.0E-10
Skin	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Spleen	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Testes	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Thymus	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Thyroid	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Uterus	5.2E-10	6.2E-10	3.4E-10	2.8E-10	1.8E-10	1.9E-10
Remainder	1.9E-09	1.5E-09	7.2E-10	5.3E-10	3.2E-10	3.3E-10
Effective Dose	6.1E-10	6.7E-10	3.6E-10	2.9E-10	1.9E-10	2.0E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.2.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for C-14 (T½ = 5.73E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Bladder Wall	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Bone Surface	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Brain	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Breast	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
GI-Tract						
Oesophagus	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
St Wall	4.1E-10	3.0E-10	1.6E-10	1.1E-10	8.1E-11	8.2E-11
SI Wall	6.0E-10	4.8E-10	2.4E-10	1.6E-10	1.0E-10	9.9E-11
ULI Wall	2.7E-09	2.0E-09	8.9E-10	5.6E-10	2.9E-10	2.6E-10
LLI Wall	7.3E-09	5.4E-09	2.3E-09	1.4E-09	7.3E-10	6.2E-10
Colon	4.7E-09	3.5E-09	1.5E-09	9.3E-10	4.8E-10	4.1E-10
Kidneys	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Liver	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Muscle	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Ovaries	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Pancreas	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Red Marrow	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Respiratory Tract						
ET Airways	2.1E-08	1.6E-08	6.8E-09	4.6E-09	2.5E-09	2.5E-09
Lungs	6.3E-08	5.0E-08	3.1E-08	2.2E-08	2.0E-08	1.6E-08
Skin	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Spleen	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Testes	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Thymus	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Thyroid	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Uterus	1.9E-10	1.8E-10	1.1E-10	8.5E-11	6.4E-11	6.8E-11
Remainder	2.1E-10	1.9E-10	1.1E-10	8.9E-11	6.6E-11	7.0E-11
Effective Dose	8.3E-09	6.6E-09	4.0E-09	2.8E-09	2.5E-09	2.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.2.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for C-14 (T½ = 5.73E+03 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Bladder Wall	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Bone Surface	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Brain	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Breast	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
GI-Tract						
Oesophagus	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
St Wall	2.7E-10	1.6E-10	7.4E-11	4.5E-11	3.1E-11	2.8E-11
SI Wall	5.9E-10	4.1E-10	1.9E-10	1.1E-10	6.2E-11	5.5E-11
ULI Wall	3.5E-09	2.4E-09	1.1E-09	6.4E-10	3.4E-10	2.9E-10
LLI Wall	1.0E-08	6.8E-09	3.0E-09	1.8E-09	9.6E-10	8.2E-10
Colon	6.3E-09	4.3E-09	1.9E-09	1.2E-09	6.1E-10	5.2E-10
Kidneys	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Liver	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Muscle	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Ovaries	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Pancreas	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Red Marrow	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Respiratory Tract						
ET Airways	7.6E-08	6.3E-08	3.1E-08	2.2E-08	1.3E-08	1.3E-08
Lungs	1.5E-07	1.4E-07	8.9E-08	6.0E-08	5.3E-08	4.7E-08
Skin	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Spleen	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Testes	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Thymus	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Thyroid	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Uterus	2.0E-11	1.7E-11	1.2E-11	9.8E-12	8.7E-12	9.3E-12
Remainder	7.1E-11	5.0E-11	2.9E-11	2.2E-11	1.6E-11	1.7E-11
Effective Dose	1.9E-08	1.7E-08	1.1E-08	7.4E-09	6.4E-09	5.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.2.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for C-14 (T½ = 5.73E+03 y).

Carbon Monoxide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Bladder Wall	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Bone Surface	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Brain	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Breast	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
GI-Tract						
Oesophagus	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
St Wall	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
SI Wall	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
ULI Wall	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
LLI Wall	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Colon	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Kidneys	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Liver	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Muscle	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Ovaries	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Pancreas	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Red Marrow	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Respiratory Tract						
ET Airways	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Lungs	9.2E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Skin	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Spleen	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Testes	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Thymus	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Thyroid	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Uterus	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Remainder	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13
Effective Dose	9.1E-12	5.7E-12	2.8E-12	1.7E-12	9.9E-13	8.0E-13

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.2.2(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for C-14 (T½ = 5.73E+03 y).

Carbon Dioxide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Bladder Wall	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Bone Surface	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Brain	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Breast	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
GI-Tract						
Oesophagus	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
St Wall	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
SI Wall	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
ULI Wall	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
LLI Wall	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Colon	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Kidneys	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Liver	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Muscle	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Ovaries	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Pancreas	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Red Marrow	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Respiratory Tract						
ET Airways	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Lungs	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Skin	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Spleen	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Testes	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Thymus	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Thyroid	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Uterus	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Remainder	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12
Effective Dose	1.9E-11	1.9E-11	1.1E-11	8.9E-12	6.3E-12	6.2E-12

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.2.2(f).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for C-14 (T½ = 5.73E+03 y).

Organic Compounds Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Bladder Wall	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Bone Surface	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Brain	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Breast	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
GI-Tract						
Oesophagus	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
St Wall	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
SI Wall	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
ULI Wall	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
LLI Wall	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Colon	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Kidneys	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Liver	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Muscle	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Ovaries	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Pancreas	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Red Marrow	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Respiratory Tract						
ET Airways	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Lungs	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Skin	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Spleen	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Testes	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Thymus	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Thyroid	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Uterus	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Remainder	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10
Effective Dose	1.3E-09	1.6E-09	9.7E-10	7.9E-10	5.7E-10	5.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.3. Sulphur

(102) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides and hydroxides of sulphur (S) to inhalation Class D. *ICRP Publication 30*, Part 2 (ICRP, 1979) assigned elemental sulphur to Class W and sulphates and sulphides to Class D or W, depending on the particular element. Gaseous forms of sulphur: sulphur dioxide (SO_2), carbonyl sulphide (COS), hydrogen sulphide (H_2S) and carbon disulphide (CS_2), were assumed to be completely and instantaneously translocated to the transfer compartment after entering the lungs.

Absorption Types

(a) *Gases and vapours*

(103) *Sulphur dioxide.* In two human studies (Speizer and Frank, 1966; Andersen *et al.*, 1974), about 85% of the inhaled SO_2 was deposited, all in the ET airways. In dogs, more than 95% of the inhaled gas was deposited in the ET airways during nose breathing and 50–90% during mouth breathing (Frank *et al.*, 1967, 1969). A further study with dogs, in which the trachea was perfused with SO_2, gave 90% deposition in the trachea (Balchum *et al.*, 1960). Studies exposing rabbits to different SO_2 concentrations gave 80% respiratory tract deposition at low concentrations (0.05 ppm), 98% at high concentrations (700 ppm) (Strandberg, 1964) and more than 90% upper airway deposition at concentrations between 100 and 300 ppm (Dalhamn and Strandberg, 1961). Absorption to blood of SO_2 deposited in the respiratory tract of dogs was consistent with assignment to Type F (Balchum *et al.*, 1960; Frank *et al.*, 1967). Sulphur dioxide is therefore assigned to Class SR-1 (85% deposition) with Type F clearance.

(104) *Carbon disulphide.* Studies have been performed with CS_2 in mice, rats, dogs and man (Bergman *et al.*, 1984; McKenna and DiStefano, 1977; McKee *et al.*, 1943; Teisinger and Souček, 1949). In all cases CS_2 was taken up by the respiratory tract and absorbed into the blood. However, there is no information on the fraction of inhaled vapour deposited, nor of the site of deposition, hence CS_2 is assigned to Class SR-1 with default deposition parameters. McKenna and DiStefano (1977), observed that CS_2 uptake into blood was characterized by a single exponential with half-life of 19.3 min, consistent with assignment to Type F.

(b) *Particulate aerosols*

(105) No detailed information is available on the rate of absorption of sulphur following respiratory tract deposition of particulate compounds. However, two cases of accidental exposure of humans, the first to elemental sulphur and the second to an unknown chemical composition formed by irradiating KCl targets, indicate high solubility in the lungs and therefore Type F behaviour (Maass *et al.*, 1963; Spate *et al.*, 1985).

(106) The respiratory tract clearance of barium sulphate ($BaSO_4$) has been studied, but it should be noted that only the barium was radiolabelled, and therefore inferences drawn here rest on the assumption that the behaviour of the barium also reflects that of the sulphur present. Results following inhalation by dogs (Cuddihy *et al.*, 1974) indicate either Type F or M behaviour for $BaSO_4$ with or without heat treatment. *In vitro* measurements showed heat-treated $BaSO_4$ to be consistent with assignment to Type M and untreated $BaSO_4$ with Type F. $^{133}BaSO_4$ has also been used as an effectively insoluble material to study the clearance and retention of particles deposited in the trachea in several species (Patrick and Stirling, 1977; Takahashi and Patrick, 1987; Patrick, 1989; Takahashi *et al.*, 1993). Most of these studies

were of short duration, but in one, measurements were made for 6 months, and indicate Type M behaviour (Takahashi and Patrick, 1987).

Dose coefficients

(107) Dose coefficients (given in Table 5.3.2) were derived for the gases and vapours given in Table 5.3.1a, for particulate aerosols, using the f_1 values given in Table 5.3.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.3.1a. Classification and absorption Types for gas and vapour compounds of sulphur

	Deposition		Absorption		
Chemical form/origin	Vapour Class	Fraction deposited (%)	Type	f_1	Biokinetic model[a]
Sulphur dioxide	SR-1	85	F	[b]	Inorganic
Carbon disulphide	SR-1	100	F	[b]	Organic
Unspecified	SR-1	100	F	[b]	Organic

[a] Biokinetic models for inorganic and organic sulphur from *ICRP Publication 67*, Tables 1.-1 and 1.-2, respectively.
[b] As for Type F in Table 5.3.1b.

Table 5.3.1b. Values of f_1 for inhaled particulate compounds of sulphur[a]

	f_1[b]	
Absorption Type	3 mo	1 y–adult
F	1	0.8
M[c]	0.2	0.1
S	0.02	0.01

[a] Following uptake into body fluids, the biokinetic data for inorganic sulphur are used (*ICRP Publication 67*, Table 1.-1).
[b] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[c] Default Type M is recommended for use in the absence of specific information.

Table 5.3.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for S-35 (T½ = 87.4 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Bladder Wall	5.3E-10	3.7E-10	2.2E-10	1.6E-10	1.2E-10	9.3E-11
Bone Surface	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Brain	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Breast	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
GI-Tract						
Oesophagus	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
St Wall	4.7E-10	3.0E-10	1.3E-10	7.9E-11	4.3E-11	3.6E-11
SI Wall	3.8E-10	2.8E-10	1.2E-10	7.4E-11	4.0E-11	3.3E-11
ULI Wall	7.4E-10	6.5E-10	2.8E-10	1.7E-10	8.6E-11	7.2E-11
LLI Wall	1.4E-09	1.4E-09	5.9E-10	3.5E-10	1.8E-10	1.5E-10
Colon	1.0E-09	9.6E-10	4.1E-10	2.5E-10	1.3E-10	1.1E-10
Kidneys	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Liver	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Muscle	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Ovaries	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Pancreas	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Red Marrow	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Respiratory Tract						
ET Airways	3.1E-09	2.1E-09	8.8E-10	5.8E-10	3.1E-10	3.0E-10
Lungs	4.1E-10	2.7E-10	1.3E-10	7.8E-11	4.8E-11	4.0E-11
Skin	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Spleen	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Testes	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Thymus	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Thyroid	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Uterus	3.7E-10	2.5E-10	1.1E-10	6.6E-11	3.7E-11	3.1E-11
Remainder	1.8E-09	1.2E-09	5.0E-10	3.2E-10	1.7E-10	1.7E-10
Effective Dose	5.5E-10	3.9E-10	1.8E-10	1.1E-10	6.0E-11	5.1E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.3.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for S-35 (T½ = 87.4 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Bladder Wall	1.5E-10	8.3E-11	5.3E-11	3.8E-11	2.9E-11	2.3E-11
Bone Surface	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Brain	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Breast	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
GI-Tract						
Oesophagus	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
St Wall	3.1E-10	1.7E-10	7.4E-11	4.3E-11	2.5E-11	2.1E-11
SI Wall	5.0E-10	3.4E-10	1.5E-10	8.8E-11	4.4E-11	3.7E-11
ULI Wall	2.6E-09	1.9E-09	7.8E-10	4.7E-10	2.3E-10	1.9E-10
LLI Wall	7.1E-09	5.1E-09	2.2E-09	1.3E-09	6.4E-10	5.3E-10
Colon	4.6E-09	3.3E-09	1.4E-09	8.3E-10	4.1E-10	3.4E-10
Kidneys	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Liver	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Muscle	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Ovaries	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Pancreas	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Red Marrow	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Respiratory Tract						
ET Airways	1.1E-08	8.1E-09	3.4E-09	2.3E-09	1.2E-09	1.2E-09
Lungs	4.4E-08	3.4E-08	2.1E-08	1.6E-08	1.5E-08	1.2E-08
Skin	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Spleen	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Testes	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Thymus	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Thyroid	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Uterus	1.0E-10	5.5E-11	2.6E-11	1.5E-11	9.1E-12	7.7E-12
Remainder	1.2E-10	6.3E-11	3.0E-11	1.8E-11	1.0E-11	8.9E-12
Effective Dose	5.9E-09	4.5E-09	2.8E-09	2.0E-09	1.8E-09	1.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.3.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for S-35 (T½ = 87.4 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Bladder Wall	1.0E-11	4.4E-12	2.7E-12	2.0E-12	1.4E-12	1.1E-12
Bone Surface	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Brain	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Breast	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
GI-Tract						
Oesophagus	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
St Wall	2.3E-10	1.3E-10	5.3E-11	3.0E-11	1.8E-11	1.4E-11
SI Wall	5.2E-10	3.4E-10	1.5E-10	8.8E-11	4.2E-11	3.5E-11
ULI Wall	3.2E-09	2.1E-09	8.8E-10	5.3E-10	2.6E-10	2.1E-10
LLI Wall	8.9E-09	5.8E-09	2.5E-09	1.5E-09	7.4E-10	6.1E-10
Colon	5.6E-09	3.7E-09	1.6E-09	9.5E-10	4.6E-10	3.8E-10
Kidneys	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Liver	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Muscle	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Ovaries	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Pancreas	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Red Marrow	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Respiratory Tract						
ET Airways	1.6E-08	1.2E-08	5.1E-09	3.4E-09	1.9E-09	1.8E-09
Lungs	5.8E-08	4.6E-08	2.9E-08	2.1E-08	1.9E-08	1.5E-08
Skin	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Spleen	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Testes	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Thymus	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Thyroid	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Uterus	7.1E-12	2.9E-12	1.3E-12	7.9E-13	4.4E-13	3.7E-13
Remainder	2.5E-11	1.4E-11	6.2E-12	4.0E-12	2.2E-12	2.0E-12
Effective Dose	7.7E-09	6.0E-09	3.6E-09	2.6E-09	2.3E-09	1.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.3.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for S-35 (T½ = 87.4 d).

Sulphur Dioxide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Bladder Wall	1.0E-09	7.5E-10	5.1E-10	3.7E-10	2.9E-10	2.2E-10
Bone Surface	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Brain	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Breast	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
GI-Tract						
Oesophagus	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
St Wall	8.0E-10	5.3E-10	2.7E-10	1.6E-10	9.5E-11	7.7E-11
SI Wall	7.4E-10	5.2E-10	2.6E-10	1.6E-10	9.2E-11	7.5E-11
ULI Wall	1.4E-09	1.1E-09	5.3E-10	3.2E-10	1.8E-10	1.5E-10
LLI Wall	2.8E-09	2.1E-09	1.0E-09	6.2E-10	3.5E-10	2.9E-10
Colon	2.0E-09	1.5E-09	7.5E-10	4.5E-10	2.6E-10	2.1E-10
Kidneys	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Liver	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Muscle	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Ovaries	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Pancreas	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Red Marrow	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Respiratory Tract						
ET Airways	1.9E-09	1.3E-09	6.6E-10	4.2E-10	2.7E-10	2.4E-10
Lungs	9.9E-10	7.1E-10	3.8E-10	2.5E-10	1.6E-10	1.4E-10
Skin	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Spleen	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Testes	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Thymus	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Thyroid	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Uterus	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	7.2E-11
Remainder	7.4E-10	5.0E-10	2.5E-10	1.5E-10	8.9E-11	1.6E-10
Effective Dose	9.4E-10	6.6E-10	3.4E-10	2.1E-10	1.3E-10	1.1E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.3.2(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for S-35 (T½ = 87.4 d).

Carbon Disulphide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Bladder Wall	6.9E-09	4.8E-09	2.5E-09	1.5E-09	9.2E-10	7.4E-10
Bone Surface	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Brain	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Breast	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
GI-Tract						
Oesophagus	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
St Wall	6.9E-09	4.7E-09	2.4E-09	1.4E-09	8.3E-10	6.8E-10
SI Wall	6.8E-09	4.7E-09	2.4E-09	1.4E-09	8.3E-10	6.7E-10
ULI Wall	7.1E-09	5.0E-09	2.5E-09	1.5E-09	8.8E-10	7.2E-10
LLI Wall	7.7E-09	5.6E-09	2.8E-09	1.7E-09	9.9E-10	8.0E-10
Colon	7.3E-09	5.3E-09	2.7E-09	1.6E-09	9.3E-10	7.5E-10
Kidneys	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Liver	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Muscle	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Ovaries	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Pancreas	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Red Marrow	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Respiratory Tract						
ET Airways	8.2E-09	5.6E-09	2.8E-09	1.7E-09	1.0E-09	8.7E-10
Lungs	7.1E-09	4.9E-09	2.5E-09	1.5E-09	9.1E-10	7.5E-10
Skin	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Spleen	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Testes	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Thymus	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Thyroid	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Uterus	6.8E-09	4.7E-09	2.3E-09	1.4E-09	8.2E-10	6.7E-10
Remainder	7.5E-09	5.1E-09	2.6E-09	1.6E-09	9.3E-10	7.7E-10
Effective Dose	6.9E-09	4.8E-09	2.4E-09	1.4E-09	8.6E-10	7.0E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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TGLD (Task Group on Lung Dynamics) (1966) Deposition and retention models for internal dosimetry of the human respiratory tract. *Health Phys.* **25**, 225–237.

5.4. Calcium

(108) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned calcium phosphate to inhalation Class D and the other compounds of calcium (Ca) listed to Class W. *ICRP Publication 30*, Part 2 (ICRP, 1980), assigned all compounds of calcium to Class W, referring only to the TGLD (1966).

Absorption Types

(109) Measurements of ^{45}Ca in the lungs of guinea-pigs following inhalation of $CaCl_2$, are consistent with assignment to Type F (Schiessle *et al.*, 1964).

Dose coefficients

(110) Dose coefficients (given in Tables 5.4.2 and 5.4.3) were derived using the f_1 values given in Table 5.4.1 and the biokinetic data given in Annexe A.

Table 5.4.1. Values of f_1 for inhaled particulate compounds of calcium

	f_1[a]					
Absorption Type	3 mo	1 y	5 y	10 y	15 y	Adult
F	0.6	0.4	0.4	0.4	0.4	0.3
M[b]	0.2	0.1	0.1	0.1	0.1	0.1
S	0.02	0.01	0.01	0.01	0.01	0.01

[a] f_1 values for the adult are taken from Table 2. Those for children are derived according to the procedure described in Paragraph 14.
[b] Default Type M is recommended for use in the absence of specific information.

Table 5.4.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ca-45 (T½ = 163 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.4	0.4	0.4	0.4	0.3
Adrenals	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Bladder Wall	3.0E-10	2.9E-10	1.7E-10	8.5E-11	3.7E-11	7.3E-11
Bone Surface	8.0E-08	4.3E-08	2.5E-08	1.8E-08	1.3E-08	5.5E-09
Brain	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Breast	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
GI-Tract						
Oesophagus	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
St Wall	4.2E-10	3.2E-10	1.4E-10	7.1E-11	3.2E-11	4.4E-11
SI Wall	4.1E-10	3.7E-10	1.7E-10	8.6E-11	3.6E-11	5.0E-11
ULI Wall	1.7E-09	1.7E-09	7.7E-10	3.9E-10	1.5E-10	2.3E-10
LLI Wall	4.3E-09	4.5E-09	2.0E-09	1.0E-09	4.0E-10	6.0E-10
Colon	2.8E-09	2.9E-09	1.3E-09	6.6E-10	2.6E-10	3.9E-10
Kidneys	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Liver	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Muscle	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Ovaries	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Pancreas	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Red Marrow	3.6E-08	1.7E-08	7.6E-09	6.2E-09	4.8E-09	2.8E-09
Respiratory Tract						
ET Airways	6.0E-09	4.1E-09	1.7E-09	1.1E-09	5.9E-10	6.0E-10
Lungs	3.1E-10	2.7E-10	1.3E-10	7.1E-11	4.0E-11	5.0E-11
Skin	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Spleen	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Testes	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Thymus	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Thyroid	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Uterus	2.7E-10	2.4E-10	1.1E-10	5.2E-11	2.1E-11	3.6E-11
Remainder	2.7E-10	2.4E-10	1.1E-10	5.3E-11	2.2E-11	3.6E-11
Effective Dose	5.7E-09	3.0E-09	1.4E-09	1.0E-09	7.6E-10	4.6E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ca parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.4.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ca-45 (T½ = 163 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Bladder Wall	1.1E-10	8.5E-11	5.0E-11	2.5E-11	1.2E-11	2.5E-11
Bone Surface	2.7E-08	1.2E-08	7.6E-09	5.6E-09	4.1E-09	1.9E-09
Brain	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Breast	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
GI-Tract						
Oesophagus	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
St Wall	4.3E-10	2.5E-10	1.1E-10	5.9E-11	3.3E-11	3.3E-11
SI Wall	7.2E-10	5.3E-10	2.3E-10	1.3E-10	6.3E-11	5.9E-11
ULI Wall	4.1E-09	3.1E-09	1.3E-09	7.7E-10	3.6E-10	3.3E-10
LLI Wall	1.2E-08	8.5E-09	3.7E-09	2.2E-09	1.0E-09	9.3E-10
Colon	7.3E-09	5.4E-09	2.3E-09	1.4E-09	6.5E-10	5.9E-10
Kidneys	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Liver	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Muscle	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Ovaries	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Pancreas	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Red Marrow	1.2E-08	4.8E-09	2.3E-09	1.9E-09	1.5E-09	9.3E-10
Respiratory Tract						
ET Airways	2.1E-08	1.5E-08	6.3E-09	4.2E-09	2.3E-09	2.2E-09
Lungs	7.8E-08	6.2E-08	3.9E-08	2.8E-08	2.6E-08	2.1E-08
Skin	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Spleen	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Testes	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Thymus	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Thyroid	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Uterus	9.3E-11	6.9E-11	3.3E-11	1.5E-11	6.8E-12	1.2E-11
Remainder	1.1E-10	8.3E-11	4.0E-11	2.0E-11	9.1E-12	1.4E-11
Effective Dose	1.2E-08	8.8E-09	5.3E-09	3.9E-09	3.5E-09	2.7E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ca parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.4.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ca-45 (T½ = 163 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Bladder Wall	7.3E-12	4.6E-12	2.6E-12	1.3E-12	6.1E-13	1.2E-12
Bone Surface	1.8E-09	6.7E-10	4.0E-10	3.0E-10	2.1E-10	9.4E-11
Brain	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Breast	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
GI-Tract						
Oesophagus	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
St Wall	3.7E-10	2.1E-10	8.6E-11	4.9E-11	2.9E-11	2.4E-11
SI Wall	8.4E-10	5.5E-10	2.4E-10	1.4E-10	7.0E-11	5.8E-11
ULI Wall	5.1E-09	3.4E-09	1.4E-09	8.7E-10	4.2E-10	3.5E-10
LLI Wall	1.5E-08	9.5E-09	4.1E-09	2.5E-09	1.2E-09	1.0E-09
Colon	9.2E-09	6.0E-09	2.6E-09	1.6E-09	7.7E-10	6.4E-10
Kidneys	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Liver	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Muscle	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Ovaries	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Pancreas	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Red Marrow	8.2E-10	2.6E-10	1.2E-10	9.9E-11	7.7E-11	4.7E-11
Respiratory Tract						
ET Airways	3.4E-08	2.5E-08	1.1E-08	7.4E-09	4.1E-09	4.0E-09
Lungs	1.1E-07	9.1E-08	5.7E-08	4.1E-08	3.7E-08	3.0E-08
Skin	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Spleen	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Testes	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Thymus	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Thyroid	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Uterus	6.3E-12	3.7E-12	1.8E-12	8.2E-13	3.5E-13	6.0E-13
Remainder	3.9E-11	2.4E-11	1.1E-11	7.0E-12	3.8E-12	3.7E-12
Effective Dose	1.5E-08	1.2E-08	7.2E-09	5.1E-09	4.6E-09	3.7E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ca parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.4.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ca-47 (T½ = 4.53 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.4	0.4	0.4	0.4	0.3
Adrenals	1.6E-09	1.2E-09	5.7E-10	3.7E-10	2.5E-10	2.1E-10
Bladder Wall	1.2E-09	1.1E-09	6.3E-10	3.5E-10	1.8E-10	2.8E-10
Bone Surface	2.2E-08	1.2E-08	6.7E-09	4.7E-09	3.1E-09	1.5E-09
Brain	1.3E-09	9.3E-10	4.9E-10	3.1E-10	2.0E-10	1.6E-10
Breast	1.0E-09	7.8E-10	3.8E-10	2.2E-10	1.1E-10	1.3E-10
GI-Tract						
Oesophagus	1.4E-09	1.1E-09	5.0E-10	2.9E-10	1.6E-10	1.6E-10
St Wall	1.8E-09	1.3E-09	6.2E-10	3.6E-10	2.0E-10	2.1E-10
SI Wall	2.1E-09	1.9E-09	9.0E-10	5.6E-10	3.0E-10	3.2E-10
ULI Wall	6.1E-09	6.4E-09	2.9E-09	1.6E-09	7.2E-10	9.1E-10
LLI Wall	1.4E-08	1.5E-08	6.7E-09	3.7E-09	1.6E-09	2.1E-09
Colon	9.6E-09	1.0E-08	4.5E-09	2.5E-09	1.1E-09	1.4E-09
Kidneys	1.4E-09	1.0E-09	5.1E-10	3.1E-10	1.9E-10	1.9E-10
Liver	1.2E-09	9.3E-10	4.6E-10	2.6E-10	1.5E-10	1.6E-10
Muscle	1.4E-09	1.0E-09	5.0E-10	3.1E-10	1.8E-10	1.7E-10
Ovaries	1.6E-09	1.4E-09	6.9E-10	4.4E-10	2.6E-10	2.7E-10
Pancreas	1.3E-09	1.0E-09	4.9E-10	3.0E-10	1.8E-10	1.9E-10
Red Marrow	1.4E-08	5.7E-09	2.6E-09	2.0E-09	1.4E-09	9.4E-10
Respiratory Tract						
ET Airways	3.4E-08	2.9E-08	1.5E-08	8.8E-09	5.1E-09	4.1E-09
Lungs	1.4E-09	1.0E-09	5.1E-10	3.1E-10	2.0E-10	1.9E-10
Skin	1.1E-09	8.3E-10	4.0E-10	2.3E-10	1.3E-10	1.3E-10
Spleen	1.2E-09	9.5E-10	4.6E-10	2.7E-10	1.5E-10	1.6E-10
Testes	9.8E-10	8.2E-10	4.1E-10	2.3E-10	1.2E-10	1.4E-10
Thymus	1.4E-09	1.1E-09	5.0E-10	2.9E-10	1.6E-10	1.6E-10
Thyroid	1.0E-09	8.6E-10	4.5E-10	2.7E-10	1.6E-10	1.6E-10
Uterus	1.3E-09	1.1E-09	5.5E-10	3.3E-10	1.9E-10	2.1E-10
Remainder	1.8E-08	1.5E-08	7.7E-09	4.5E-09	2.6E-09	2.2E-09
Effective Dose	4.9E-09	3.6E-09	1.7E-09	1.1E-09	6.1E-10	5.5E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ca parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.4.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ca-47 (T½ = 4.53 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.1E-09	7.9E-10	4.4E-10	2.7E-10	1.9E-10	1.5E-10
Bladder Wall	7.4E-10	5.7E-10	2.8E-10	1.8E-10	9.0E-11	1.0E-10
Bone Surface	6.0E-09	2.5E-09	1.4E-09	9.8E-10	6.4E-10	3.5E-10
Brain	3.9E-10	2.3E-10	1.3E-10	8.5E-11	5.5E-11	4.8E-11
Breast	8.4E-10	6.3E-10	3.9E-10	2.6E-10	1.5E-10	1.4E-10
GI-Tract						
Oesophagus	1.2E-09	8.7E-10	4.6E-10	3.0E-10	2.0E-10	1.8E-10
St Wall	2.4E-09	1.5E-09	6.9E-10	4.2E-10	2.6E-10	2.1E-10
SI Wall	4.0E-09	3.0E-09	1.4E-09	8.6E-10	4.3E-10	3.7E-10
ULI Wall	1.7E-08	1.3E-08	5.5E-09	3.4E-09	1.6E-09	1.4E-09
LLI Wall	4.4E-08	3.2E-08	1.4E-08	8.3E-09	3.9E-09	3.4E-09
Colon	2.9E-08	2.1E-08	9.0E-09	5.5E-09	2.6E-09	2.2E-09
Kidneys	7.7E-10	5.4E-10	2.7E-10	1.7E-10	1.1E-10	9.4E-11
Liver	9.1E-10	6.8E-10	3.7E-10	2.3E-10	1.6E-10	1.4E-10
Muscle	8.1E-10	5.7E-10	2.9E-10	1.8E-10	1.2E-10	1.0E-10
Ovaries	1.6E-09	1.3E-09	6.2E-10	4.2E-10	2.5E-10	2.1E-10
Pancreas	9.9E-10	7.1E-10	3.8E-10	2.4E-10	1.6E-10	1.3E-10
Red Marrow	3.7E-09	1.3E-09	6.3E-10	4.8E-10	3.5E-10	2.6E-10
Respiratory Tract						
ET Airways	3.8E-08	3.2E-08	1.6E-08	9.6E-09	5.5E-09	4.5E-09
Lungs	4.7E-08	3.6E-08	2.2E-08	1.7E-08	1.6E-08	1.2E-08
Skin	5.0E-10	3.3E-10	1.6E-10	1.0E-10	6.2E-11	5.9E-11
Spleen	8.9E-10	6.5E-10	3.4E-10	2.1E-10	1.4E-10	1.2E-10
Testes	4.4E-10	3.0E-10	1.5E-10	8.5E-11	4.4E-11	4.1E-11
Thymus	1.2E-09	8.7E-10	4.6E-10	3.0E-10	2.0E-10	1.8E-10
Thyroid	5.8E-10	4.2E-10	2.3E-10	1.4E-10	9.3E-11	8.6E-11
Uterus	9.9E-10	7.7E-10	3.6E-10	2.4E-10	1.3E-10	1.1E-10
Remainder	8.1E-10	5.6E-10	2.9E-10	1.9E-10	1.2E-10	1.1E-10
Effective Dose	1.0E-08	7.7E-09	4.2E-09	2.9E-09	2.4E-09	1.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ca parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.4.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ca-47 (T½ = 4.53 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	8.7E-10	6.7E-10	4.0E-10	2.4E-10	1.7E-10	1.4E-10
Bladder Wall	6.4E-10	4.8E-10	2.1E-10	1.5E-10	7.4E-11	6.3E-11
Bone Surface	9.3E-10	5.2E-10	2.7E-10	1.7E-10	1.2E-10	9.0E-11
Brain	1.2E-10	8.4E-11	5.0E-11	3.8E-11	2.6E-11	2.4E-11
Breast	7.1E-10	5.7E-10	3.7E-10	2.6E-10	1.5E-10	1.4E-10
GI-Tract						
Oesophagus	1.0E-09	7.9E-10	4.3E-10	2.9E-10	2.0E-10	1.7E-10
St Wall	2.4E-09	1.5E-09	6.8E-10	4.2E-10	2.7E-10	2.1E-10
SI Wall	4.8E-09	3.3E-09	1.5E-09	9.4E-10	4.7E-10	3.9E-10
ULI Wall	2.2E-08	1.4E-08	6.2E-09	3.8E-09	1.8E-09	1.5E-09
LLI Wall	5.5E-08	3.6E-08	1.5E-08	9.4E-09	4.5E-09	3.7E-09
Colon	3.6E-08	2.4E-08	1.0E-08	6.2E-09	3.0E-09	2.5E-09
Kidneys	5.5E-10	4.2E-10	2.2E-10	1.4E-10	8.8E-11	7.3E-11
Liver	7.8E-10	6.1E-10	3.4E-10	2.2E-10	1.6E-10	1.3E-10
Muscle	6.1E-10	4.6E-10	2.4E-10	1.6E-10	1.0E-10	8.6E-11
Ovaries	1.7E-09	1.3E-09	6.2E-10	4.3E-10	2.5E-10	2.0E-10
Pancreas	8.3E-10	6.3E-10	3.5E-10	2.2E-10	1.5E-10	1.1E-10
Red Marrow	6.4E-10	3.8E-10	2.3E-10	1.8E-10	1.3E-10	1.1E-10
Respiratory Tract						
ET Airways	3.9E-08	3.2E-08	1.6E-08	9.7E-09	5.6E-09	4.6E-09
Lungs	5.3E-08	4.1E-08	2.6E-08	1.9E-08	1.8E-08	1.4E-08
Skin	3.0E-10	2.2E-10	1.1E-10	7.5E-11	4.8E-11	4.3E-11
Spleen	7.3E-10	5.7E-10	3.1E-10	2.0E-10	1.4E-10	1.1E-10
Testes	2.8E-10	2.0E-10	9.7E-11	5.6E-11	2.8E-11	2.1E-11
Thymus	1.0E-09	7.9E-10	4.3E-10	2.9E-10	2.0E-10	1.7E-10
Thyroid	4.0E-10	3.2E-10	1.8E-10	1.1E-10	7.6E-11	6.7E-11
Uterus	9.3E-10	7.2E-10	3.3E-10	2.2E-10	1.2E-10	9.1E-11
Remainder	6.2E-10	4.6E-10	2.4E-10	1.6E-10	1.1E-10	9.1E-11
Effective Dose	1.2E-08	8.5E-09	4.6E-09	3.3E-09	2.6E-09	2.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ca parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

References

ICRP (1980) *Limits for Intakes of Radionuclides by Workers*, ICRP Publication 30, Part 2. *Annals of the ICRP* 4(3/4). Pergamon Press, Oxford.

Schiessle, W., Schmidtke, I., Philipp, K., Schroff, E. (1964). Inhalationsuntersuchungen mit radioactivem Calcium (Ca^{45}) beim Meerschweinchen. *Z. Aerosolforsch.* **11**, 373–396.

TGLD (Task Group on Lung Dynamics) (1966) Deposition and retention models for internal dosimetry of the human respiratory tract. *Health Phys.* **12**, 173–207.

5.5. Iron

(111) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides, halides and nitrates of iron (Fe) to inhalation Class W and all other compounds of the element to Class D. *ICRP Publication 30*, Part 2 (ICRP, 1980), broadly endorsed this classification: oxides, hydroxides and halides of iron were assigned to Class W and all other commonly occurring compounds to Class D. Experiments on rats and dogs were cited, which indicated that both $FeCl_3$ and Fe_2O_3 should be assigned to Class W (Fisher *et al.*, 1973; Morrow *et al.*, 1964, 1968). It was noted that in man, experiments with ^{51}Cr-labelled submicron particles of ferric oxide indicate a clearance half-time for the ^{51}Cr of 270 d (Ramsden and Waite, 1972). This long half-time was attributed by ICRP in *ICRP Publication 30* to ^{51}Cr leached from the ferric oxide, since other studies had shown that ferric oxide is cleared from the lungs with a biological half-life of 70 d.

Absorption Types

(112) Studies of $^{59}FeCl_3$ and ^{51}Cr-labelled $Fe(OH)_n$ inhaled by rats and dogs indicate Type M behaviour (Morrow *et al.*, 1968).

(113) Radiolabelled ferric oxide, Fe_2O_3 has been used as a test material in many studies of the respiratory tract deposition and clearance of inhaled particles, including several human studies of lung retention of duration 2–8 months (*ICRP Publication 66*, Annexe E, Table E.19) (ICRP, 1994). Over this period, retention could be represented adequately by a single exponential function, with a half-time between about 60 and 600 d, but in most cases less than 200 d, indicating Type M behaviour. The retention followed was that of the label, which varied, in some cases being ^{51}Cr (Albert *et al.*, 1967; Morrow *et al.*, 1967a,b; Waite and Ramsden, 1971a) and in one ^{237}Pu (Waite and Ramsden, 1971b). As observed in *ICRP Publication 30* (ICRP, 1980) this raises questions about the contributions to retention made by the iron oxide particle matrix itself, and by the chemical form of the label. In three studies, however, the particles were labelled with ^{59}Fe (Albert *et al.*, 1967; Le Bouffant *et al.*, 1972; Le Bouffant and Hénin, 1974). Results following inhalation of $^{59}Fe_2O_3$ by rats and dogs also indicate Type M behaviour (Gibb and Morrow, 1962; Morrow *et al.*, 1968; Muhle and Bellman, 1986).

(114) Measurements of lung retention of magnetite (Fe_3O_4) made in groups of volunteers for up to about a year after inhalation, using magneto-pneumography (MPG) (Cohen *et al.*, 1979; Freedman *et al.*, 1988; Möller, 1991; Stahlhofen and Möller, 1991), are consistent with assignment to Type M.

(115) Kalliomäki *et al.* (1978, 1983, 1985) used MPG to measure the lung contents of magnetic dusts in groups of welders with similar exposures. A single exponential model was applied to lung retention. Repeated measurements over a 6 y period on welders who worked with mild steel gave a clearance constant of 0.2 y^{-1} ($t_{1/2}$ ~3.5 y). Results of a cross-sectional study on stainless steel welders gave a $t_{1/2}$ of 8.5 y. Both indicate Type S behaviour for at least some of the material.

(116) Kalliomäki *et al.* (1986a, 1986b, 1987) followed lung retention in rats after intratracheal instillation of neutron-activated fumes from welding of mild steel or stainless steel. Results indicate Type M or S behaviour for the ^{59}Fe present, but were of insufficient duration to distinguish between the two. The stainless steel fumes were, however, retained in the lung longer than the mild steel fumes.

(117) Measurements following instillation into rats of corrosion products from a water-cooled reactor indicate Type M behaviour for the ^{59}Fe present (Collier *et al.*, 1994).

(118) Measurements following inhalation of neutron-activated fly ash by hamsters indicate Type M behaviour for the ^{59}Fe present (Wehner and Wilkerson, 1981). Measurements following inhalation of neutron-activated volcanic ash by rats indicate Type M or S behaviour for the ^{59}Fe present (Wehner *et al.*, 1984).

Dose coefficients

(119) Dose coefficients (given in Tables 5.5.2 and 5.5.3) were derived using the f_1 values given in Table 5.5.1 and the biokinetic data given in *ICRP Publication 69* (ICRP, 1995).

Table 5.5.1. Recommended f_1 values for inhaled compounds of iron

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.2	0.1
M[b]	0.2	0.1
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.5.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Fe-55 (T½ = 2.70 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.2	0.2	0.2	0.2	0.1
Adrenals	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Bladder Wall	1.5E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Bone Surface	1.2E-08	9.0E-09	6.0E-09	3.8E-09	2.3E-09	1.5E-09
Brain	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Breast	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
GI-Tract						
Oesophagus	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
St Wall	1.5E-09	1.1E-09	6.1E-10	3.7E-10	2.5E-10	2.1E-10
SI Wall	1.5E-09	1.1E-09	6.1E-10	3.7E-10	2.5E-10	2.2E-10
ULI Wall	1.6E-09	1.2E-09	6.5E-10	4.0E-10	2.6E-10	2.3E-10
LLI Wall	1.9E-09	1.5E-09	7.5E-10	4.6E-10	2.9E-10	2.5E-10
Colon	1.7E-09	1.3E-09	7.0E-10	4.2E-10	2.7E-10	2.4E-10
Kidneys	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Liver	9.0E-09	6.3E-09	4.1E-09	2.5E-09	1.8E-09	1.8E-09
Muscle	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Ovaries	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Pancreas	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Red Marrow	1.5E-08	1.2E-08	8.8E-09	5.6E-09	3.7E-09	2.8E-09
Respiratory Tract						
ET Airways	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Lungs	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Skin	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Spleen	2.8E-08	2.1E-08	1.5E-08	1.1E-08	7.4E-09	6.3E-09
Testes	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Thymus	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Thyroid	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Uterus	1.4E-09	1.1E-09	6.0E-10	3.7E-10	2.5E-10	2.1E-10
Remainder	1.5E-08	1.1E-08	8.0E-09	5.4E-09	3.8E-09	3.3E-09
Effective Dose	4.2E-09	3.2E-09	2.2E-09	1.4E-09	9.4E-10	7.7E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.5.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Fe-55 (T½ = 2.70 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Bladder Wall	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Bone Surface	4.6E-09	3.3E-09	2.3E-09	1.5E-09	9.5E-10	6.8E-10
Brain	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Breast	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
GI-Tract						
Oesophagus	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
St Wall	5.8E-10	4.2E-10	2.4E-10	1.5E-10	1.0E-10	9.7E-11
SI Wall	6.1E-10	4.4E-10	2.5E-10	1.5E-10	1.1E-10	9.9E-11
ULI Wall	8.8E-10	6.4E-10	3.4E-10	2.0E-10	1.3E-10	1.2E-10
LLI Wall	1.5E-09	1.1E-09	5.2E-10	3.1E-10	1.9E-10	1.7E-10
Colon	1.1E-09	8.3E-10	4.2E-10	2.5E-10	1.5E-10	1.4E-10
Kidneys	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Liver	3.4E-09	2.3E-09	1.6E-09	9.6E-10	7.6E-10	7.9E-10
Muscle	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Ovaries	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Pancreas	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Red Marrow	5.6E-09	4.3E-09	3.4E-09	2.2E-09	1.5E-09	1.2E-09
Respiratory Tract						
ET Airways	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Lungs	2.7E-09	2.1E-09	1.2E-09	6.8E-10	4.6E-10	4.0E-10
Skin	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Spleen	1.1E-08	7.9E-09	6.0E-09	4.1E-09	3.1E-09	2.8E-09
Testes	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Thymus	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Thyroid	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Uterus	5.6E-10	4.0E-10	2.4E-10	1.4E-10	1.0E-10	9.5E-11
Remainder	5.6E-09	4.1E-09	3.1E-09	2.1E-09	1.6E-09	1.4E-09
Effective Dose	1.9E-09	1.4E-09	9.9E-10	6.2E-10	4.4E-10	3.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.5.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Fe-55 (T½ = 2.70 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Bladder Wall	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.6E-12	7.2E-12
Bone Surface	3.6E-10	2.3E-10	1.6E-10	1.0E-10	6.6E-11	5.1E-11
Brain	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Breast	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
GI-Tract						
Oesophagus	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
St Wall	7.2E-11	4.4E-11	2.4E-11	1.4E-11	1.0E-11	9.2E-12
SI Wall	1.1E-10	7.2E-11	3.6E-11	2.2E-11	1.3E-11	1.2E-11
ULI Wall	4.5E-10	3.0E-10	1.4E-10	8.2E-11	4.4E-11	3.7E-11
LLI Wall	1.2E-09	8.1E-10	3.6E-10	2.1E-10	1.1E-10	9.5E-11
Colon	7.8E-10	5.2E-10	2.3E-10	1.4E-10	7.3E-11	6.2E-11
Kidneys	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Liver	2.6E-10	1.6E-10	1.1E-10	6.9E-11	5.7E-11	6.0E-11
Muscle	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Ovaries	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Pancreas	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Red Marrow	4.5E-10	3.1E-10	2.4E-10	1.6E-10	1.1E-10	9.4E-11
Respiratory Tract						
ET Airways	4.5E-11	3.0E-11	1.8E-11	1.1E-11	7.9E-12	7.6E-12
Lungs	6.7E-09	6.0E-09	3.5E-09	2.1E-09	1.5E-09	1.3E-09
Skin	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Spleen	8.4E-10	5.7E-10	4.3E-10	2.9E-10	2.3E-10	2.1E-10
Testes	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Thymus	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Thyroid	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Uterus	4.3E-11	2.8E-11	1.7E-11	1.0E-11	7.5E-12	7.2E-12
Remainder	4.8E-11	3.1E-11	1.9E-11	1.2E-11	8.8E-12	8.5E-12
Effective Dose	1.0E-09	8.5E-10	5.0E-10	2.9E-10	2.0E-10	1.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.5.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Fe-59 (T½ = 44.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.2	0.2	0.2	0.2	0.1
Adrenals	1.7E-08	1.1E-08	6.3E-09	4.4E-09	2.8E-09	2.5E-09
Bladder Wall	1.2E-08	7.8E-09	4.2E-09	2.4E-09	1.5E-09	1.5E-09
Bone Surface	4.1E-08	2.3E-08	1.0E-08	6.1E-09	3.6E-09	2.5E-09
Brain	1.1E-08	7.8E-09	3.6E-09	2.3E-09	1.4E-09	1.2E-09
Breast	1.0E-08	6.9E-09	3.5E-09	2.2E-09	1.5E-09	1.2E-09
GI-Tract						
Oesophagus	1.3E-08	8.7E-09	4.2E-09	2.8E-09	1.8E-09	1.5E-09
St Wall	1.5E-08	9.4E-09	5.2E-09	3.1E-09	2.1E-09	1.7E-09
SI Wall	1.5E-08	1.1E-08	5.5E-09	3.7E-09	2.3E-09	1.9E-09
ULI Wall	1.7E-08	1.2E-08	6.4E-09	4.0E-09	2.4E-09	2.1E-09
LLI Wall	1.8E-08	1.4E-08	7.1E-09	4.5E-09	2.6E-09	2.4E-09
Colon	1.7E-08	1.3E-08	6.7E-09	4.2E-09	2.5E-09	2.2E-09
Kidneys	1.6E-08	1.0E-08	5.8E-09	3.8E-09	2.5E-09	2.1E-09
Liver	4.3E-08	2.4E-08	1.8E-08	1.2E-08	7.6E-09	7.3E-09
Muscle	1.2E-08	8.4E-09	4.1E-09	2.7E-09	1.7E-09	1.5E-09
Ovaries	1.4E-08	1.0E-08	5.1E-09	3.4E-09	2.2E-09	1.8E-09
Pancreas	1.9E-08	1.2E-08	6.8E-09	4.4E-09	2.8E-09	2.4E-09
Red Marrow	4.2E-08	2.4E-08	1.3E-08	7.6E-09	4.6E-09	3.4E-09
Respiratory Tract						
ET Airways	4.9E-08	4.1E-08	2.1E-08	1.2E-08	7.4E-09	5.9E-09
Lungs	1.4E-08	9.0E-09	4.6E-09	3.1E-09	2.1E-09	1.7E-09
Skin	9.9E-09	6.6E-09	3.1E-09	1.9E-09	1.3E-09	1.1E-09
Spleen	7.2E-08	3.6E-08	1.9E-08	1.1E-08	6.2E-09	4.6E-09
Testes	1.1E-08	7.4E-09	3.6E-09	2.3E-09	1.5E-09	1.2E-09
Thymus	1.3E-08	8.7E-09	4.2E-09	2.8E-09	1.8E-09	1.5E-09
Thyroid	1.3E-08	8.9E-09	4.2E-09	2.7E-09	1.7E-09	1.4E-09
Uterus	1.4E-08	9.6E-09	4.9E-09	3.3E-09	2.1E-09	1.7E-09
Remainder	4.2E-08	2.5E-08	1.3E-08	2.8E-09	1.8E-09	1.5E-09
Effective Dose	2.1E-08	1.3E-08	7.1E-09	4.2E-09	2.6E-09	2.2E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.5.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Fe-59 ($T½$ = 44.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	8.7E-09	6.0E-09	3.6E-09	2.2E-09	1.6E-09	1.4E-09
Bladder Wall	4.3E-09	2.7E-09	1.4E-09	8.3E-10	5.0E-10	4.8E-10
Bone Surface	1.4E-08	7.3E-09	3.4E-09	2.0E-09	1.3E-09	9.8E-10
Brain	3.7E-09	2.3E-09	1.1E-09	7.1E-10	4.5E-10	3.8E-10
Breast	6.3E-09	4.5E-09	2.8E-09	1.9E-09	1.2E-09	1.1E-09
GI-Tract						
Oesophagus	7.0E-09	5.1E-09	3.0E-09	2.0E-09	1.5E-09	1.3E-09
St Wall	7.0E-09	4.5E-09	2.5E-09	1.5E-09	1.1E-09	9.2E-10
SI Wall	7.4E-09	4.9E-09	2.5E-09	1.6E-09	9.8E-10	8.3E-10
ULI Wall	1.3E-08	8.9E-09	4.3E-09	2.7E-09	1.5E-09	1.3E-09
LLI Wall	2.4E-08	1.7E-08	7.7E-09	4.8E-09	2.6E-09	2.2E-09
Colon	1.8E-08	1.2E-08	5.8E-09	3.6E-09	2.0E-09	1.7E-09
Kidneys	6.3E-09	4.1E-09	2.3E-09	1.5E-09	9.7E-10	8.5E-10
Liver	1.6E-08	8.7E-09	6.1E-09	3.9E-09	2.7E-09	2.6E-09
Muscle	5.4E-09	3.6E-09	1.9E-09	1.2E-09	8.5E-10	7.2E-10
Ovaries	6.3E-09	4.2E-09	2.1E-09	1.4E-09	9.0E-10	7.4E-10
Pancreas	8.5E-09	5.6E-09	3.2E-09	2.0E-09	1.4E-09	1.1E-09
Red Marrow	1.4E-08	7.3E-09	4.1E-09	2.5E-09	1.6E-09	1.3E-09
Respiratory Tract						
ET Airways	5.2E-08	4.3E-08	2.2E-08	1.3E-08	7.7E-09	6.3E-09
Lungs	8.6E-08	6.7E-08	4.2E-08	3.1E-08	2.9E-08	2.3E-08
Skin	3.8E-09	2.4E-09	1.2E-09	7.8E-10	5.2E-10	4.6E-10
Spleen	2.4E-08	1.2E-08	6.3E-09	3.6E-09	2.3E-09	1.8E-09
Testes	3.6E-09	2.2E-09	1.1E-09	6.8E-10	4.4E-10	3.7E-10
Thymus	7.0E-09	5.1E-09	3.0E-09	2.0E-09	1.5E-09	1.3E-09
Thyroid	5.5E-09	3.7E-09	1.9E-09	1.2E-09	7.9E-10	6.7E-10
Uterus	5.3E-09	3.5E-09	1.7E-09	1.1E-09	7.1E-10	5.9E-10
Remainder	5.3E-09	3.4E-09	1.8E-09	1.2E-09	8.4E-10	7.2E-10
Effective Dose	1.8E-08	1.3E-08	7.9E-09	5.5E-09	4.6E-09	3.7E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.5.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Fe-59 (T½ = 44.5 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.4E-09	4.4E-09	2.8E-09	1.6E-09	1.2E-09	9.8E-10
Bladder Wall	1.4E-09	9.9E-10	4.6E-10	3.0E-10	1.6E-10	1.3E-10
Bone Surface	3.3E-09	2.3E-09	1.2E-09	7.3E-10	5.2E-10	4.4E-10
Brain	6.6E-10	4.6E-10	2.6E-10	1.8E-10	1.2E-10	1.1E-10
Breast	4.5E-09	3.9E-09	2.7E-09	1.9E-09	1.1E-09	1.1E-09
GI-Tract						
Oesophagus	4.7E-09	4.0E-09	2.6E-09	1.8E-09	1.4E-09	1.2E-09
St Wall	3.9E-09	3.0E-09	1.7E-09	1.0E-09	8.5E-10	6.4E-10
SI Wall	4.3E-09	3.1E-09	1.5E-09	9.6E-10	5.5E-10	4.5E-10
ULI Wall	1.1E-08	7.8E-09	3.6E-09	2.3E-09	1.2E-09	9.9E-10
LLI Wall	2.6E-08	1.8E-08	7.8E-09	4.9E-09	2.5E-09	2.1E-09
Colon	1.8E-08	1.2E-08	5.4E-09	3.4E-09	1.8E-09	1.5E-09
Kidneys	2.7E-09	2.2E-09	1.1E-09	7.0E-10	4.9E-10	4.1E-10
Liver	4.8E-09	3.7E-09	2.2E-09	1.4E-09	1.1E-09	9.3E-10
Muscle	2.6E-09	2.1E-09	1.2E-09	7.5E-10	5.7E-10	4.7E-10
Ovaries	3.1E-09	2.3E-09	1.2E-09	7.5E-10	4.5E-10	3.5E-10
Pancreas	4.5E-09	3.5E-09	2.1E-09	1.3E-09	1.0E-09	7.3E-10
Red Marrow	2.6E-09	1.9E-09	1.2E-09	8.4E-10	6.6E-10	6.1E-10
Respiratory Tract						
ET Airways	5.3E-08	4.5E-08	2.3E-08	1.4E-08	7.9E-09	6.5E-09
Lungs	1.1E-07	8.4E-08	5.3E-08	3.9E-08	3.6E-08	2.9E-08
Skin	1.4E-09	1.1E-09	6.2E-10	4.2E-10	2.8E-10	2.6E-10
Spleen	5.2E-09	3.7E-09	2.1E-09	1.3E-09	9.7E-10	7.8E-10
Testes	7.4E-10	4.9E-10	2.3E-10	1.4E-10	7.4E-11	5.4E-11
Thymus	4.7E-09	4.0E-09	2.6E-09	1.8E-09	1.4E-09	1.2E-09
Thyroid	2.6E-09	2.2E-09	1.2E-09	7.5E-10	5.1E-10	4.4E-10
Uterus	2.0E-09	1.5E-09	6.9E-10	4.3E-10	2.4E-10	1.9E-10
Remainder	2.3E-09	1.8E-09	1.1E-09	7.1E-10	5.5E-10	4.5E-10
Effective Dose	1.7E-08	1.3E-08	8.1E-09	5.8E-09	5.1E-09	4.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.6. Cobalt

(120) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides, halides and nitrates of cobalt (Co) to inhalation Class W and all other compounds of the element to Class D. *ICRP Publication 30*, Part 1 (ICRP, 1979) cited experiments in which cobalt chloride was administered to mice (TGLD, 1966; Willard, 1963) and cobalt oxide to dogs (Barnes *et al.*, 1976), which supported this classification. Noting, however, that experience in man (Newton and Rundo, 1971) indicated that insoluble compounds of cobalt may be more tenaciously retained, ICRP assigned oxides, hydroxides, halides and nitrates of cobalt to Class Y and all other compounds to Class W.

Absorption Types

(121) Studies in several animal species (Kreyling *et al.*, 1986; Menzel *et al.*, 1989; Patrick *et al.*, 1994) have shown that when cobalt is deposited in the lungs in a soluble form as chloride or nitrate, most of the cobalt is rapidly absorbed, but a small fraction, up to about 5%, is absorbed over several months. Overall, the absorption is consistent with assignment to Type F.

(122) Clearance studies of cobalt in the rat after inhalation of neutron-activated fly ash (Griffis *et al.*, 1981) or volcanic ash (Wehner *et al.*, 1984) indicated leaching of cobalt out of the particle matrix. As a result, the absorption of cobalt from these mineral dusts is consistent with assignment to Type M.

(123) Although numerous studies have been carried out on the toxicity of inhaled cobalt-containing alloys, no data are available from them on the clearance kinetics of cobalt. The data obtained from diamond polishers (Van den Oever *et al.*, 1990) or after exposure of rats (Brune and Beltesbrekke, 1980), however, suggest long-term retention in the lungs indicative of Type M or S behaviour.

(124) Detailed studies have been conducted of the lung clearance kinetics of various physical forms of cobaltosic oxide (Co_3O_4) (Kreyling *et al.*, 1986, 1988). These included two direct intercomparisons of clearance in different mammalian species, one of which involved human volunteers, baboon, dog, guinea-pig, rat, hamster and mouse (Bailey *et al.*, 1989), and the other baboon, dog and rat (Kreyling *et al.*, 1991). Lung retention was longer in humans and baboons than in the other species. Absorption from the human lung was consistent with assignment to Type M, since in that study the test material was designed by means of its physical and chemical parameters to be moderately soluble. When the test material was selected to be less soluble, absorption in baboons and dogs was consistent with assignment to Type S (Kreyling *et al.*, 1988, 1991). Human retention studies after accidental inhalation of radioactive cobalt oxide aerosols (Gupton and Brown, 1972; Hedge *et al.*, 1979; Ramsden, 1976; Beleznay and Osvay, 1994) show very long-term lung retention, indicative of Type S behaviour.

(125) It has been demonstrated that when cobalt is incorporated into a matrix of fused aluminosilicate or polystyrene, only a small fraction may be absorbed rapidly. The rest is retained within the particles and is absorbed slowly, at a rate of the order of 0.0005 d^{-1} for the former and 0.00005 d^{-1} for the latter (Kreyling *et al.*, 1988, 1992) consistent with assignment to Type S.

Dose coefficients

(126) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the

absence of specific information (see Paragraph 58). Dose coefficients (in Tables 5.6.2–4) were derived using the f_1 values given in Table 5.6.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.6.1. Values of f_1 for inhaled particulate compounds of cobalt

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.2	0.1
M[b]	0.2	0.1
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.6.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-57 (T½ = 271 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.1
Adrenals	1.3E-09	9.2E-10	5.0E-10	3.3E-10	2.2E-10	1.8E-10
Bladder Wall	1.2E-09	8.8E-10	4.8E-10	3.4E-10	2.4E-10	1.7E-10
Bone Surface	1.6E-09	1.2E-09	6.2E-10	4.2E-10	2.7E-10	2.3E-10
Brain	1.0E-09	7.1E-10	3.8E-10	2.3E-10	1.4E-10	1.2E-10
Breast	8.6E-10	6.0E-10	3.0E-10	1.9E-10	1.2E-10	1.0E-10
GI-Tract						
Oesophagus	1.1E-09	7.9E-10	4.1E-10	2.6E-10	1.7E-10	1.3E-10
St Wall	1.2E-09	8.7E-10	4.6E-10	3.1E-10	1.9E-10	1.5E-10
SI Wall	1.3E-09	9.9E-10	5.2E-10	3.4E-10	2.1E-10	1.8E-10
ULI Wall	1.7E-09	1.4E-09	7.0E-10	4.3E-10	2.6E-10	2.2E-10
LLI Wall	2.6E-09	2.2E-09	1.0E-09	6.5E-10	3.6E-10	3.2E-10
Colon	2.1E-09	1.7E-09	8.3E-10	5.3E-10	3.0E-10	2.6E-10
Kidneys	1.2E-09	8.6E-10	4.6E-10	3.0E-10	1.9E-10	1.6E-10
Liver	2.8E-09	2.0E-09	1.1E-09	7.3E-10	4.9E-10	3.9E-10
Muscle	1.0E-09	7.4E-10	3.8E-10	2.4E-10	1.5E-10	1.3E-10
Ovaries	1.3E-09	9.4E-10	5.0E-10	3.3E-10	2.1E-10	1.7E-10
Pancreas	1.4E-09	9.8E-10	5.2E-10	3.5E-10	2.2E-10	1.8E-10
Red Marrow	1.0E-09	7.2E-10	3.8E-10	2.6E-10	1.6E-10	1.4E-10
Respiratory Tract						
ET Airways	5.3E-09	4.5E-09	2.4E-09	1.4E-09	8.2E-10	6.4E-10
Lungs	1.1E-09	8.0E-10	4.2E-10	2.8E-10	1.8E-10	1.5E-10
Skin	8.2E-10	5.6E-10	2.9E-10	1.8E-10	1.1E-10	9.3E-11
Spleen	1.2E-09	8.2E-10	4.3E-10	2.8E-10	1.8E-10	1.4E-10
Testes	9.8E-10	6.9E-10	3.6E-10	2.3E-10	1.5E-10	1.2E-10
Thymus	1.1E-09	7.9E-10	4.1E-10	2.6E-10	1.7E-10	1.3E-10
Thyroid	1.2E-09	8.3E-10	4.4E-10	2.7E-10	1.7E-10	1.4E-10
Uterus	1.3E-09	9.1E-10	4.9E-10	3.2E-10	2.0E-10	1.7E-10
Remainder	3.2E-09	2.6E-09	1.4E-09	8.1E-10	4.9E-10	3.8E-10
Effective Dose	1.5E-09	1.1E-09	5.6E-10	3.7E-10	2.3E-10	1.9E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-57 (T½ = 271 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.4E-09	1.1E-09	6.7E-10	4.3E-10	3.2E-10	2.7E-10
Bladder Wall	5.5E-10	3.8E-10	2.1E-10	1.4E-10	9.8E-11	7.9E-11
Bone Surface	1.3E-09	9.9E-10	5.5E-10	3.6E-10	2.7E-10	2.4E-10
Brain	4.1E-10	2.7E-10	1.5E-10	9.2E-11	6.0E-11	5.3E-11
Breast	9.9E-10	8.3E-10	5.7E-10	3.8E-10	2.4E-10	2.3E-10
GI-Tract						
Oesophagus	1.1E-09	9.3E-10	6.3E-10	4.4E-10	3.4E-10	3.0E-10
St Wall	1.0E-09	7.7E-10	4.6E-10	3.0E-10	2.2E-10	1.7E-10
SI Wall	9.5E-10	6.9E-10	3.6E-10	2.3E-10	1.4E-10	1.2E-10
ULI Wall	2.1E-09	1.5E-09	7.2E-10	4.5E-10	2.5E-10	2.0E-10
LLI Wall	4.3E-09	3.2E-09	1.4E-09	8.8E-10	4.7E-10	3.9E-10
Colon	3.0E-09	2.2E-09	1.0E-09	6.3E-10	3.4E-10	2.9E-10
Kidneys	7.9E-10	5.9E-10	3.4E-10	2.1E-10	1.5E-10	1.2E-10
Liver	1.7E-09	1.2E-09	7.3E-10	5.0E-10	3.8E-10	3.2E-10
Muscle	7.5E-10	5.6E-10	3.2E-10	2.1E-10	1.6E-10	1.3E-10
Ovaries	7.4E-10	5.4E-10	2.9E-10	1.9E-10	1.2E-10	9.9E-11
Pancreas	1.2E-09	9.8E-10	5.7E-10	3.7E-10	2.7E-10	2.2E-10
Red Marrow	6.5E-10	4.9E-10	3.0E-10	2.1E-10	1.7E-10	1.5E-10
Respiratory Tract						
ET Airways	6.2E-09	5.3E-09	2.7E-09	1.6E-09	9.6E-10	7.7E-10
Lungs	1.4E-08	1.2E-08	7.0E-09	4.8E-09	4.1E-09	3.3E-09
Skin	4.6E-10	3.3E-10	1.8E-10	1.1E-10	7.6E-11	7.1E-11
Spleen	1.1E-09	8.6E-10	5.1E-10	3.2E-10	2.4E-10	2.0E-10
Testes	4.0E-10	2.6E-10	1.4E-10	8.5E-11	5.6E-11	5.0E-11
Thymus	1.1E-09	9.3E-10	6.3E-10	4.4E-10	3.4E-10	3.0E-10
Thyroid	8.4E-10	6.6E-10	3.8E-10	2.3E-10	1.5E-10	1.3E-10
Uterus	6.3E-10	4.4E-10	2.4E-10	1.5E-10	9.6E-11	8.2E-11
Remainder	6.9E-10	5.2E-10	3.0E-10	2.0E-10	1.5E-10	1.3E-10
Effective Dose	2.8E-09	2.2E-09	1.3E-09	8.5E-10	6.7E-10	5.5E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-57 (T½ = 271 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.0E-09	1.8E-09	1.2E-09	7.6E-10	5.9E-10	4.9E-10
Bladder Wall	2.4E-10	1.8E-10	8.5E-11	4.8E-11	2.7E-11	2.0E-11
Bone Surface	1.6E-09	1.4E-09	8.2E-10	5.3E-10	4.3E-10	3.7E-10
Brain	1.2E-10	9.3E-11	5.9E-11	3.6E-11	2.4E-11	2.1E-11
Breast	1.6E-09	1.5E-09	1.1E-09	7.5E-10	4.8E-10	4.8E-10
GI-Tract						
Oesophagus	1.6E-09	1.6E-09	1.2E-09	8.6E-10	6.9E-10	6.2E-10
St Wall	1.2E-09	1.1E-09	6.9E-10	4.5E-10	3.5E-10	2.7E-10
SI Wall	8.1E-10	6.3E-10	3.2E-10	1.9E-10	1.1E-10	8.5E-11
ULI Wall	2.2E-09	1.6E-09	7.6E-10	4.6E-10	2.4E-10	2.0E-10
LLI Wall	5.1E-09	3.4E-09	1.5E-09	9.3E-10	4.9E-10	4.0E-10
Colon	3.5E-09	2.4E-09	1.1E-09	6.7E-10	3.5E-10	2.9E-10
Kidneys	8.1E-10	7.2E-10	4.4E-10	2.7E-10	1.9E-10	1.5E-10
Liver	1.5E-09	1.4E-09	9.0E-10	6.2E-10	5.1E-10	4.3E-10
Muscle	8.2E-10	7.4E-10	4.5E-10	2.9E-10	2.4E-10	2.0E-10
Ovaries	5.0E-10	4.0E-10	2.0E-10	1.2E-10	6.9E-11	5.5E-11
Pancreas	1.7E-09	1.5E-09	9.4E-10	6.0E-10	4.6E-10	3.7E-10
Red Marrow	6.5E-10	6.0E-10	4.1E-10	3.0E-10	2.6E-10	2.4E-10
Respiratory Tract						
ET Airways	7.9E-09	6.9E-09	3.6E-09	2.1E-09	1.3E-09	1.1E-09
Lungs	2.7E-08	2.4E-08	1.5E-08	9.7E-09	8.0E-09	6.6E-09
Skin	3.8E-10	3.3E-10	2.0E-10	1.3E-10	9.1E-11	8.7E-11
Spleen	1.5E-09	1.4E-09	8.6E-10	5.5E-10	4.2E-10	3.5E-10
Testes	1.1E-10	8.1E-11	3.1E-11	1.9E-11	9.1E-12	6.8E-12
Thymus	1.6E-09	1.6E-09	1.2E-09	8.6E-10	6.9E-10	6.2E-10
Thyroid	9.7E-10	9.1E-10	5.7E-10	3.4E-10	2.3E-10	1.9E-10
Uterus	3.5E-10	2.8E-10	1.3E-10	7.6E-11	4.3E-11	3.1E-11
Remainder	7.0E-10	6.3E-10	4.0E-10	2.7E-10	2.3E-10	1.9E-10
Effective Dose	4.4E-09	3.7E-09	2.3E-09	1.5E-09	1.2E-09	1.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.6.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Co-58 (T½ = 70.8 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.1
Adrenals	3.3E-09	2.3E-09	1.2E-09	8.4E-10	5.5E-10	4.4E-10
Bladder Wall	2.8E-09	1.9E-09	1.2E-09	7.6E-10	5.0E-10	4.6E-10
Bone Surface	2.9E-09	2.0E-09	1.0E-09	6.9E-10	4.4E-10	3.7E-10
Brain	2.4E-09	1.7E-09	8.6E-10	5.4E-10	3.2E-10	2.7E-10
Breast	2.0E-09	1.4E-09	7.0E-10	4.5E-10	3.1E-10	2.5E-10
GI-Tract						
Oesophagus	3.1E-09	2.1E-09	1.0E-09	6.7E-10	4.2E-10	3.3E-10
St Wall	3.0E-09	2.1E-09	1.1E-09	6.7E-10	4.5E-10	3.8E-10
SI Wall	3.6E-09	2.7E-09	1.4E-09	9.4E-10	5.7E-10	4.9E-10
ULI Wall	4.3E-09	3.4E-09	1.7E-09	1.1E-09	6.6E-10	5.9E-10
LLI Wall	5.8E-09	4.8E-09	2.4E-09	1.5E-09	8.5E-10	8.3E-10
Colon	5.0E-09	4.0E-09	2.0E-09	1.3E-09	7.4E-10	7.0E-10
Kidneys	3.1E-09	2.2E-09	1.2E-09	7.7E-10	4.9E-10	4.0E-10
Liver	5.5E-09	3.9E-09	2.1E-09	1.5E-09	9.8E-10	7.9E-10
Muscle	2.7E-09	1.9E-09	9.6E-10	6.3E-10	4.0E-10	3.3E-10
Ovaries	3.6E-09	2.7E-09	1.4E-09	9.5E-10	5.9E-10	5.0E-10
Pancreas	3.6E-09	2.5E-09	1.3E-09	8.8E-10	5.6E-10	4.5E-10
Red Marrow	2.4E-09	1.7E-09	9.4E-10	6.6E-10	4.3E-10	3.6E-10
Respiratory Tract						
ET Airways	3.0E-08	2.7E-08	1.4E-08	8.3E-09	4.9E-09	3.8E-09
Lungs	2.8E-09	1.9E-09	9.8E-10	6.5E-10	4.3E-10	3.4E-10
Skin	1.9E-09	1.3E-09	6.5E-10	4.1E-10	2.7E-10	2.2E-10
Spleen	2.9E-09	2.1E-09	1.1E-09	7.0E-10	4.5E-10	3.6E-10
Testes	2.4E-09	1.7E-09	8.8E-10	5.7E-10	3.7E-10	3.1E-10
Thymus	3.1E-09	2.1E-09	1.0E-09	6.7E-10	4.2E-10	3.3E-10
Thyroid	3.0E-09	2.1E-09	1.1E-09	6.7E-10	4.1E-10	3.3E-10
Uterus	3.3E-09	2.4E-09	1.3E-09	8.6E-10	5.3E-10	4.5E-10
Remainder	1.6E-08	1.4E-08	7.7E-09	4.5E-09	2.7E-09	2.1E-09
Effective Dose	4.0E-09	3.0E-09	1.6E-09	1.0E-09	6.4E-10	5.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.12.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Nb-95 (T½ = 35.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.8E-09	2.3E-09	1.4E-09	8.8E-10	6.4E-10	5.3E-10
Bladder Wall	9.2E-10	7.1E-10	3.6E-10	2.5E-10	1.4E-10	1.2E-10
Bone Surface	6.4E-09	4.6E-09	2.9E-09	1.4E-09	8.6E-10	8.5E-10
Brain	5.0E-10	3.8E-10	2.2E-10	1.4E-10	9.9E-11	8.8E-11
Breast	2.1E-09	1.8E-09	1.2E-09	8.4E-10	5.2E-10	4.7E-10
GI-Tract						
Oesophagus	2.3E-09	1.9E-09	1.3E-09	8.5E-10	6.4E-10	5.6E-10
St Wall	2.0E-09	1.6E-09	8.8E-10	5.7E-10	4.3E-10	3.3E-10
SI Wall	2.4E-09	1.8E-09	9.2E-10	6.1E-10	3.5E-10	2.9E-10
ULI Wall	5.2E-09	3.7E-09	1.8E-09	1.1E-09	6.2E-10	5.2E-10
LLI Wall	1.1E-08	7.5E-09	3.4E-09	2.2E-09	1.2E-09	9.7E-10
Colon	7.6E-09	5.3E-09	2.5E-09	1.6E-09	8.5E-10	7.1E-10
Kidneys	2.0E-09	1.6E-09	8.6E-10	6.4E-10	4.6E-10	3.9E-10
Liver	3.1E-09	2.7E-09	1.5E-09	1.1E-09	8.0E-10	6.7E-10
Muscle	1.4E-09	1.2E-09	6.4E-10	4.1E-10	3.1E-10	2.5E-10
Ovaries	2.1E-09	1.6E-09	8.2E-10	5.4E-10	3.4E-10	2.7E-10
Pancreas	2.3E-09	1.9E-09	1.1E-09	7.0E-10	5.3E-10	4.1E-10
Red Marrow	2.5E-09	1.7E-09	9.4E-10	6.0E-10	4.6E-10	4.1E-10
Respiratory Tract						
ET Airways	2.8E-08	2.4E-08	1.3E-08	7.5E-09	4.4E-09	3.5E-09
Lungs	3.6E-08	2.8E-08	1.8E-08	1.3E-08	1.2E-08	9.5E-09
Skin	8.2E-10	6.5E-10	3.5E-10	2.3E-10	1.6E-10	1.4E-10
Spleen	2.1E-09	1.7E-09	9.3E-10	6.2E-10	4.6E-10	3.7E-10
Testes	5.2E-10	3.9E-10	1.9E-10	1.2E-10	7.3E-11	6.0E-11
Thymus	2.3E-09	1.9E-09	1.3E-09	8.5E-10	6.4E-10	5.6E-10
Thyroid	1.2E-09	1.0E-09	6.1E-10	3.8E-10	2.6E-10	2.2E-10
Uterus	1.3E-09	1.0E-09	5.1E-10	3.2E-10	1.9E-10	1.6E-10
Remainder	1.3E-09	1.1E-09	6.0E-10	4.0E-10	3.0E-10	2.5E-10
Effective Dose	6.8E-09	5.2E-09	3.1E-09	2.2E-09	1.9E-09	1.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.12.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Nb-95 (T½ = 35.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.0E-09	2.5E-09	1.5E-09	9.1E-10	6.7E-10	5.5E-10
Bladder Wall	7.8E-10	5.8E-10	2.7E-10	1.8E-10	9.0E-11	7.3E-11
Bone Surface	2.2E-09	1.5E-09	7.9E-10	4.6E-10	3.2E-10	2.8E-10
Brain	2.8E-10	2.1E-10	1.3E-10	8.3E-11	5.8E-11	5.2E-11
Breast	2.5E-09	2.2E-09	1.5E-09	1.0E-09	6.3E-10	5.8E-10
GI-Tract						
Oesophagus	2.6E-09	2.2E-09	1.5E-09	1.0E-09	7.7E-10	6.7E-10
St Wall	2.1E-09	1.6E-09	9.2E-10	5.9E-10	4.7E-10	3.4E-10
SI Wall	2.3E-09	1.7E-09	8.4E-10	5.4E-10	3.0E-10	2.5E-10
ULI Wall	5.2E-09	3.7E-09	1.7E-09	1.1E-09	5.9E-10	4.9E-10
LLI Wall	1.1E-08	7.7E-09	3.5E-09	2.2E-09	1.2E-09	9.6E-10
Colon	7.8E-09	5.4E-09	2.5E-09	1.6E-09	8.4E-10	7.0E-10
Kidneys	1.5E-09	1.2E-09	6.2E-10	4.0E-10	2.8E-10	2.2E-10
Liver	2.5E-09	2.0E-09	1.2E-09	7.8E-10	6.0E-10	4.9E-10
Muscle	1.4E-09	1.2E-09	6.5E-10	4.2E-10	3.2E-10	2.6E-10
Ovaries	1.9E-09	1.4E-09	7.3E-10	4.8E-10	2.9E-10	2.2E-10
Pancreas	2.4E-09	1.9E-09	1.2E-09	7.1E-10	5.5E-10	4.1E-10
Red Marrow	1.3E-09	9.8E-10	6.1E-10	4.5E-10	3.6E-10	3.4E-10
Respiratory Tract						
ET Airways	3.0E-08	2.6E-08	1.3E-08	7.9E-09	4.6E-09	3.7E-09
Lungs	4.5E-08	3.5E-08	2.2E-08	1.6E-08	1.5E-08	1.2E-08
Skin	7.4E-10	5.9E-10	3.4E-10	2.1E-10	1.5E-10	1.3E-10
Spleen	2.2E-09	1.9E-09	1.0E-09	6.7E-10	5.1E-10	4.0E-10
Testes	3.7E-10	2.6E-10	1.2E-10	7.1E-11	3.4E-11	2.6E-11
Thymus	2.6E-09	2.2E-09	1.5E-09	1.0E-09	7.7E-10	6.7E-10
Thyroid	1.3E-09	1.1E-09	6.5E-10	4.0E-10	2.7E-10	2.3E-10
Uterus	1.1E-09	8.6E-10	4.2E-10	2.5E-10	1.4E-10	1.1E-10
Remainder	1.3E-09	1.0E-09	5.9E-10	3.9E-10	3.0E-10	2.5E-10
Effective Dose	7.7E-09	5.9E-09	3.6E-09	2.5E-09	2.2E-09	1.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.13. Molybdenum

(166) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides and hydroxides of molybdenum (Mo) to inhalation Class Y, sulphides, halides and nitrates to Class W, and all other compounds of molybdenum to Class D. *ICRP Publication 30*, Part 1 (ICRP, 1979) assigned oxides, hydroxides, and MoS_2 to Class Y, and and all other compounds of molybdenum to Class D, citing experiments on dogs with ammonium molybdate, molybdenum oxide and molybdenum chloride (Cuddihy *et al.*, 1969).

Absorption Types

(167) Measurements following intake of an aerosol during handling of a ^{99}Mo source, by workers at a company manufacturing ^{99m}Tc generators for use in nuclear medicine, indicate Type F behaviour (Alvarez *et al.*, 1994).

(168) The results of experiments on dogs in which the disposition of ^{99}Mo was followed for 8 days after inhalation indicate Type F behaviour for ammonium molybdate and molybdenum chloride, and Type M behaviour for molybdenum oxide (Cuddihy *et al.*, 1969).

Dose coefficients

(169) Dose coefficients (given in Table 5.13.2) were derived using the f_1 values given in Table 5.13.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.13.1. Values of f_1 for inhaled particulate compounds of molybdenum

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	1	0.8
M[b]	0.2	0.1
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type M is recommended for use in the absence of specific information.

Table 5.13.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Mo-99 (T½ = 2.75 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	1.2E-09	7.3E-10	3.4E-10	2.2E-10	1.3E-10	1.1E-10
Bladder Wall	1.2E-09	7.4E-10	3.9E-10	2.6E-10	1.7E-10	1.4E-10
Bone Surface	2.7E-09	1.9E-09	1.1E-09	6.2E-10	3.3E-10	3.3E-10
Brain	1.0E-09	6.1E-10	2.8E-10	1.7E-10	9.4E-11	8.0E-11
Breast	1.0E-09	6.1E-10	2.7E-10	1.7E-10	9.3E-11	7.9E-11
GI-Tract						
Oesophagus	1.1E-09	6.9E-10	3.0E-10	1.8E-10	1.0E-10	8.6E-11
St Wall	1.9E-09	1.1E-09	4.8E-10	2.9E-10	1.6E-10	1.3E-10
SI Wall	1.1E-09	9.3E-10	4.1E-10	2.6E-10	1.4E-10	1.2E-10
ULI Wall	1.5E-09	2.2E-09	9.3E-10	5.7E-10	2.8E-10	2.3E-10
LLI Wall	2.0E-09	4.0E-09	1.7E-09	1.0E-09	4.9E-10	4.2E-10
Colon	1.7E-09	3.0E-09	1.3E-09	7.7E-10	3.7E-10	3.1E-10
Kidneys	9.4E-09	5.6E-09	2.7E-09	1.8E-09	1.2E-09	1.0E-09
Liver	9.5E-09	6.1E-09	2.8E-09	1.9E-09	1.1E-09	9.0E-10
Muscle	1.0E-09	6.5E-10	2.9E-10	1.8E-10	1.0E-10	8.6E-11
Ovaries	1.1E-09	6.8E-10	3.1E-10	1.9E-10	1.1E-10	9.2E-11
Pancreas	1.2E-09	7.4E-10	3.4E-10	2.1E-10	1.2E-10	1.0E-10
Red Marrow	3.3E-09	1.9E-09	8.1E-10	4.6E-10	2.5E-10	2.0E-10
Respiratory Tract						
ET Airways	1.5E-08	1.1E-08	5.3E-09	3.3E-09	1.9E-09	1.6E-09
Lungs	1.2E-09	7.3E-10	3.4E-10	2.2E-10	1.4E-10	1.1E-10
Skin	9.8E-10	6.0E-10	2.7E-10	1.6E-10	9.0E-11	7.7E-11
Spleen	1.1E-09	6.7E-10	3.1E-10	1.9E-10	1.1E-10	9.1E-11
Testes	9.9E-10	6.1E-10	2.7E-10	1.7E-10	9.3E-11	7.9E-11
Thymus	1.1E-09	6.9E-10	3.0E-10	1.8E-10	1.0E-10	8.6E-11
Thyroid	1.0E-09	6.3E-10	2.9E-10	1.8E-10	9.8E-11	8.4E-11
Uterus	1.1E-09	6.6E-10	3.0E-10	1.9E-10	1.1E-10	8.9E-11
Remainder	8.1E-09	6.1E-09	2.8E-09	1.7E-09	9.8E-10	8.6E-10
Effective Dose	2.3E-09	1.7E-09	7.7E-10	4.7E-10	2.6E-10	2.2E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.13.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Mo-99 (T½ = 2.75 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	3.6E-10	2.1E-10	1.1E-10	6.6E-11	4.3E-11	3.5E-11
Bladder Wall	3.4E-10	1.9E-10	9.6E-11	6.6E-11	3.9E-11	3.2E-11
Bone Surface	6.6E-10	3.6E-10	2.0E-10	1.2E-10	6.6E-11	6.2E-11
Brain	2.2E-10	1.0E-10	4.7E-11	2.9E-11	1.7E-11	1.5E-11
Breast	3.0E-10	1.7E-10	9.1E-11	5.8E-11	3.3E-11	3.0E-11
GI-Tract						
Oesophagus	3.8E-10	2.2E-10	1.1E-10	6.9E-11	4.3E-11	3.6E-11
St Wall	1.9E-09	1.1E-09	4.4E-10	2.6E-10	1.5E-10	1.2E-10
SI Wall	3.3E-09	2.3E-09	1.0E-09	6.1E-10	2.9E-10	2.4E-10
ULI Wall	1.6E-08	1.2E-08	4.8E-09	2.9E-09	1.3E-09	1.1E-09
LLI Wall	3.6E-08	2.6E-08	1.1E-08	6.6E-09	3.1E-09	2.6E-09
Colon	2.5E-08	1.8E-08	7.4E-09	4.5E-09	2.1E-09	1.7E-09
Kidneys	2.0E-09	8.9E-10	4.3E-10	2.9E-10	1.9E-10	1.5E-10
Liver	2.1E-09	9.9E-10	4.5E-10	3.0E-10	1.8E-10	1.5E-10
Muscle	3.1E-10	1.7E-10	8.0E-11	5.0E-11	3.0E-11	2.5E-11
Ovaries	5.1E-10	3.4E-10	1.7E-10	1.1E-10	6.3E-11	5.0E-11
Pancreas	3.6E-10	2.1E-10	1.0E-10	6.4E-11	4.0E-11	3.2E-11
Red Marrow	7.4E-10	3.3E-10	1.5E-10	9.2E-11	5.5E-11	4.5E-11
Respiratory Tract						
ET Airways	1.7E-08	1.3E-08	5.9E-09	3.7E-09	2.1E-09	1.8E-09
Lungs	2.1E-08	1.6E-08	9.7E-09	7.2E-09	6.6E-09	5.3E-09
Skin	2.4E-10	1.2E-10	5.4E-11	3.3E-11	1.9E-11	1.7E-11
Spleen	3.3E-10	1.8E-10	9.0E-11	5.7E-11	3.5E-11	2.9E-11
Testes	2.5E-10	1.2E-10	5.5E-11	3.4E-11	1.8E-11	1.5E-11
Thymus	3.8E-10	2.2E-10	1.1E-10	6.9E-11	4.3E-11	3.6E-11
Thyroid	2.6E-10	1.4E-10	6.7E-11	4.1E-11	2.5E-11	2.1E-11
Uterus	3.7E-10	2.3E-10	1.1E-10	6.9E-11	3.7E-11	3.0E-11
Remainder	3.7E-10	2.1E-10	9.9E-11	6.4E-11	3.8E-11	3.2E-11
Effective Dose	6.0E-09	4.4E-09	2.2E-09	1.5E-09	1.1E-09	8.9E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.13.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Mo-99 (T½ = 2.75 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.6E-10	1.2E-10	6.7E-11	4.1E-11	2.9E-11	2.3E-11
Bladder Wall	1.5E-10	1.1E-10	5.0E-11	3.5E-11	1.8E-11	1.5E-11
Bone Surface	1.6E-10	1.1E-10	5.4E-11	3.5E-11	2.3E-11	2.0E-11
Brain	3.1E-11	1.7E-11	9.4E-12	6.8E-12	4.5E-12	4.1E-12
Breast	1.2E-10	9.2E-11	6.0E-11	4.0E-11	2.3E-11	2.1E-11
GI-Tract						
Oesophagus	1.9E-10	1.4E-10	7.6E-11	4.9E-11	3.3E-11	2.8E-11
St Wall	1.8E-09	1.0E-09	4.3E-10	2.5E-10	1.5E-10	1.2E-10
SI Wall	4.0E-09	2.6E-09	1.1E-09	6.8E-10	3.2E-10	2.7E-10
ULI Wall	2.0E-08	1.3E-08	5.5E-09	3.3E-09	1.5E-09	1.3E-09
LLI Wall	4.6E-08	3.0E-08	1.2E-08	7.5E-09	3.6E-09	2.9E-09
Colon	3.1E-08	2.0E-08	8.5E-09	5.2E-09	2.4E-09	2.0E-09
Kidneys	2.3E-10	1.2E-10	5.9E-11	3.9E-11	2.4E-11	1.9E-11
Liver	2.8E-10	1.6E-10	7.9E-11	5.2E-11	3.4E-11	2.7E-11
Muscle	1.3E-10	9.0E-11	4.5E-11	2.9E-11	1.9E-11	1.6E-11
Ovaries	4.0E-10	2.9E-10	1.4E-10	1.0E-10	5.7E-11	4.4E-11
Pancreas	1.6E-10	1.2E-10	6.3E-11	3.9E-11	2.7E-11	2.0E-11
Red Marrow	1.2E-10	7.4E-11	4.4E-11	3.3E-11	2.3E-11	2.0E-11
Respiratory Tract						
ET Airways	1.7E-08	1.3E-08	5.9E-09	3.7E-09	2.1E-09	1.9E-09
Lungs	2.3E-08	1.8E-08	1.1E-08	8.1E-09	7.5E-09	6.0E-09
Skin	6.1E-11	3.9E-11	2.0E-11	1.3E-11	7.9E-12	6.9E-12
Spleen	1.4E-10	1.0E-10	5.4E-11	3.5E-11	2.3E-11	1.8E-11
Testes	7.3E-11	4.7E-11	2.0E-11	1.3E-11	5.9E-12	4.6E-12
Thymus	1.9E-10	1.4E-10	7.6E-11	4.9E-11	3.3E-11	2.8E-11
Thyroid	7.6E-11	5.4E-11	3.1E-11	1.9E-11	1.3E-11	1.1E-11
Uterus	2.2E-10	1.6E-10	7.7E-11	5.1E-11	2.7E-11	2.1E-11
Remainder	1.9E-10	1.3E-10	6.3E-11	4.2E-11	2.6E-11	2.1E-11
Effective Dose	6.9E-09	4.8E-09	2.4E-09	1.7E-09	1.2E-09	9.9E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.14. Technetium

(170) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides, halides and nitrates of technetium (Tc) to inhalation Class W, and all other compounds of the element to Class D. This classification was adopted without change in *ICRP Publication 30*, Part 2 (ICRP, 1980). Human studies with ^{99m}Tc pertechnetate (Cooke and Lander, 1971) supported the assignment to Class D. Consideration is given to the use of both soluble and insoluble ^{99m}Tc-labelled aerosols in clinical studies in *ICRP Publication 53* (ICRP, 1987)

Absorption Types

(171) Measurements following intake of an aerosol during handling of a ^{99}Mo source, by workers at a company manufacturing ^{99m}Tc generators for use in nuclear medicine, indicate Type F behaviour (Alvarez *et al.*, 1994).

(172) Studies of technetium as pertechnetate showed the lung absorption of technetium to be very rapid: after administration to humans (Yeates *et al.*, 1973), dogs and rats (Barrowcliffe *et al.*, 1986; Man *et al.*, 1989), total absorption occurred within a few hours, consistent with assignment to Type F. ^{99m}Tc-labelled DTPA (diethylenetriaminepentaacetic acid) is used to study lung permeability: the half-time for absorption is approximately 1 h (Jones *et al.*, 1980; Jefferies *et al.*, 1984).

(173) The use of ^{99m}Tc-labelled materials such as albumin, erythrocytes, ferric oxide, polystyrene, resin and teflon to study mucociliary clearance from the bronchial tree relies on there being relatively little absorption from the lungs to the body fluids over the first day or so after deposition (Isawa *et al.*, 1984; Matthys *et al.*, 1983; Albert *et al.*, 1969; Sutton *et al.*, 1981; Puchelle *et al.*, 1979; Mossberg and Camner, 1980).

Dose coefficients

(174) Dose coefficients (given in Tables 5.14.2 and 5.14.3) were derived using the f_1 values given in Table 5.14.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.14.1. Values of f_1 for inhaled particulate compounds of technetium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	1	0.8
M[b]	0.2	0.1
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type M is recommended for use in the absence of specific information.

Table 5.14.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Tc-99 (T½ = 2.13E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Bladder Wall	5.3E-10	3.6E-10	2.3E-10	1.8E-10	1.3E-10	1.0E-10
Bone Surface	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Brain	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Breast	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
GI-Tract						
Oesophagus	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
St Wall	2.0E-08	1.1E-08	4.2E-09	2.4E-09	1.6E-09	1.3E-09
SI Wall	3.4E-10	2.7E-10	1.1E-10	6.9E-11	3.6E-11	3.0E-11
ULI Wall	4.4E-09	3.1E-09	1.3E-09	8.0E-10	4.1E-10	3.4E-10
LLI Wall	1.2E-08	8.3E-09	3.7E-09	2.2E-09	1.1E-09	9.5E-10
Colon	7.6E-09	5.3E-09	2.3E-09	1.4E-09	7.2E-10	6.0E-10
Kidneys	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Liver	3.6E-10	2.3E-10	1.0E-10	6.9E-11	4.1E-11	3.3E-11
Muscle	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Ovaries	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Pancreas	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Red Marrow	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Respiratory Tract						
ET Airways	7.9E-09	5.3E-09	2.2E-09	1.5E-09	7.8E-10	7.7E-10
Lungs	4.0E-10	2.5E-10	1.2E-10	7.7E-11	5.2E-11	4.2E-11
Skin	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Spleen	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Testes	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Thymus	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Thyroid	9.9E-09	8.4E-09	3.8E-09	1.7E-09	1.0E-09	6.4E-10
Uterus	3.4E-10	2.1E-10	9.0E-11	5.4E-11	2.9E-11	2.5E-11
Remainder	3.4E-10	2.1E-10	9.1E-11	5.5E-11	3.0E-11	2.5E-11
Effective Dose	4.0E-09	2.5E-09	1.0E-09	5.9E-10	3.6E-10	2.9E-10

GI-Tract Gastrointestinal Tract
St Stomach
SI Small Intestine
ULI Upper Large Intestine
LLI Lower Large Intestine
ET Airways Extrathoracic airways
Lungs Thoracic airways

Table 5.14.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Tc-99 (T½ = 2.13E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Bladder Wall	1.8E-10	1.1E-10	7.8E-11	5.8E-11	4.8E-11	3.8E-11
Bone Surface	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Brain	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Breast	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
GI-Tract						
Oesophagus	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
St Wall	6.8E-09	3.4E-09	1.5E-09	8.4E-10	6.2E-10	5.2E-10
SI Wall	9.5E-10	6.8E-10	2.9E-10	1.8E-10	8.7E-11	7.3E-11
ULI Wall	6.6E-09	4.6E-09	2.0E-09	1.2E-09	6.0E-10	5.0E-10
LLI Wall	1.9E-08	1.3E-08	5.7E-09	3.4E-09	1.7E-09	1.4E-09
Colon	1.2E-08	8.2E-09	3.6E-09	2.1E-09	1.1E-09	9.1E-10
Kidneys	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Liver	1.2E-10	7.1E-11	3.5E-11	2.3E-11	1.5E-11	1.2E-11
Muscle	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Ovaries	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Pancreas	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Red Marrow	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Respiratory Tract						
ET Airways	3.4E-08	2.5E-08	1.1E-08	7.3E-09	4.0E-09	3.9E-09
Lungs	1.2E-07	9.8E-08	6.1E-08	4.4E-08	4.0E-08	3.2E-08
Skin	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Spleen	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Testes	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Thymus	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Thyroid	3.5E-09	2.5E-09	1.3E-09	5.5E-10	3.6E-10	2.4E-10
Uterus	1.1E-10	6.2E-11	3.0E-11	1.8E-11	1.1E-11	9.2E-12
Remainder	1.4E-10	8.3E-11	4.0E-11	2.4E-11	1.4E-11	1.2E-11
Effective Dose	1.7E-08	1.3E-08	8.0E-09	5.7E-09	5.0E-09	4.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.14.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Tc-99 (T½ = 2.13E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Bladder Wall	1.7E-11	1.1E-11	8.5E-12	6.5E-12	5.7E-12	5.2E-12
Bone Surface	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Brain	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Breast	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
GI-Tract						
Oesophagus	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
St Wall	1.0E-09	5.6E-10	2.6E-10	1.6E-10	1.2E-10	1.0E-10
SI Wall	1.2E-09	8.0E-10	3.6E-10	2.1E-10	1.1E-10	9.5E-11
ULI Wall	7.3E-09	5.0E-09	2.2E-09	1.3E-09	6.9E-10	5.8E-10
LLI Wall	2.1E-08	1.4E-08	6.3E-09	3.8E-09	2.0E-09	1.7E-09
Colon	1.3E-08	8.9E-09	4.0E-09	2.4E-09	1.3E-09	1.1E-09
Kidneys	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Liver	1.0E-11	6.1E-12	3.5E-12	2.4E-12	1.8E-12	1.7E-12
Muscle	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Ovaries	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Pancreas	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Red Marrow	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Respiratory Tract						
ET Airways	1.1E-07	9.4E-08	4.6E-08	3.2E-08	1.9E-08	1.9E-08
Lungs	3.3E-07	3.0E-07	2.0E-07	1.4E-07	1.2E-07	1.1E-07
Skin	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Spleen	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Testes	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Thymus	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Thyroid	3.1E-10	2.1E-10	1.1E-10	5.6E-11	4.0E-11	3.3E-11
Uterus	9.4E-12	5.3E-12	2.9E-12	1.8E-12	1.3E-12	1.2E-12
Remainder	9.1E-11	5.8E-11	3.0E-11	2.1E-11	1.3E-11	1.3E-11
Effective Dose	4.1E-08	3.7E-08	2.4E-08	1.7E-08	1.5E-08	1.3E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.14.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Tc-99m (T½ = 6.02 h).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	0.8	0.8	0.8	0.8	0.8
Adrenals	1.4E-11	1.0E-11	5.0E-12	3.3E-12	2.0E-12	1.7E-12
Bladder Wall	1.6E-11	1.3E-11	7.5E-12	5.8E-12	4.1E-12	3.3E-12
Bone Surface	1.9E-11	1.4E-11	7.0E-12	4.8E-12	3.0E-12	2.7E-12
Brain	1.1E-11	7.4E-12	3.9E-12	2.6E-12	1.6E-12	1.5E-12
Breast	1.1E-11	7.3E-12	3.5E-12	2.1E-12	1.2E-12	1.0E-12
GI-Tract						
Oesophagus	2.9E-11	2.0E-11	7.9E-12	4.5E-12	2.3E-12	1.8E-12
St Wall	2.8E-10	1.5E-10	6.4E-11	3.9E-11	2.6E-11	2.1E-11
SI Wall	1.8E-11	2.4E-11	1.1E-11	7.5E-12	4.1E-12	3.5E-12
ULI Wall	5.0E-11	5.7E-11	2.7E-11	1.7E-11	9.0E-12	7.5E-12
LLI Wall	4.0E-11	4.3E-11	2.0E-11	1.3E-11	6.6E-12	5.6E-12
Colon	4.6E-11	5.1E-11	2.4E-11	1.5E-11	8.0E-12	6.7E-12
Kidneys	1.3E-11	9.2E-12	4.8E-12	3.2E-12	1.9E-12	1.7E-12
Liver	1.5E-11	1.1E-11	5.3E-12	3.5E-12	2.1E-12	1.7E-12
Muscle	1.6E-11	1.1E-11	5.3E-12	3.5E-12	2.0E-12	1.7E-12
Ovaries	1.6E-11	1.4E-11	7.2E-12	4.9E-12	2.9E-12	2.5E-12
Pancreas	2.0E-11	1.5E-11	7.7E-12	5.3E-12	3.3E-12	2.8E-12
Red Marrow	1.2E-11	8.1E-12	4.2E-12	3.0E-12	1.9E-12	1.7E-12
Respiratory Tract						
ET Airways	1.5E-09	1.3E-09	6.3E-10	3.8E-10	2.2E-10	1.8E-10
Lungs	2.5E-11	1.8E-11	1.0E-11	7.3E-12	6.0E-12	4.7E-12
Skin	9.4E-12	6.2E-12	2.9E-12	1.9E-12	1.1E-12	9.8E-13
Spleen	1.6E-11	1.1E-11	5.7E-12	3.9E-12	2.4E-12	2.1E-12
Testes	9.8E-12	6.8E-12	3.3E-12	2.1E-12	1.3E-12	1.1E-12
Thymus	2.9E-11	2.0E-11	7.9E-12	4.5E-12	2.3E-12	1.8E-12
Thyroid	5.3E-10	4.4E-10	2.1E-10	9.5E-11	5.9E-11	3.9E-11
Uterus	1.4E-11	1.2E-11	6.3E-12	4.2E-12	2.4E-12	2.1E-12
Remainder	7.7E-10	6.3E-10	3.2E-10	1.9E-10	1.1E-10	9.0E-11
Effective Dose	1.2E-10	8.7E-11	4.1E-11	2.4E-11	1.5E-11	1.2E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.14.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Tc-99m (T½ = 6.02 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.3E-11	9.4E-12	5.0E-12	3.1E-12	2.0E-12	1.6E-12
Bladder Wall	1.3E-11	9.6E-12	5.0E-12	3.4E-12	1.9E-12	1.5E-12
Bone Surface	1.5E-11	1.1E-11	5.5E-12	3.8E-12	2.4E-12	2.1E-12
Brain	3.5E-12	2.2E-12	1.3E-12	9.9E-13	6.5E-13	6.3E-13
Breast	8.7E-12	6.5E-12	3.8E-12	2.4E-12	1.3E-12	1.2E-12
GI-Tract						
Oesophagus	2.4E-11	1.7E-11	7.3E-12	4.3E-12	2.4E-12	1.9E-12
St Wall	1.2E-10	6.8E-11	2.9E-11	1.8E-11	1.1E-11	9.0E-12
SI Wall	1.1E-10	8.5E-11	3.8E-11	2.5E-11	1.2E-11	1.0E-11
ULI Wall	2.5E-10	1.8E-10	8.0E-11	5.2E-11	2.5E-11	2.1E-11
LLI Wall	1.8E-10	1.3E-10	5.6E-11	3.5E-11	1.7E-11	1.5E-11
Colon	2.2E-10	1.6E-10	7.0E-11	4.5E-11	2.2E-11	1.8E-11
Kidneys	1.1E-11	8.3E-12	4.4E-12	2.9E-12	1.7E-12	1.4E-12
Liver	1.5E-11	1.1E-11	5.6E-12	3.5E-12	2.0E-12	1.6E-12
Muscle	1.3E-11	9.5E-12	4.6E-12	3.0E-12	1.8E-12	1.5E-12
Ovaries	3.4E-11	2.7E-11	1.4E-11	9.6E-12	5.3E-12	4.3E-12
Pancreas	1.8E-11	1.4E-11	7.0E-12	4.7E-12	2.8E-12	2.3E-12
Red Marrow	7.6E-12	5.9E-12	3.5E-12	2.8E-12	1.9E-12	1.6E-12
Respiratory Tract						
ET Airways	1.8E-09	1.4E-09	7.0E-10	4.3E-10	2.5E-10	2.1E-10
Lungs	2.7E-10	2.0E-10	1.3E-10	1.0E-10	9.8E-11	7.7E-11
Skin	5.3E-12	3.6E-12	1.7E-12	1.1E-12	6.5E-13	5.7E-13
Spleen	1.3E-11	9.9E-12	5.1E-12	3.4E-12	2.1E-12	1.7E-12
Testes	5.4E-12	3.8E-12	1.6E-12	9.9E-13	4.6E-13	3.4E-13
Thymus	2.4E-11	1.7E-11	7.3E-12	4.3E-12	2.4E-12	1.9E-12
Thyroid	8.9E-11	5.7E-11	2.7E-11	1.3E-11	7.9E-12	5.4E-12
Uterus	2.4E-11	1.9E-11	9.6E-12	6.5E-12	3.4E-12	2.7E-12
Remainder	8.9E-10	7.2E-10	3.5E-10	2.1E-10	1.2E-10	1.0E-10
Effective Dose	1.3E-10	9.9E-11	5.1E-11	3.4E-11	2.4E-11	1.9E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.14.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Tc-99m ($T\frac{1}{2}$ = 6.02 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.2E-11	9.2E-12	4.9E-12	3.1E-12	2.0E-12	1.6E-12
Bladder Wall	1.3E-11	9.3E-12	4.7E-12	3.1E-12	1.6E-12	1.3E-12
Bone Surface	1.4E-11	1.1E-11	5.3E-12	3.6E-12	2.4E-12	2.0E-12
Brain	2.1E-12	1.5E-12	9.5E-13	7.7E-13	5.3E-13	5.3E-13
Breast	8.2E-12	6.3E-12	3.8E-12	2.4E-12	1.3E-12	1.2E-12
GI-Tract						
Oesophagus	2.3E-11	1.7E-11	7.2E-12	4.2E-12	2.4E-12	1.9E-12
St Wall	9.3E-11	5.6E-11	2.5E-11	1.5E-11	9.1E-12	7.4E-12
SI Wall	1.4E-10	9.4E-11	4.2E-11	2.8E-11	1.4E-11	1.1E-11
ULI Wall	2.9E-10	2.0E-10	8.8E-11	5.7E-11	2.8E-11	2.3E-11
LLI Wall	2.1E-10	1.4E-10	6.2E-11	3.9E-11	1.9E-11	1.6E-11
Colon	2.6E-10	1.8E-10	7.7E-11	4.9E-11	2.4E-11	2.0E-11
Kidneys	1.1E-11	8.1E-12	4.4E-12	2.9E-12	1.7E-12	1.4E-12
Liver	1.5E-11	1.1E-11	5.6E-12	3.5E-12	2.0E-12	1.6E-12
Muscle	1.2E-11	9.3E-12	4.6E-12	3.0E-12	1.8E-12	1.4E-12
Ovaries	3.8E-11	2.9E-11	1.5E-11	1.0E-11	5.6E-12	4.6E-12
Pancreas	1.8E-11	1.4E-11	6.8E-12	4.6E-12	2.8E-12	2.2E-12
Red Marrow	6.9E-12	5.6E-12	3.5E-12	2.8E-12	1.9E-12	1.6E-12
Respiratory Tract						
ET Airways	1.8E-09	1.5E-09	7.1E-10	4.3E-10	2.5E-10	2.1E-10
Lungs	2.9E-10	2.2E-10	1.4E-10	1.1E-10	1.1E-10	8.5E-11
Skin	4.5E-12	3.2E-12	1.5E-12	9.9E-13	5.9E-13	5.2E-13
Spleen	1.3E-11	9.6E-12	5.0E-12	3.3E-12	2.1E-12	1.7E-12
Testes	4.8E-12	3.4E-12	1.4E-12	8.5E-13	3.6E-13	2.5E-13
Thymus	2.3E-11	1.7E-11	7.2E-12	4.2E-12	2.4E-12	1.9E-12
Thyroid	9.9E-12	6.2E-12	3.2E-12	2.0E-12	1.2E-12	1.0E-12
Uterus	2.6E-11	2.0E-11	1.0E-11	6.9E-12	3.5E-12	2.9E-12
Remainder	9.1E-10	7.3E-10	3.6E-10	2.2E-10	1.3E-10	1.0E-10
Effective Dose	1.3E-10	1.0E-10	5.2E-11	3.5E-11	2.5E-11	2.0E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.15. Ruthenium

(175) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides and hydroxides of ruthenium (Ru) to inhalation Class Y, halides to Class W and all other compounds to Class D. This was endorsed by ICRP in *Publication 30*, Part 2 (ICRP, 1980), in which the assignment of ruthenium dioxide to Class Y was supported by reference to experiments with dogs (Stuart, 1970).

Absorption Types

(a) *Gases and vapours*

(176) Following an accidental human inhalation of ruthenium tetroxide vapour, it was concluded that deposition occurred only in the extrathoracic airways, where the compound was subsequently retained (Webber and Harvey, 1975). Experiments on rats and dogs have confirmed that inhalation of ruthenium tetroxide vapour results in complete deposition in the extrathoracic airways (Runkle and Snipes, 1979; Runkle *et al.*, 1980; Snipes, 1981). Based on these studies ruthenium tetroxide vapour is assigned to Class SR-1 (100% deposition), with Type F clearance.

(b) *Particulate aerosols*

(177) The results of a human investigation following inhalation of an unknown ruthenium compound indicate Type M behaviour (Pusch, 1968). Animal investigations using ruthenium citrate and dioxide, indicate that these compounds also exhibit Type M behaviour (Bair *et al.*, 1961; Boecker and Harris, 1969; Snipes, 1979). However, data from other animal experiments indicate Type M behaviour for oxalate, with Type S for dioxide (Newton *et al.*, 1976; Newton and Latven, 1971).

(178) The results of two human studies following accidental inhalation of ruthenium dioxide (Hesp and Coote, 1970; Howells *et al.*, 1977) indicate Type S behaviour. A study on dogs (Stuart, 1970) using ruthenium dioxide also indicates Type S behaviour.

(179) Environmental ruthenium could well be inhaled in particles in which it is a minor constituent. For example, following an accidental release it could be present in fragments of irradiated fuel, where the matrix would be predominantly uranium oxide. Results of a study in which irradiated UO_2 powder was administered to rats by intratracheal instillation were consistent with assignment of the ruthenium present to Type M (Lang *et al.*, 1994). Studies of the *in vitro* dissolution of particles released from the Chernobyl accident (Cuddihy *et al.*, 1989) were consistent with assignment of the ruthenium present to Type M.

Dose coefficients

(180) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (in Tables 5.15.2 and 5.15.3) were derived for the vapour given in Table 5.15.1a, for particulate aerosols using the f_1 values given in Table 5.15.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.15.1a. Classification and absorption Types for gas and vapour compounds of ruthenium

	Deposition		Absorption	
Chemical form/origin	Vapour Class	Fraction deposited (%)	Type	f_1
Tetroxide	SR-1	100[a]	F	b

[a] 100% in ET_2.
[b] As for Type F in Table 5.15.1b.

Table 5.15.1b. Values of f_1 for inhaled particulate compounds of ruthenium[a]

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.1	0.05
M[b]	0.1	0.05
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[b] Default Type M is recommended for use in the absence of specific information.

Table 5.15.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-103 (T½ = 39.3 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	2.9E-09	2.1E-09	1.1E-09	6.7E-10	4.2E-10	3.6E-10
Bladder Wall	2.9E-09	2.0E-09	1.2E-09	7.4E-10	4.9E-10	4.4E-10
Bone Surface	2.9E-09	2.1E-09	1.0E-09	6.5E-10	4.1E-10	3.6E-10
Brain	2.6E-09	1.9E-09	9.2E-10	5.6E-10	3.4E-10	2.9E-10
Breast	2.3E-09	1.6E-09	7.8E-10	4.8E-10	3.1E-10	2.7E-10
GI-Tract						
Oesophagus	3.0E-09	2.1E-09	1.0E-09	6.3E-10	4.0E-10	3.4E-10
St Wall	3.0E-09	2.0E-09	1.0E-09	6.3E-10	4.0E-10	3.5E-10
SI Wall	3.7E-09	2.7E-09	1.3E-09	8.5E-10	5.1E-10	4.4E-10
ULI Wall	6.9E-09	4.8E-09	2.2E-09	1.4E-09	7.5E-10	6.5E-10
LLI Wall	1.4E-08	9.4E-09	4.2E-09	2.6E-09	1.3E-09	1.2E-09
Colon	9.8E-09	6.8E-09	3.1E-09	1.9E-09	1.0E-09	8.8E-10
Kidneys	2.9E-09	2.1E-09	1.0E-09	6.5E-10	4.0E-10	3.5E-10
Liver	2.9E-09	2.1E-09	1.0E-09	6.5E-10	4.0E-10	3.5E-10
Muscle	2.7E-09	1.9E-09	9.5E-10	6.0E-10	3.7E-10	3.2E-10
Ovaries	3.4E-09	2.5E-09	1.3E-09	8.2E-10	5.0E-10	4.3E-10
Pancreas	3.1E-09	2.2E-09	1.1E-09	7.0E-10	4.4E-10	3.8E-10
Red Marrow	2.6E-09	1.9E-09	9.4E-10	6.2E-10	3.9E-10	3.5E-10
Respiratory Tract						
ET Airways	2.0E-08	1.7E-08	8.9E-09	5.3E-09	3.1E-09	2.5E-09
Lungs	2.8E-09	2.0E-09	9.7E-10	6.1E-10	4.0E-10	3.3E-10
Skin	2.3E-09	1.6E-09	7.6E-10	4.7E-10	2.9E-10	2.5E-10
Spleen	2.9E-09	2.1E-09	1.0E-09	6.5E-10	4.0E-10	3.5E-10
Testes	2.6E-09	1.9E-09	9.1E-10	5.8E-10	3.6E-10	3.2E-10
Thymus	3.0E-09	2.1E-09	1.0E-09	6.3E-10	4.0E-10	3.4E-10
Thyroid	2.9E-09	2.1E-09	1.0E-09	6.5E-10	3.9E-10	3.3E-10
Uterus	3.2E-09	2.3E-09	1.2E-09	7.5E-10	4.6E-10	4.0E-10
Remainder	1.1E-08	9.6E-09	4.9E-09	2.9E-09	1.7E-09	1.4E-09
Effective Dose	4.2E-09	3.0E-09	1.5E-09	9.3E-10	5.6E-10	4.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-103 (T½ = 39.3 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	2.3E-09	1.8E-09	9.8E-10	6.2E-10	4.3E-10	3.7E-10
Bladder Wall	1.1E-09	7.2E-10	4.0E-10	2.6E-10	1.5E-10	1.3E-10
Bone Surface	1.5E-09	1.1E-09	5.4E-10	3.3E-10	2.4E-10	2.0E-10
Brain	7.9E-10	4.9E-10	2.6E-10	1.6E-10	1.0E-10	8.7E-11
Breast	1.8E-09	1.5E-09	9.3E-10	6.3E-10	3.9E-10	3.5E-10
GI-Tract						
Oesophagus	2.1E-09	1.6E-09	9.9E-10	6.7E-10	4.9E-10	4.2E-10
St Wall	2.1E-09	1.4E-09	7.5E-10	4.9E-10	3.4E-10	2.7E-10
SI Wall	2.7E-09	1.9E-09	9.1E-10	5.8E-10	3.2E-10	2.7E-10
ULI Wall	8.3E-09	5.7E-09	2.5E-09	1.6E-09	8.1E-10	6.7E-10
LLI Wall	2.0E-08	1.4E-08	6.0E-09	3.7E-09	1.9E-09	1.6E-09
Colon	1.3E-08	9.2E-09	4.0E-09	2.5E-09	1.3E-09	1.1E-09
Kidneys	1.4E-09	9.9E-10	5.2E-10	3.2E-10	2.2E-10	1.8E-10
Liver	1.9E-09	1.4E-09	8.1E-10	5.3E-10	3.9E-10	3.2E-10
Muscle	1.4E-09	1.0E-09	5.4E-10	3.4E-10	2.4E-10	2.0E-10
Ovaries	1.8E-09	1.3E-09	6.6E-10	4.3E-10	2.6E-10	2.1E-10
Pancreas	2.0E-09	1.5E-09	8.4E-10	5.1E-10	3.7E-10	3.0E-10
Red Marrow	1.2E-09	8.8E-10	5.1E-10	3.5E-10	2.7E-10	2.5E-10
Respiratory Tract						
ET Airways	2.9E-08	2.4E-08	1.2E-08	7.1E-09	4.1E-09	3.4E-09
Lungs	6.9E-08	5.3E-08	3.3E-08	2.4E-08	2.2E-08	1.8E-08
Skin	9.4E-10	6.3E-10	3.4E-10	2.0E-10	1.4E-10	1.2E-10
Spleen	1.9E-09	1.4E-09	7.6E-10	4.9E-10	3.5E-10	2.8E-10
Testes	8.5E-10	5.4E-10	2.5E-10	1.6E-10	9.5E-11	8.3E-11
Thymus	2.1E-09	1.6E-09	9.9E-10	6.7E-10	4.9E-10	4.2E-10
Thyroid	1.4E-09	1.0E-09	5.8E-10	3.4E-10	2.2E-10	1.9E-10
Uterus	1.4E-09	9.4E-10	4.7E-10	2.9E-10	1.7E-10	1.4E-10
Remainder	1.3E-09	9.6E-10	5.2E-10	3.3E-10	2.4E-10	2.0E-10
Effective Dose	1.1E-08	8.4E-09	5.0E-09	3.5E-09	3.0E-09	2.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-103 ($T\frac{1}{2}$ = 39.3 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.2E-09	1.8E-09	1.0E-09	6.5E-10	4.7E-10	4.0E-10
Bladder Wall	5.5E-10	3.9E-10	1.9E-10	1.3E-10	6.1E-11	5.0E-11
Bone Surface	1.1E-09	8.5E-10	4.4E-10	2.7E-10	2.0E-10	1.7E-10
Brain	2.1E-10	1.5E-10	8.7E-11	5.3E-11	3.7E-11	3.3E-11
Breast	1.7E-09	1.5E-09	1.0E-09	7.2E-10	4.3E-10	4.0E-10
GI-Tract						
Oesophagus	1.8E-09	1.6E-09	1.1E-09	7.3E-10	5.5E-10	4.8E-10
St Wall	1.8E-09	1.3E-09	7.1E-10	4.7E-10	3.4E-10	2.5E-10
SI Wall	2.4E-09	1.7E-09	8.0E-10	5.0E-10	2.6E-10	2.2E-10
ULI Wall	8.7E-09	5.9E-09	2.6E-09	1.6E-09	8.0E-10	6.6E-10
LLI Wall	2.2E-08	1.5E-08	6.4E-09	3.9E-09	2.0E-09	1.6E-09
Colon	1.4E-08	9.7E-09	4.2E-09	2.6E-09	1.3E-09	1.1E-09
Kidneys	1.0E-09	7.7E-10	4.2E-10	2.5E-10	1.8E-10	1.4E-10
Liver	1.7E-09	1.4E-09	8.0E-10	5.3E-10	4.1E-10	3.3E-10
Muscle	1.0E-09	8.3E-10	4.6E-10	2.9E-10	2.2E-10	1.8E-10
Ovaries	1.3E-09	1.0E-09	5.0E-10	3.3E-10	1.9E-10	1.4E-10
Pancreas	1.7E-09	1.4E-09	8.3E-10	4.9E-10	3.7E-10	3.0E-10
Red Marrow	8.0E-10	6.6E-10	4.1E-10	3.0E-10	2.5E-10	2.3E-10
Respiratory Tract						
ET Airways	3.2E-08	2.6E-08	1.3E-08	7.8E-09	4.5E-09	3.8E-09
Lungs	8.7E-08	6.7E-08	4.2E-08	3.0E-08	2.7E-08	2.2E-08
Skin	5.3E-10	4.1E-10	2.4E-10	1.4E-10	1.1E-10	8.9E-11
Spleen	1.6E-09	1.4E-09	7.4E-10	4.8E-10	3.5E-10	2.8E-10
Testes	2.9E-10	2.0E-10	7.6E-11	5.1E-11	2.2E-11	1.9E-11
Thymus	1.8E-09	1.6E-09	1.1E-09	7.3E-10	5.5E-10	4.8E-10
Thyroid	9.5E-10	7.7E-10	4.9E-10	2.8E-10	1.9E-10	1.6E-10
Uterus	7.8E-10	5.9E-10	2.9E-10	1.7E-10	9.2E-11	7.3E-11
Remainder	9.3E-10	7.4E-10	4.2E-10	2.8E-10	2.1E-10	1.8E-10
Effective Dose	1.3E-08	1.0E-08	6.0E-09	4.2E-09	3.7E-09	3.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-103 (T½ = 39.3 d).

Ruthenium Tetroxide Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	6.1E-09	4.2E-09	2.3E-09	1.5E-09	9.4E-10	7.8E-10
Bladder Wall	6.2E-09	4.2E-09	2.6E-09	1.7E-09	1.1E-09	9.8E-10
Bone Surface	5.9E-09	4.1E-09	2.2E-09	1.4E-09	9.1E-10	7.7E-10
Brain	5.4E-09	3.7E-09	1.9E-09	1.2E-09	7.3E-10	6.1E-10
Breast	4.7E-09	3.2E-09	1.7E-09	1.0E-09	6.8E-10	5.6E-10
GI-Tract						
Oesophagus	5.7E-09	3.9E-09	2.1E-09	1.3E-09	8.5E-10	7.0E-10
St Wall	6.6E-09	4.3E-09	2.4E-09	1.5E-09	9.7E-10	8.2E-10
SI Wall	9.0E-09	6.3E-09	3.4E-09	2.2E-09	1.4E-09	1.1E-09
ULI Wall	1.9E-08	1.3E-08	7.0E-09	4.3E-09	2.6E-09	2.1E-09
LLI Wall	4.2E-08	2.9E-08	1.5E-08	9.1E-09	5.3E-09	4.4E-09
Colon	2.9E-08	2.0E-08	1.0E-08	6.4E-09	3.8E-09	3.1E-09
Kidneys	6.0E-09	4.1E-09	2.2E-09	1.4E-09	9.1E-10	7.6E-10
Liver	6.1E-09	4.1E-09	2.2E-09	1.4E-09	9.1E-10	7.6E-10
Muscle	5.6E-09	3.8E-09	2.0E-09	1.3E-09	8.2E-10	6.9E-10
Ovaries	7.7E-09	5.5E-09	3.1E-09	2.0E-09	1.3E-09	1.1E-09
Pancreas	6.4E-09	4.4E-09	2.4E-09	1.5E-09	9.9E-10	8.2E-10
Red Marrow	5.4E-09	3.7E-09	2.1E-09	1.4E-09	9.0E-10	7.6E-10
Respiratory Tract						
ET Airways	8.8E-09	6.1E-09	3.3E-09	2.0E-09	1.3E-09	1.1E-09
Lungs	5.5E-09	3.8E-09	2.0E-09	1.3E-09	8.3E-10	6.8E-10
Skin	4.7E-09	3.1E-09	1.6E-09	1.0E-09	6.3E-10	5.4E-10
Spleen	6.0E-09	4.1E-09	2.2E-09	1.4E-09	9.1E-10	7.5E-10
Testes	5.5E-09	3.8E-09	2.0E-09	1.3E-09	8.1E-10	6.9E-10
Thymus	5.7E-09	3.9E-09	2.1E-09	1.3E-09	8.5E-10	7.0E-10
Thyroid	6.0E-09	4.1E-09	2.2E-09	1.4E-09	8.5E-10	7.0E-10
Uterus	6.9E-09	4.8E-09	2.7E-09	1.7E-09	1.1E-09	9.2E-10
Remainder	5.6E-09	3.8E-09	2.0E-09	1.3E-09	8.3E-10	7.0E-10
Effective Dose	9.0E-09	6.2E-09	3.3E-09	2.1E-09	1.3E-09	1.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-106 (T½ = 1.01 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.3E-09	7.2E-09
Bladder Wall	6.3E-08	4.8E-08	2.5E-08	1.5E-08	9.7E-09	8.2E-09
Bone Surface	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.3E-09	7.1E-09
Brain	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.1E-09	7.0E-09
Breast	6.0E-08	4.6E-08	2.3E-08	1.3E-08	8.1E-09	7.0E-09
GI-Tract						
Oesophagus	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
St Wall	6.4E-08	4.8E-08	2.4E-08	1.4E-08	8.4E-09	7.3E-09
SI Wall	6.7E-08	5.1E-08	2.5E-08	1.5E-08	8.8E-09	7.5E-09
ULI Wall	1.1E-07	7.9E-08	3.7E-08	2.2E-08	1.2E-08	1.0E-08
LLI Wall	2.0E-07	1.4E-07	6.2E-08	3.7E-08	2.0E-08	1.7E-08
Colon	1.5E-07	1.1E-07	4.8E-08	2.9E-08	1.5E-08	1.3E-08
Kidneys	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.3E-09	7.1E-09
Liver	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.3E-09	7.1E-09
Muscle	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
Ovaries	6.1E-08	4.7E-08	2.3E-08	1.4E-08	8.3E-09	7.2E-09
Pancreas	6.1E-08	4.7E-08	2.3E-08	1.4E-08	8.3E-09	7.2E-09
Red Marrow	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
Respiratory Tract						
ET Airways	7.5E-08	5.7E-08	2.8E-08	1.7E-08	1.0E-08	8.7E-09
Lungs	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.3E-09	7.1E-09
Skin	6.0E-08	4.6E-08	2.3E-08	1.3E-08	8.1E-09	7.0E-09
Spleen	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.3E-09	7.1E-09
Testes	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
Thymus	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
Thyroid	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
Uterus	6.1E-08	4.7E-08	2.3E-08	1.4E-08	8.3E-09	7.2E-09
Remainder	6.1E-08	4.6E-08	2.3E-08	1.4E-08	8.2E-09	7.1E-09
Effective Dose	7.2E-08	5.4E-08	2.6E-08	1.6E-08	9.2E-09	7.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-106 (T½ = 1.01 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	2.3E-08	1.6E-08	8.6E-09	5.1E-09	3.4E-09	3.0E-09
Bladder Wall	2.2E-08	1.5E-08	8.5E-09	5.2E-09	3.5E-09	3.1E-09
Bone Surface	2.2E-08	1.5E-08	8.1E-09	4.8E-09	3.1E-09	2.8E-09
Brain	2.1E-08	1.5E-08	7.8E-09	4.6E-09	2.9E-09	2.6E-09
Breast	2.2E-08	1.6E-08	8.5E-09	5.1E-09	3.3E-09	2.9E-09
GI-Tract						
Oesophagus	2.2E-08	1.6E-08	8.6E-09	5.1E-09	3.4E-09	3.0E-09
St Wall	2.8E-08	1.9E-08	9.6E-09	5.7E-09	3.7E-09	3.2E-09
SI Wall	3.5E-08	2.4E-08	1.2E-08	7.1E-09	4.2E-09	3.6E-09
ULI Wall	1.1E-07	7.3E-08	3.3E-08	2.0E-08	1.0E-08	8.7E-09
LLI Wall	2.6E-07	1.8E-07	7.9E-08	4.7E-08	2.4E-08	2.0E-08
Colon	1.7E-07	1.2E-07	5.3E-08	3.1E-08	1.6E-08	1.4E-08
Kidneys	2.2E-08	1.5E-08	8.1E-09	4.8E-09	3.1E-09	2.7E-09
Liver	2.2E-08	1.6E-08	8.4E-09	5.0E-09	3.3E-09	2.9E-09
Muscle	2.2E-08	1.5E-08	8.1E-09	4.8E-09	3.1E-09	2.7E-09
Ovaries	2.2E-08	1.5E-08	8.1E-09	4.8E-09	3.1E-09	2.7E-09
Pancreas	2.2E-08	1.6E-08	8.5E-09	5.0E-09	3.3E-09	2.9E-09
Red Marrow	2.1E-08	1.5E-08	8.1E-09	4.8E-09	3.1E-09	2.8E-09
Respiratory Tract						
ET Airways	6.3E-08	4.7E-08	2.2E-08	1.4E-08	8.2E-09	7.5E-09
Lungs	8.4E-07	7.1E-07	4.2E-07	2.8E-07	2.2E-07	2.0E-07
Skin	2.1E-08	1.5E-08	7.8E-09	4.6E-09	3.0E-09	2.6E-09
Spleen	2.2E-08	1.6E-08	8.4E-09	5.0E-09	3.2E-09	2.8E-09
Testes	2.1E-08	1.5E-08	7.8E-09	4.6E-09	3.0E-09	2.6E-09
Thymus	2.2E-08	1.6E-08	8.6E-09	5.1E-09	3.4E-09	3.0E-09
Thyroid	2.2E-08	1.5E-08	8.2E-09	4.8E-09	3.1E-09	2.7E-09
Uterus	2.1E-08	1.5E-08	8.0E-09	4.7E-09	3.0E-09	2.7E-09
Remainder	2.2E-08	1.5E-08	8.1E-09	4.8E-09	3.1E-09	2.8E-09
Effective Dose	1.4E-07	1.1E-07	6.4E-08	4.1E-08	3.1E-08	2.8E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-106 (T½ = 1.01 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.7E-09	4.5E-09	2.7E-09	1.7E-09	1.2E-09	1.1E-09
Bladder Wall	2.4E-09	1.4E-09	7.4E-10	4.5E-10	2.8E-10	2.4E-10
Bone Surface	3.6E-09	2.5E-09	1.4E-09	8.4E-10	6.1E-10	5.4E-10
Brain	2.2E-09	1.2E-09	6.8E-10	4.0E-10	2.6E-10	2.3E-10
Breast	5.2E-09	4.1E-09	2.8E-09	1.8E-09	1.2E-09	1.1E-09
GI-Tract						
Oesophagus	5.1E-09	4.0E-09	2.7E-09	1.9E-09	1.4E-09	1.3E-09
St Wall	1.1E-08	6.6E-09	3.3E-09	2.0E-09	1.4E-09	1.1E-09
SI Wall	1.9E-08	1.2E-08	5.5E-09	3.3E-09	1.7E-09	1.4E-09
ULI Wall	9.9E-08	6.6E-08	2.9E-08	1.7E-08	8.6E-09	7.1E-09
LLI Wall	2.8E-07	1.8E-07	8.0E-08	4.8E-08	2.4E-08	2.0E-08
Colon	1.8E-07	1.2E-07	5.1E-08	3.1E-08	1.5E-08	1.3E-08
Kidneys	3.5E-09	2.4E-09	1.3E-09	8.0E-10	5.6E-10	4.7E-10
Liver	4.7E-09	3.6E-09	2.2E-09	1.4E-09	1.1E-09	9.2E-10
Muscle	3.5E-09	2.4E-09	1.4E-09	8.7E-10	6.4E-10	5.5E-10
Ovaries	2.8E-09	1.7E-09	9.1E-10	5.3E-10	3.3E-10	2.8E-10
Pancreas	4.8E-09	3.6E-09	2.2E-09	1.3E-09	1.0E-09	8.3E-10
Red Marrow	3.2E-09	2.2E-09	1.3E-09	8.9E-10	7.0E-10	6.6E-10
Respiratory Tract						
ET Airways	8.4E-08	6.7E-08	3.1E-08	2.0E-08	1.2E-08	1.1E-08
Lungs	1.9E-06	1.7E-06	1.1E-06	7.2E-07	5.7E-07	5.3E-07
Skin	2.7E-09	1.7E-09	9.9E-10	5.9E-10	4.1E-10	3.7E-10
Spleen	4.7E-09	3.6E-09	2.1E-09	1.3E-09	9.5E-10	8.0E-10
Testes	2.2E-09	1.2E-09	5.9E-10	3.5E-10	2.1E-10	1.9E-10
Thymus	5.1E-09	4.0E-09	2.7E-09	1.9E-09	1.4E-09	1.3E-09
Thyroid	3.6E-09	2.5E-09	1.5E-09	9.0E-10	6.0E-10	5.4E-10
Uterus	2.6E-09	1.5E-09	7.9E-10	4.5E-10	2.8E-10	2.4E-10
Remainder	3.6E-09	2.4E-09	1.4E-09	8.9E-10	6.5E-10	5.6E-10
Effective Dose	2.6E-07	2.3E-07	1.4E-07	9.1E-08	7.1E-08	6.6E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.15.3(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ru-106 (T½ = 1.01 y).

Ruthenium Tetroxide Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	1.3E-07	9.1E-08	5.0E-08	3.0E-08	1.8E-08	1.5E-08
Bladder Wall	1.3E-07	9.5E-08	5.4E-08	3.3E-08	2.1E-08	1.8E-08
Bone Surface	1.3E-07	9.1E-08	4.9E-08	3.0E-08	1.8E-08	1.5E-08
Brain	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Breast	1.2E-07	9.0E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
GI-Tract						
Oesophagus	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
St Wall	1.4E-07	9.6E-08	5.2E-08	3.1E-08	1.9E-08	1.6E-08
SI Wall	1.5E-07	1.1E-07	5.7E-08	3.4E-08	2.1E-08	1.7E-08
ULI Wall	2.8E-07	2.0E-07	1.0E-07	6.1E-08	3.6E-08	2.9E-08
LLI Wall	5.7E-07	3.9E-07	2.0E-07	1.2E-07	6.9E-08	5.6E-08
Colon	4.1E-07	2.8E-07	1.4E-07	8.6E-08	5.0E-08	4.1E-08
Kidneys	1.3E-07	9.1E-08	4.9E-08	3.0E-08	1.8E-08	1.5E-08
Liver	1.3E-07	9.1E-08	4.9E-08	3.0E-08	1.8E-08	1.5E-08
Muscle	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Ovaries	1.3E-07	9.2E-08	5.0E-08	3.0E-08	1.8E-08	1.5E-08
Pancreas	1.3E-07	9.2E-08	5.0E-08	3.0E-08	1.8E-08	1.5E-08
Red Marrow	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Respiratory Tract						
ET Airways	1.3E-07	9.5E-08	5.1E-08	3.1E-08	1.9E-08	1.6E-08
Lungs	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Skin	1.2E-07	9.0E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Spleen	1.3E-07	9.1E-08	4.9E-08	3.0E-08	1.8E-08	1.5E-08
Testes	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Thymus	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Thyroid	1.3E-07	9.1E-08	5.0E-08	3.0E-08	1.8E-08	1.5E-08
Uterus	1.3E-07	9.2E-08	5.0E-08	3.0E-08	1.8E-08	1.5E-08
Remainder	1.3E-07	9.1E-08	4.9E-08	2.9E-08	1.8E-08	1.5E-08
Effective Dose	1.6E-07	1.1E-07	6.1E-08	3.7E-08	2.2E-08	1.8E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.16. Silver

(181) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides and hydroxides of silver (Ag) to inhalation Class Y, nitrates and sulphides to Class W and all other compounds of the element to Class D. In the absence of any relevant experimental data this classification was also adopted in *ICRP Publication 30*, Part 2 (ICRP, 1980). The assignment of metallic silver to Class D was justified on the basis of a study on dogs by Phalen and Morrow (1973).

Absorption Types

(182) There have been very few studies of the biokinetics of silver following inhalation. In one case of accidental human inhalation of ^{110m}Ag associated with particles of unknown composition, most of the ^{110m}Ag was rapidly cleared from the lungs within a few days (Newton and Holmes, 1966). Measurements of lung retention following inhalation of activated corrosion products by several workers indicate Type M behaviour of the ^{110m}Ag present (Poulheim, 1984).

(183) Retention following inhalation of metallic silver fume by dogs was consistent with assignment to Type F (Phalen and Morrow, 1973). Retention following inhalation of silver iodide by dogs and rats, however, was consistent with assignment to Type M or S, but of insufficient duration (3 months) to distinguish between the two (Morrow *et al.*, 1968).

Dose coefficients

(184) Dose coefficients (given in Tables 5.16.2 and 5.16.3) were derived using the f_1 values given in Table 5.16.1, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.16.1. Values of f_1 for inhaled particulate compounds of silver

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.1	0.05
M[b]	0.1	0.05
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.16.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ag-108m (T½ = 1.27E+02 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	4.0E-08	3.3E-08	2.0E-08	1.5E-08	1.0E-08	9.1E-09
Bladder Wall	1.7E-08	1.3E-08	7.9E-09	4.6E-09	3.0E-09	2.9E-09
Bone Surface	2.1E-08	1.7E-08	9.0E-09	5.9E-09	4.1E-09	3.6E-09
Brain	1.2E-08	9.9E-09	5.4E-09	3.4E-09	2.1E-09	1.9E-09
Breast	1.8E-08	1.5E-08	8.1E-09	5.1E-09	3.3E-09	2.9E-09
GI-Tract						
Oesophagus	1.9E-08	1.5E-08	8.5E-09	5.5E-09	3.8E-09	3.3E-09
St Wall	3.6E-08	2.9E-08	1.5E-08	8.4E-09	5.3E-09	4.7E-09
SI Wall	3.2E-08	2.6E-08	1.4E-08	9.0E-09	5.5E-09	4.9E-09
ULI Wall	4.6E-08	3.6E-08	1.9E-08	1.2E-08	7.1E-09	6.4E-09
LLI Wall	3.9E-08	3.0E-08	1.6E-08	9.7E-09	5.9E-09	5.4E-09
Colon	4.3E-08	3.4E-08	1.8E-08	1.1E-08	6.6E-09	6.0E-09
Kidneys	3.3E-08	2.8E-08	1.7E-08	1.1E-08	7.7E-09	6.9E-09
Liver	2.0E-07	1.6E-07	9.5E-08	6.8E-08	4.8E-08	4.2E-08
Muscle	2.0E-08	1.6E-08	8.7E-09	5.7E-09	3.9E-09	3.4E-09
Ovaries	2.5E-08	2.1E-08	1.1E-08	7.1E-09	4.5E-09	3.9E-09
Pancreas	4.8E-08	4.0E-08	2.3E-08	1.5E-08	9.5E-09	8.1E-09
Red Marrow	1.7E-08	1.4E-08	8.3E-09	5.9E-09	4.2E-09	3.9E-09
Respiratory Tract						
ET Airways	6.4E-08	5.8E-08	3.1E-08	1.8E-08	1.1E-08	8.6E-09
Lungs	2.8E-08	2.3E-08	1.3E-08	8.7E-09	6.1E-09	5.1E-09
Skin	1.3E-08	1.1E-08	5.6E-09	3.6E-09	2.5E-09	2.2E-09
Spleen	2.3E-08	1.9E-08	1.1E-08	6.8E-09	4.4E-09	3.7E-09
Testes	1.4E-08	1.1E-08	5.8E-09	3.7E-09	2.5E-09	2.3E-09
Thymus	1.9E-08	1.5E-08	8.5E-09	5.5E-09	3.8E-09	3.3E-09
Thyroid	1.7E-08	1.4E-08	7.3E-09	4.5E-09	2.9E-09	2.5E-09
Uterus	2.3E-08	1.9E-08	1.0E-08	6.5E-09	4.1E-09	3.6E-09
Remainder	1.9E-08	1.5E-08	8.5E-09	5.6E-09	3.9E-09	3.4E-09
Effective Dose	3.5E-08	2.8E-08	1.6E-08	1.0E-08	6.9E-09	6.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.16.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ag-108m (T½ = 1.27E+02 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	3.1E-08	2.6E-08	1.6E-08	1.1E-08	8.1E-09	7.2E-09
Bladder Wall	8.4E-09	6.4E-09	3.8E-09	2.2E-09	1.5E-09	1.4E-09
Bone Surface	1.5E-08	1.2E-08	6.9E-09	4.3E-09	3.3E-09	2.9E-09
Brain	5.8E-09	4.5E-09	2.7E-09	1.6E-09	1.1E-09	1.0E-09
Breast	2.0E-08	1.7E-08	1.2E-08	7.8E-09	5.0E-09	4.7E-09
GI-Tract						
Oesophagus	2.0E-08	1.7E-08	1.2E-08	7.9E-09	6.0E-09	5.4E-09
St Wall	2.2E-08	1.8E-08	1.0E-08	6.2E-09	4.6E-09	3.8E-09
SI Wall	1.8E-08	1.4E-08	7.9E-09	4.8E-09	3.1E-09	2.7E-09
ULI Wall	2.7E-08	2.1E-08	1.1E-08	6.8E-09	4.3E-09	3.8E-09
LLI Wall	3.2E-08	2.3E-08	1.2E-08	7.3E-09	4.5E-09	3.9E-09
Colon	2.9E-08	2.2E-08	1.2E-08	7.0E-09	4.4E-09	3.9E-09
Kidneys	1.9E-08	1.6E-08	9.7E-09	6.3E-09	4.6E-09	4.1E-09
Liver	8.8E-08	7.0E-08	4.4E-08	3.0E-08	2.3E-08	2.1E-08
Muscle	1.4E-08	1.1E-08	6.7E-09	4.3E-09	3.3E-09	2.9E-09
Ovaries	1.4E-08	1.1E-08	6.2E-09	3.8E-09	2.5E-09	2.2E-09
Pancreas	3.0E-08	2.5E-08	1.5E-08	9.5E-09	7.0E-09	5.9E-09
Red Marrow	1.2E-08	9.6E-09	6.3E-09	4.5E-09	3.6E-09	3.5E-09
Respiratory Tract						
ET Airways	7.0E-08	6.3E-08	3.5E-08	2.0E-08	1.2E-08	9.7E-09
Lungs	1.2E-07	1.0E-07	6.5E-08	4.4E-08	3.7E-08	3.1E-08
Skin	8.4E-09	6.7E-09	3.9E-09	2.5E-09	1.8E-09	1.7E-09
Spleen	2.0E-08	1.7E-08	9.9E-09	6.3E-09	4.7E-09	3.9E-09
Testes	6.1E-09	4.6E-09	2.6E-09	1.6E-09	1.1E-09	1.0E-09
Thymus	2.0E-08	1.7E-08	1.2E-08	7.9E-09	6.0E-09	5.4E-09
Thyroid	1.3E-08	1.1E-08	6.6E-09	3.9E-09	2.7E-09	2.4E-09
Uterus	1.2E-08	9.1E-09	5.2E-09	3.1E-09	2.1E-09	1.8E-09
Remainder	1.3E-08	1.0E-08	6.3E-09	4.1E-09	3.2E-09	2.8E-09
Effective Dose	3.3E-08	2.7E-08	1.7E-08	1.1E-08	8.6E-09	7.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.16.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ag-108m (T½ = 1.27E+02 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	7.8E-08	7.6E-08	5.3E-08	3.5E-08	2.9E-08	2.8E-08
Bladder Wall	6.1E-09	5.3E-09	2.9E-09	1.6E-09	1.0E-09	8.7E-10
Bone Surface	3.4E-08	3.2E-08	2.1E-08	1.4E-08	1.2E-08	1.2E-08
Brain	5.6E-09	5.3E-09	3.7E-09	2.5E-09	2.1E-09	2.0E-09
Breast	7.1E-08	7.2E-08	5.5E-08	3.7E-08	2.9E-08	2.9E-08
GI-Tract						
Oesophagus	6.9E-08	7.0E-08	5.5E-08	3.9E-08	3.5E-08	3.4E-08
St Wall	3.9E-08	3.8E-08	2.7E-08	1.9E-08	1.6E-08	1.4E-08
SI Wall	1.7E-08	1.5E-08	8.9E-09	5.2E-09	3.7E-09	3.4E-09
ULI Wall	2.5E-08	2.1E-08	1.2E-08	7.2E-09	5.0E-09	4.5E-09
LLI Wall	3.0E-08	2.3E-08	1.2E-08	7.1E-09	4.4E-09	3.7E-09
Colon	2.7E-08	2.2E-08	1.2E-08	7.1E-09	4.7E-09	4.2E-09
Kidneys	3.0E-08	2.9E-08	1.9E-08	1.2E-08	1.0E-08	9.5E-09
Liver	6.6E-08	6.3E-08	4.4E-08	3.1E-08	2.7E-08	2.6E-08
Muscle	3.1E-08	3.0E-08	2.1E-08	1.4E-08	1.3E-08	1.2E-08
Ovaries	1.2E-08	1.0E-08	5.9E-09	3.4E-09	2.4E-09	2.1E-09
Pancreas	5.8E-08	5.7E-08	3.9E-08	2.6E-08	2.2E-08	2.1E-08
Red Marrow	2.7E-08	2.7E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Respiratory Tract						
ET Airways	1.9E-07	1.8E-07	1.1E-07	7.6E-08	5.2E-08	4.9E-08
Lungs	5.1E-07	5.0E-07	3.7E-07	2.6E-07	2.4E-07	2.3E-07
Skin	1.6E-08	1.6E-08	1.1E-08	7.2E-09	6.3E-09	6.1E-09
Spleen	5.5E-08	5.4E-08	3.6E-08	2.5E-08	2.1E-08	2.0E-08
Testes	3.1E-09	2.5E-09	1.3E-09	7.8E-10	4.7E-10	4.0E-10
Thymus	6.9E-08	7.0E-08	5.5E-08	3.9E-08	3.5E-08	3.4E-08
Thyroid	3.4E-08	3.3E-08	2.3E-08	1.4E-08	1.2E-08	1.1E-08
Uterus	9.4E-09	8.2E-09	4.5E-09	2.4E-09	1.7E-09	1.5E-09
Remainder	2.7E-08	2.6E-08	1.9E-08	1.3E-08	1.2E-08	1.1E-08
Effective Dose	8.9E-08	8.7E-08	6.2E-08	4.4E-08	3.9E-08	3.7E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.16.3(a).
Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ag-110m (T½ = 250 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	4.0E-08	3.2E-08	1.9E-08	1.4E-08	9.5E-09	8.3E-09
Bladder Wall	1.8E-08	1.4E-08	7.8E-09	4.4E-09	2.7E-09	2.7E-09
Bone Surface	2.1E-08	1.6E-08	8.3E-09	5.5E-09	3.7E-09	3.2E-09
Brain	1.2E-08	9.7E-09	5.1E-09	3.2E-09	1.9E-09	1.7E-09
Breast	1.9E-08	1.5E-08	7.9E-09	5.0E-09	3.2E-09	2.6E-09
GI-Tract						
Oesophagus	1.9E-08	1.5E-08	8.2E-09	5.3E-09	3.5E-09	3.0E-09
St Wall	3.7E-08	2.9E-08	1.4E-08	8.1E-09	5.0E-09	4.3E-09
SI Wall	3.4E-08	2.7E-08	1.4E-08	9.1E-09	5.4E-09	4.6E-09
ULI Wall	4.8E-08	3.7E-08	2.0E-08	1.2E-08	7.1E-09	6.2E-09
LLI Wall	4.4E-08	3.3E-08	1.7E-08	1.1E-08	6.2E-09	5.6E-09
Colon	4.6E-08	3.5E-08	1.9E-08	1.1E-08	6.7E-09	6.0E-09
Kidneys	3.3E-08	2.7E-08	1.6E-08	1.1E-08	7.1E-09	6.2E-09
Liver	1.8E-07	1.5E-07	8.3E-08	6.0E-08	4.1E-08	3.6E-08
Muscle	2.0E-08	1.6E-08	8.3E-09	5.4E-09	3.6E-09	3.1E-09
Ovaries	2.7E-08	2.2E-08	1.1E-08	7.3E-09	4.5E-09	3.8E-09
Pancreas	4.8E-08	3.9E-08	2.1E-08	1.4E-08	8.8E-09	7.3E-09
Red Marrow	1.7E-08	1.4E-08	7.9E-09	5.7E-09	3.9E-09	3.5E-09
Respiratory Tract						
ET Airways	9.0E-08	8.1E-08	4.4E-08	2.5E-08	1.5E-08	1.2E-08
Lungs	2.8E-08	2.3E-08	1.2E-08	8.1E-09	5.6E-09	4.6E-09
Skin	1.4E-08	1.1E-08	5.4E-09	3.4E-09	2.3E-09	2.1E-09
Spleen	2.4E-08	1.9E-08	1.0E-08	6.5E-09	4.1E-09	3.3E-09
Testes	1.4E-08	1.1E-08	5.7E-09	3.6E-09	2.3E-09	2.0E-09
Thymus	1.9E-08	1.5E-08	8.2E-09	5.3E-09	3.5E-09	3.0E-09
Thyroid	1.7E-08	1.3E-08	7.0E-09	4.3E-09	2.7E-09	2.3E-09
Uterus	2.4E-08	1.9E-08	1.0E-08	6.4E-09	4.0E-09	3.3E-09
Remainder	1.9E-08	1.5E-08	8.2E-09	5.4E-09	3.6E-09	3.1E-09
Effective Dose	3.5E-08	2.8E-08	1.5E-08	9.7E-09	6.3E-09	5.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.16.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ag-110m (T½ = 250 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.1	0.05	0.05	0.05	0.05	0.05
Adrenals	3.1E-08	2.6E-08	1.6E-08	1.0E-08	7.6E-09	6.5E-09
Bladder Wall	8.6E-09	6.3E-09	3.6E-09	2.0E-09	1.3E-09	1.2E-09
Bone Surface	1.5E-08	1.2E-08	6.5E-09	4.1E-09	3.0E-09	2.6E-09
Brain	5.5E-09	4.1E-09	2.3E-09	1.5E-09	1.0E-09	8.9E-10
Breast	2.2E-08	1.9E-08	1.3E-08	8.4E-09	5.3E-09	4.9E-09
GI-Tract						
Oesophagus	2.2E-08	1.8E-08	1.2E-08	8.3E-09	6.3E-09	5.6E-09
St Wall	2.3E-08	1.8E-08	9.9E-09	5.9E-09	4.5E-09	3.6E-09
SI Wall	1.9E-08	1.4E-08	7.7E-09	4.8E-09	2.9E-09	2.5E-09
ULI Wall	2.9E-08	2.1E-08	1.1E-08	7.0E-09	4.2E-09	3.6E-09
LLI Wall	3.7E-08	2.7E-08	1.3E-08	8.4E-09	4.9E-09	4.2E-09
Colon	3.2E-08	2.4E-08	1.2E-08	7.6E-09	4.5E-09	3.9E-09
Kidneys	1.9E-08	1.5E-08	8.9E-09	5.8E-09	4.1E-09	3.5E-09
Liver	7.5E-08	5.7E-08	3.4E-08	2.4E-08	1.8E-08	1.6E-08
Muscle	1.5E-08	1.2E-08	6.6E-09	4.2E-09	3.2E-09	2.7E-09
Ovaries	1.5E-08	1.1E-08	6.2E-09	3.9E-09	2.5E-09	2.1E-09
Pancreas	3.0E-08	2.4E-08	1.4E-08	8.9E-09	6.6E-09	5.2E-09
Red Marrow	1.2E-08	9.6E-09	6.1E-09	4.4E-09	3.5E-09	3.3E-09
Respiratory Tract						
ET Airways	1.0E-07	9.2E-08	4.9E-08	2.9E-08	1.7E-08	1.4E-08
Lungs	1.4E-07	1.1E-07	7.3E-08	5.1E-08	4.4E-08	3.6E-08
Skin	8.8E-09	6.8E-09	3.8E-09	2.4E-09	1.8E-09	1.6E-09
Spleen	2.1E-08	1.8E-08	9.9E-09	6.4E-09	4.7E-09	3.8E-09
Testes	6.0E-09	4.3E-09	2.3E-09	1.4E-09	9.2E-10	8.0E-10
Thymus	2.2E-08	1.8E-08	1.2E-08	8.3E-09	6.3E-09	5.6E-09
Thyroid	1.4E-08	1.1E-08	6.5E-09	4.0E-09	2.7E-09	2.3E-09
Uterus	1.2E-08	9.1E-09	4.8E-09	2.9E-09	1.9E-09	1.6E-09
Remainder	1.3E-08	1.0E-08	6.1E-09	4.0E-09	3.1E-09	2.6E-09
Effective Dose	3.5E-08	2.8E-08	1.7E-08	1.2E-08	9.2E-09	7.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.16.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ag-110m (T½ = 250 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.0E-08	3.6E-08	2.3E-08	1.4E-08	1.0E-08	8.9E-09
Bladder Wall	5.1E-09	4.0E-09	2.0E-09	1.2E-09	6.4E-10	4.9E-10
Bone Surface	1.8E-08	1.6E-08	8.9E-09	5.5E-09	4.1E-09	3.6E-09
Brain	3.2E-09	2.8E-09	1.7E-09	1.1E-09	8.1E-10	7.3E-10
Breast	3.4E-08	3.2E-08	2.3E-08	1.6E-08	1.0E-08	9.5E-09
GI-Tract						
Oesophagus	3.3E-08	3.1E-08	2.2E-08	1.5E-08	1.2E-08	1.1E-08
St Wall	2.2E-08	1.9E-08	1.2E-08	7.6E-09	6.4E-09	4.9E-09
SI Wall	1.3E-08	1.1E-08	5.7E-09	3.4E-09	2.1E-09	1.7E-09
ULI Wall	2.1E-08	1.7E-08	8.5E-09	5.2E-09	3.1E-09	2.6E-09
LLI Wall	3.4E-08	2.4E-08	1.2E-08	7.3E-09	4.1E-09	3.4E-09
Colon	2.7E-08	2.0E-08	9.8E-09	6.1E-09	3.5E-09	2.9E-09
Kidneys	1.8E-08	1.6E-08	8.7E-09	5.4E-09	3.9E-09	3.3E-09
Liver	3.5E-08	3.0E-08	1.8E-08	1.2E-08	9.8E-09	8.2E-09
Muscle	1.7E-08	1.5E-08	8.9E-09	5.8E-09	4.6E-09	3.9E-09
Ovaries	1.1E-08	8.3E-09	4.5E-09	2.7E-09	1.7E-09	1.3E-09
Pancreas	3.1E-08	2.7E-08	1.7E-08	1.1E-08	8.4E-09	6.5E-09
Red Marrow	1.3E-08	1.2E-08	8.3E-09	6.0E-09	5.1E-09	4.9E-09
Respiratory Tract						
ET Airways	1.3E-07	1.2E-07	6.2E-08	3.7E-08	2.2E-08	1.8E-08
Lungs	2.5E-07	2.2E-07	1.4E-07	1.0E-07	8.6E-08	7.1E-08
Skin	8.9E-09	7.9E-09	4.9E-09	3.1E-09	2.3E-09	2.1E-09
Spleen	2.9E-08	2.6E-08	1.5E-08	1.0E-08	7.8E-09	6.4E-09
Testes	2.6E-09	2.0E-09	8.9E-10	5.5E-10	2.8E-10	2.1E-10
Thymus	3.3E-08	3.1E-08	2.2E-08	1.5E-08	1.2E-08	1.1E-08
Thyroid	1.8E-08	1.6E-08	1.0E-08	6.1E-09	4.2E-09	3.7E-09
Uterus	7.6E-09	6.1E-09	3.1E-09	1.7E-09	9.9E-10	7.9E-10
Remainder	1.4E-08	1.3E-08	8.0E-09	5.4E-09	4.3E-09	3.7E-09
Effective Dose	4.6E-08	4.1E-08	2.6E-08	1.8E-08	1.5E-08	1.2E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.17. Antimony

(185) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned the oxides, hydroxides, halides, sulphides, sulphates and nitrates of antimony (Sb) to inhalation Class W and all other common compounds to Class D. This same classification was adopted in *ICRP Publication 30*, Part 3 (ICRP, 1981). The deposition and absorption of antimony have not been extensively studied in laboratory animals, although a number of acute and chronic studies have been performed using inhaled antimony (Felicetti *et al.*, 1974a,b; Newton *et al.*, 1994; Thomas *et al.*, 1973). Studies of occupationally exposed workers have been summarized by IARC (1989).

Absorption Types

(186) Felicetti *et al.* (1974a,b) showed that ^{124}Sb tartrate was 90% eliminated from the body of hamsters 7 d after inhalation. Both trivalent and pentavalent forms were consistent with Type F. When the antimony tartrate aerosols were heat treated at 100, 500 or 1 000°C before being inhaled by dogs or mice, differences in lung retention were observed. The authors did not speculate on the chemical form of the antimony after heat treatment. At 32 d after dogs inhaled the aerosols, 0.23% of the 100°C aerosol was retained in the lung, 25% of the 500°C aerosol, and 5% of the 1 000°C aerosol. Therefore, the 100°C and 1 000°C aerosols are Type F, and the 500°C aerosol is Type M. The lung retention pattern in mice was somewhat different with the 1 000°C aerosol retained in the lung as long or longer than the 500°C aerosol (Thomas *et al.*, 1973).

(187) Smelter workers exposed by inhalation to antimony trioxide and pentoxide showed a positive relationship between measured antimony lung content and period of employment, such that there was about a ten-fold increase for 40 years of employment (McCallum *et al.*, 1971). Other workers with pulmonary changes related to exposure to antimony trioxide had measured urinary excretion of antimony in hundreds of $\mu g\ l^{-1}$. both during and after employment (McCallum, 1963). Although the human data suggest possible Type M and S behaviours, the paucity of results does not provide a basis for firmer classification. On the other hand, findings in rats with high retention of Sb_2O_3 in lung 1 year after a 1-year chronic aerosol exposure are indicative of Type M behaviour (Newton *et al.*, 1994).

Dose coefficients

(188) Dose coefficients (given in Tables 5.17.2–5) were derived using the f_1 values given in Table 5.17.1 and the biokinetic data given in *ICRP Publication 69* (ICRP, 1995).

Table 5.17.1. Values of f_1 for inhaled particulate compounds of antimony

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.2	0.1
M[b]	0.02	0.01
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type M is recommended for use in the absence of specific information.

Table 5.17.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-124 (T½ = 60.2 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.8E-09	3.6E-09	1.8E-09	1.2E-09	8.3E-10	7.3E-10
Bladder Wall	4.7E-09	3.4E-09	2.2E-09	1.5E-09	1.1E-09	9.3E-10
Bone Surface	4.1E-08	3.3E-08	2.1E-08	1.1E-08	6.5E-09	6.6E-09
Brain	3.7E-09	2.7E-09	1.3E-09	8.5E-10	5.5E-10	4.8E-10
Breast	3.1E-09	2.2E-09	1.1E-09	6.9E-10	4.3E-10	3.8E-10
GI-Tract						
Oesophagus	4.2E-09	3.0E-09	1.4E-09	8.9E-10	5.5E-10	4.7E-10
St Wall	4.8E-09	3.2E-09	1.6E-09	1.0E-09	6.4E-10	5.5E-10
SI Wall	6.7E-09	5.0E-09	2.5E-09	1.6E-09	9.8E-10	8.4E-10
ULI Wall	1.8E-08	1.3E-08	5.9E-09	3.7E-09	2.0E-09	1.7E-09
LLI Wall	4.2E-08	3.0E-08	1.3E-08	8.2E-09	4.2E-09	3.6E-09
Colon	2.9E-08	2.0E-08	9.1E-09	5.7E-09	2.9E-09	2.5E-09
Kidneys	4.3E-09	3.1E-09	1.6E-09	1.1E-09	7.0E-10	6.1E-10
Liver	9.2E-09	6.7E-09	3.3E-09	2.3E-09	1.5E-09	1.2E-09
Muscle	4.0E-09	2.9E-09	1.4E-09	9.3E-10	5.9E-10	5.1E-10
Ovaries	5.6E-09	4.2E-09	2.2E-09	1.5E-09	9.6E-10	8.0E-10
Pancreas	4.4E-09	3.2E-09	1.6E-09	1.1E-09	7.0E-10	6.2E-10
Red Marrow	2.9E-08	1.8E-08	8.3E-09	4.8E-09	2.9E-09	2.3E-09
Respiratory Tract						
ET Airways	5.6E-08	4.9E-08	2.6E-08	1.5E-08	8.9E-09	7.0E-09
Lungs	4.0E-09	2.9E-09	1.4E-09	9.3E-10	6.2E-10	5.3E-10
Skin	3.2E-09	2.3E-09	1.1E-09	6.8E-10	4.2E-10	3.7E-10
Spleen	3.9E-09	2.8E-09	1.4E-09	9.2E-10	5.7E-10	4.9E-10
Testes	3.3E-09	2.4E-09	1.2E-09	7.6E-10	4.8E-10	4.0E-10
Thymus	4.2E-09	3.0E-09	1.4E-09	8.9E-10	5.5E-10	4.7E-10
Thyroid	3.6E-09	2.6E-09	1.3E-09	8.5E-10	5.5E-10	4.8E-10
Uterus	4.5E-09	3.4E-09	1.8E-09	1.2E-09	7.4E-10	6.3E-10
Remainder	3.0E-08	2.6E-08	1.4E-08	8.1E-09	4.8E-09	3.8E-09
Effective Dose	1.2E-08	8.8E-09	4.3E-09	2.6E-09	1.6E-09	1.3E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-124 (T½ = 60.2 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	7.5E-09	6.3E-09	3.8E-09	2.3E-09	1.7E-09	1.4E-09
Bladder Wall	2.4E-09	1.8E-09	9.8E-10	6.5E-10	4.1E-10	3.4E-10
Bone Surface	1.1E-08	8.8E-09	5.4E-09	3.1E-09	2.0E-09	1.9E-09
Brain	1.2E-09	9.4E-10	5.3E-10	3.5E-10	2.5E-10	2.2E-10
Breast	6.2E-09	5.4E-09	3.6E-09	2.5E-09	1.5E-09	1.4E-09
GI-Tract						
Oesophagus	6.5E-09	5.7E-09	3.6E-09	2.5E-09	1.9E-09	1.7E-09
St Wall	6.4E-09	4.8E-09	2.6E-09	1.6E-09	1.2E-09	9.7E-10
SI Wall	8.4E-09	6.1E-09	2.9E-09	1.8E-09	1.0E-09	8.5E-10
ULI Wall	2.9E-08	2.0E-08	8.9E-09	5.5E-09	2.8E-09	2.4E-09
LLI Wall	7.5E-08	4.9E-08	2.2E-08	1.3E-08	6.7E-09	5.6E-09
Colon	4.9E-08	3.3E-08	1.4E-08	8.9E-09	4.5E-09	3.8E-09
Kidneys	3.9E-09	3.2E-09	1.7E-09	1.0E-09	7.5E-10	6.2E-10
Liver	6.7E-09	5.6E-09	3.2E-09	2.1E-09	1.7E-09	1.3E-09
Muscle	3.8E-09	3.1E-09	1.7E-09	1.1E-09	8.4E-10	6.9E-10
Ovaries	4.8E-09	3.7E-09	1.9E-09	1.2E-09	7.6E-10	6.0E-10
Pancreas	6.2E-09	5.0E-09	3.0E-09	1.8E-09	1.4E-09	1.1E-09
Red Marrow	7.6E-09	5.5E-09	3.0E-09	1.9E-09	1.4E-09	1.2E-09
Respiratory Tract						
ET Airways	7.0E-08	6.1E-08	3.1E-08	1.9E-08	1.1E-08	8.8E-09
Lungs	1.7E-07	1.4E-07	8.6E-08	6.1E-08	5.3E-08	4.4E-08
Skin	2.2E-09	1.8E-09	9.9E-10	6.3E-10	4.4E-10	3.9E-10
Spleen	5.6E-09	4.8E-09	2.7E-09	1.7E-09	1.3E-09	1.0E-09
Testes	1.3E-09	9.6E-10	4.7E-10	2.9E-10	1.7E-10	1.4E-10
Thymus	6.5E-09	5.7E-09	3.6E-09	2.5E-09	1.9E-09	1.7E-09
Thyroid	3.7E-09	3.1E-09	1.8E-09	1.1E-09	7.4E-10	6.5E-10
Uterus	3.0E-09	2.4E-09	1.2E-09	7.3E-10	4.4E-10	3.5E-10
Remainder	3.5E-09	2.8E-09	1.6E-09	1.1E-09	8.1E-10	6.8E-10
Effective Dose	3.1E-08	2.4E-08	1.4E-08	9.6E-09	7.7E-09	6.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-124 (T½ = 60.2 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	9.6E-09	8.3E-09	5.0E-09	3.0E-09	2.2E-09	1.9E-09
Bladder Wall	2.0E-09	1.5E-09	7.3E-10	4.6E-10	2.5E-10	2.0E-10
Bone Surface	5.6E-09	4.3E-09	2.3E-09	1.4E-09	1.0E-09	8.8E-10
Brain	8.6E-10	6.8E-10	4.0E-10	2.8E-10	2.0E-10	1.8E-10
Breast	8.2E-09	7.3E-09	5.0E-09	3.5E-09	2.2E-09	2.0E-09
GI-Tract						
Oesophagus	8.3E-09	7.4E-09	4.9E-09	3.4E-09	2.7E-09	2.3E-09
St Wall	7.5E-09	5.8E-09	3.2E-09	2.0E-09	1.6E-09	1.2E-09
SI Wall	8.7E-09	6.3E-09	3.0E-09	1.9E-09	1.0E-09	8.4E-10
ULI Wall	3.1E-08	2.1E-08	9.3E-09	5.8E-09	2.9E-09	2.4E-09
LLI Wall	7.8E-08	5.2E-08	2.3E-08	1.4E-08	7.0E-09	5.8E-09
Colon	5.1E-08	3.4E-08	1.5E-08	9.2E-09	4.7E-09	3.9E-09
Kidneys	4.5E-09	3.8E-09	2.0E-09	1.2E-09	8.8E-10	7.2E-10
Liver	7.4E-09	6.5E-09	3.8E-09	2.5E-09	2.0E-09	1.6E-09
Muscle	4.5E-09	3.7E-09	2.1E-09	1.4E-09	1.0E-09	8.6E-10
Ovaries	4.7E-09	3.6E-09	1.8E-09	1.2E-09	7.0E-10	5.4E-10
Pancreas	7.7E-09	6.4E-09	3.9E-09	2.4E-09	1.8E-09	1.4E-09
Red Marrow	4.1E-09	3.2E-09	2.0E-09	1.4E-09	1.2E-09	1.1E-09
Respiratory Tract						
ET Airways	7.8E-08	6.7E-08	3.4E-08	2.0E-08	1.2E-08	9.8E-09
Lungs	2.4E-07	2.0E-07	1.2E-07	8.5E-08	7.3E-08	6.1E-08
Skin	2.3E-09	1.9E-09	1.1E-09	7.3E-10	5.1E-10	4.7E-10
Spleen	7.1E-09	6.2E-09	3.6E-09	2.3E-09	1.7E-09	1.4E-09
Testes	9.5E-10	6.9E-10	3.1E-10	2.0E-10	9.7E-11	7.0E-11
Thymus	8.3E-09	7.4E-09	4.9E-09	3.4E-09	2.7E-09	2.3E-09
Thyroid	4.4E-09	3.9E-09	2.4E-09	1.4E-09	9.3E-10	8.2E-10
Uterus	2.9E-09	2.3E-09	1.1E-09	6.5E-10	3.7E-10	2.8E-10
Remainder	3.9E-09	3.3E-09	1.9E-09	1.3E-09	1.0E-09	8.3E-10
Effective Dose	3.9E-08	3.1E-08	1.8E-08	1.3E-08	1.0E-08	8.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-125 (T½ = 2.77 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.6E-09	3.8E-09	2.2E-09	1.5E-09	1.1E-09	1.0E-09
Bladder Wall	3.5E-09	2.8E-09	1.7E-09	1.2E-09	8.2E-10	7.6E-10
Bone Surface	1.0E-07	9.1E-08	5.7E-08	3.3E-08	2.2E-08	2.3E-08
Brain	3.5E-09	2.9E-09	1.6E-09	1.0E-09	7.2E-10	6.6E-10
Breast	2.8E-09	2.2E-09	1.2E-09	8.0E-10	5.5E-10	5.1E-10
GI-Tract						
Oesophagus	3.5E-09	2.8E-09	1.5E-09	9.9E-10	6.9E-10	6.3E-10
St Wall	3.6E-09	2.8E-09	1.6E-09	1.0E-09	7.0E-10	6.5E-10
SI Wall	4.5E-09	3.7E-09	2.1E-09	1.4E-09	9.5E-10	8.6E-10
ULI Wall	7.6E-09	5.8E-09	3.0E-09	1.9E-09	1.2E-09	1.1E-09
LLI Wall	1.4E-08	1.1E-08	5.1E-09	3.3E-09	1.9E-09	1.7E-09
Colon	1.1E-08	7.9E-09	3.9E-09	2.5E-09	1.5E-09	1.3E-09
Kidneys	4.0E-09	3.3E-09	1.9E-09	1.3E-09	8.9E-10	8.2E-10
Liver	9.3E-09	7.6E-09	4.3E-09	3.0E-09	2.1E-09	1.9E-09
Muscle	3.5E-09	2.8E-09	1.6E-09	1.0E-09	7.2E-10	6.6E-10
Ovaries	4.3E-09	3.6E-09	2.1E-09	1.4E-09	9.8E-10	8.8E-10
Pancreas	4.1E-09	3.3E-09	1.9E-09	1.3E-09	9.0E-10	8.4E-10
Red Marrow	2.7E-08	2.1E-08	1.1E-08	6.2E-09	4.1E-09	3.5E-09
Respiratory Tract						
ET Airways	2.2E-08	1.8E-08	9.6E-09	5.8E-09	3.5E-09	2.9E-09
Lungs	3.7E-09	3.0E-09	1.7E-09	1.1E-09	7.9E-10	7.2E-10
Skin	2.9E-09	2.3E-09	1.2E-09	7.8E-10	5.3E-10	4.9E-10
Spleen	3.6E-09	2.9E-09	1.6E-09	1.1E-09	7.3E-10	6.7E-10
Testes	3.0E-09	2.4E-09	1.3E-09	8.5E-10	5.9E-10	5.4E-10
Thymus	3.5E-09	2.8E-09	1.5E-09	9.9E-10	6.9E-10	6.3E-10
Thyroid	3.4E-09	2.7E-09	1.5E-09	1.0E-09	7.0E-10	6.5E-10
Uterus	3.8E-09	3.1E-09	1.8E-09	1.2E-09	8.4E-10	7.7E-10
Remainder	3.6E-09	2.9E-09	1.6E-09	1.1E-09	7.3E-10	6.7E-10
Effective Dose	8.7E-09	6.8E-09	3.7E-09	2.3E-09	1.5E-09	1.4E-09

GI-Tract Gastrointestinal Tract
St Stomach
SI Small Intestine
ULI Upper Large Intestine
LLI Lower Large Intestine
ET Airways Extrathoracic airways
Lungs Thoracic airways

Table 5.17.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-125 (T½ = 2.77 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.4E-09	4.7E-09	2.9E-09	1.8E-09	1.3E-09	1.2E-09
Bladder Wall	1.5E-09	1.2E-09	7.6E-10	4.9E-10	3.5E-10	3.2E-10
Bone Surface	3.1E-08	2.9E-08	2.0E-08	1.1E-08	8.3E-09	8.7E-09
Brain	1.2E-09	1.0E-09	6.4E-10	4.0E-10	3.1E-10	2.9E-10
Breast	4.1E-09	3.8E-09	2.6E-09	1.8E-09	1.1E-09	1.0E-09
GI-Tract						
Oesophagus	4.2E-09	3.8E-09	2.6E-09	1.8E-09	1.4E-09	1.2E-09
St Wall	3.5E-09	2.9E-09	1.7E-09	1.1E-09	8.6E-10	6.9E-10
SI Wall	3.5E-09	2.7E-09	1.5E-09	9.4E-10	6.0E-10	5.3E-10
ULI Wall	9.5E-09	6.8E-09	3.2E-09	2.0E-09	1.1E-09	9.7E-10
LLI Wall	2.2E-08	1.5E-08	7.0E-09	4.3E-09	2.3E-09	2.0E-09
Colon	1.5E-08	1.0E-08	4.9E-09	3.0E-09	1.7E-09	1.4E-09
Kidneys	2.7E-09	2.4E-09	1.4E-09	8.5E-10	6.5E-10	5.5E-10
Liver	5.6E-09	4.9E-09	3.0E-09	2.0E-09	1.6E-09	1.4E-09
Muscle	2.7E-09	2.4E-09	1.4E-09	8.8E-10	6.9E-10	6.0E-10
Ovaries	2.5E-09	2.1E-09	1.2E-09	7.6E-10	5.3E-10	4.6E-10
Pancreas	4.2E-09	3.7E-09	2.3E-09	1.4E-09	1.1E-09	8.9E-10
Red Marrow	8.6E-09	7.3E-09	4.2E-09	2.5E-09	1.9E-09	1.7E-09
Respiratory Tract						
ET Airways	4.6E-08	3.7E-08	1.8E-08	1.1E-08	6.5E-09	5.8E-09
Lungs	1.2E-07	1.0E-07	6.4E-08	4.5E-08	4.0E-08	3.2E-08
Skin	1.6E-09	1.4E-09	8.3E-10	5.0E-10	3.9E-10	3.5E-10
Spleen	4.0E-09	3.5E-09	2.0E-09	1.3E-09	9.7E-10	8.1E-10
Testes	1.0E-09	8.8E-10	5.0E-10	3.2E-10	2.3E-10	2.1E-10
Thymus	4.2E-09	3.8E-09	2.6E-09	1.8E-09	1.4E-09	1.2E-09
Thyroid	2.6E-09	2.3E-09	1.4E-09	8.6E-10	6.1E-10	5.5E-10
Uterus	1.8E-09	1.6E-09	8.9E-10	5.5E-10	3.9E-10	3.5E-10
Remainder	2.5E-09	2.2E-09	1.3E-09	8.5E-10	6.7E-10	5.9E-10
Effective Dose	2.0E-08	1.6E-08	1.0E-08	6.8E-09	5.8E-09	4.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-125 (T½ = 2.77 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.4E-08	1.3E-08	8.3E-09	5.1E-09	3.9E-09	3.5E-09
Bladder Wall	1.2E-09	9.7E-10	5.2E-10	2.9E-10	1.6E-10	1.3E-10
Bone Surface	1.1E-08	9.4E-09	5.6E-09	3.3E-09	2.5E-09	2.4E-09
Brain	9.0E-10	8.0E-10	5.3E-10	3.2E-10	2.5E-10	2.3E-10
Breast	1.2E-08	1.2E-08	8.6E-09	5.6E-09	3.7E-09	3.6E-09
GI-Tract						
Oesophagus	1.1E-08	1.1E-08	8.3E-09	5.7E-09	4.5E-09	4.2E-09
St Wall	7.2E-09	6.5E-09	4.3E-09	2.8E-09	2.2E-09	1.8E-09
SI Wall	4.1E-09	3.3E-09	1.8E-09	1.0E-09	6.2E-10	5.2E-10
ULI Wall	1.1E-08	8.0E-09	3.9E-09	2.3E-09	1.3E-09	1.1E-09
LLI Wall	2.4E-08	1.7E-08	7.6E-09	4.6E-09	2.5E-09	2.1E-09
Colon	1.7E-08	1.2E-08	5.5E-09	3.3E-09	1.8E-09	1.5E-09
Kidneys	5.2E-09	4.7E-09	2.8E-09	1.7E-09	1.3E-09	1.1E-09
Liver	1.0E-08	9.7E-09	6.4E-09	4.2E-09	3.4E-09	3.0E-09
Muscle	5.6E-09	5.2E-09	3.3E-09	2.1E-09	1.7E-09	1.5E-09
Ovaries	2.5E-09	2.0E-09	1.1E-09	6.2E-10	4.0E-10	3.3E-10
Pancreas	1.0E-08	9.5E-09	6.2E-09	3.7E-09	2.9E-09	2.5E-09
Red Marrow	5.2E-09	4.7E-09	3.2E-09	2.3E-09	2.0E-09	1.9E-09
Respiratory Tract						
ET Airways	1.1E-07	9.4E-08	4.7E-08	3.1E-08	1.8E-08	1.7E-08
Lungs	3.0E-07	2.7E-07	1.7E-07	1.2E-07	9.9E-08	8.7E-08
Skin	2.7E-09	2.6E-09	1.6E-09	1.0E-09	8.0E-10	7.3E-10
Spleen	9.9E-09	9.3E-09	5.8E-09	3.7E-09	2.8E-09	2.4E-09
Testes	6.0E-10	4.7E-10	2.1E-10	1.3E-10	6.8E-11	5.3E-11
Thymus	1.1E-08	1.1E-08	8.3E-09	5.7E-09	4.5E-09	4.2E-09
Thyroid	5.8E-09	5.5E-09	3.6E-09	2.1E-09	1.5E-09	1.3E-09
Uterus	1.8E-09	1.5E-09	7.9E-10	4.0E-10	2.5E-10	2.1E-10
Remainder	4.8E-09	4.5E-09	2.9E-09	2.0E-09	1.6E-09	1.5E-09
Effective Dose	4.2E-08	3.8E-08	2.4E-08	1.6E-08	1.4E-08	1.2E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-126 (T½ = 12.4 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	3.3E-09	2.5E-09	1.3E-09	8.7E-10	5.9E-10	5.1E-10
Bladder Wall	3.5E-09	2.6E-09	1.7E-09	1.2E-09	8.2E-10	7.1E-10
Bone Surface	1.4E-08	1.1E-08	6.7E-09	3.8E-09	2.2E-09	2.2E-09
Brain	2.4E-09	1.7E-09	8.7E-10	5.8E-10	3.7E-10	3.3E-10
Breast	2.0E-09	1.4E-09	6.8E-10	4.4E-10	2.7E-10	2.4E-10
GI-Tract						
Oesophagus	3.4E-09	2.4E-09	1.1E-09	6.7E-10	3.9E-10	3.3E-10
St Wall	3.6E-09	2.4E-09	1.2E-09	7.6E-10	4.7E-10	4.1E-10
SI Wall	5.7E-09	4.3E-09	2.2E-09	1.5E-09	8.6E-10	7.3E-10
ULI Wall	1.4E-08	1.0E-08	4.7E-09	3.0E-09	1.6E-09	1.4E-09
LLI Wall	3.0E-08	2.2E-08	9.8E-09	6.2E-09	3.2E-09	2.7E-09
Colon	2.1E-08	1.5E-08	6.9E-09	4.4E-09	2.3E-09	2.0E-09
Kidneys	3.0E-09	2.2E-09	1.2E-09	7.8E-10	5.0E-10	4.3E-10
Liver	5.1E-09	3.6E-09	1.8E-09	1.3E-09	8.3E-10	7.0E-10
Muscle	2.9E-09	2.1E-09	1.0E-09	6.9E-10	4.3E-10	3.7E-10
Ovaries	5.1E-09	4.0E-09	2.1E-09	1.4E-09	9.0E-10	7.3E-10
Pancreas	3.2E-09	2.3E-09	1.2E-09	7.8E-10	5.0E-10	4.4E-10
Red Marrow	1.2E-08	7.3E-09	3.5E-09	2.1E-09	1.4E-09	1.1E-09
Respiratory Tract						
ET Airways	8.1E-08	7.3E-08	3.9E-08	2.3E-08	1.3E-08	1.0E-08
Lungs	2.8E-09	2.0E-09	9.9E-10	6.6E-10	4.4E-10	3.7E-10
Skin	2.1E-09	1.4E-09	7.0E-10	4.4E-10	2.7E-10	2.4E-10
Spleen	2.7E-09	1.9E-09	9.7E-10	6.4E-10	4.0E-10	3.4E-10
Testes	2.3E-09	1.6E-09	8.2E-10	5.2E-10	3.2E-10	2.8E-10
Thymus	3.4E-09	2.4E-09	1.1E-09	6.7E-10	3.9E-10	3.3E-10
Thyroid	2.3E-09	1.7E-09	8.7E-10	5.7E-10	3.8E-10	3.3E-10
Uterus	3.7E-09	2.8E-09	1.5E-09	9.9E-10	6.1E-10	5.1E-10
Remainder	4.2E-08	3.8E-08	2.0E-08	1.2E-08	6.9E-09	5.4E-09
Effective Dose	8.8E-09	6.6E-09	3.3E-09	2.1E-09	1.2E-09	1.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-126 (T½ = 12.4 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.6E-09	3.7E-09	2.2E-09	1.3E-09	9.5E-10	7.9E-10
Bladder Wall	2.4E-09	1.8E-09	8.9E-10	6.3E-10	3.4E-10	2.8E-10
Bone Surface	4.1E-09	3.2E-09	1.8E-09	1.1E-09	7.0E-10	6.4E-10
Brain	7.0E-10	5.2E-10	3.0E-10	2.0E-10	1.4E-10	1.2E-10
Breast	3.6E-09	3.0E-09	2.0E-09	1.4E-09	8.4E-10	7.7E-10
GI-Tract						
Oesophagus	4.5E-09	3.6E-09	2.2E-09	1.5E-09	1.1E-09	9.2E-10
St Wall	4.9E-09	3.4E-09	1.8E-09	1.2E-09	8.2E-10	6.2E-10
SI Wall	7.8E-09	5.7E-09	2.7E-09	1.8E-09	9.7E-10	8.0E-10
ULI Wall	2.3E-08	1.6E-08	7.1E-09	4.6E-09	2.3E-09	1.9E-09
LLI Wall	5.4E-08	3.6E-08	1.6E-08	1.0E-08	5.0E-09	4.2E-09
Colon	3.6E-08	2.5E-08	1.1E-08	6.9E-09	3.5E-09	2.9E-09
Kidneys	2.6E-09	2.0E-09	1.1E-09	6.6E-10	4.5E-10	3.6E-10
Liver	4.1E-09	3.3E-09	1.8E-09	1.2E-09	8.9E-10	7.2E-10
Muscle	2.8E-09	2.1E-09	1.1E-09	7.3E-10	5.2E-10	4.2E-10
Ovaries	5.9E-09	4.5E-09	2.2E-09	1.5E-09	9.0E-10	6.9E-10
Pancreas	4.0E-09	3.1E-09	1.8E-09	1.1E-09	8.1E-10	6.2E-10
Red Marrow	3.3E-09	2.4E-09	1.4E-09	9.6E-10	7.2E-10	6.4E-10
Respiratory Tract						
ET Airways	8.7E-08	7.8E-08	4.1E-08	2.4E-08	1.4E-08	1.1E-08
Lungs	6.5E-08	5.1E-08	3.2E-08	2.3E-08	2.1E-08	1.7E-08
Skin	1.4E-09	1.1E-09	5.8E-10	3.6E-10	2.5E-10	2.2E-10
Spleen	3.7E-09	2.9E-09	1.6E-09	1.0E-09	7.3E-10	5.8E-10
Testes	1.2E-09	8.4E-10	3.8E-10	2.4E-10	1.2E-10	9.9E-11
Thymus	4.5E-09	3.6E-09	2.2E-09	1.5E-09	1.1E-09	9.2E-10
Thyroid	2.1E-09	1.7E-09	9.9E-10	6.1E-10	4.1E-10	3.6E-10
Uterus	3.3E-09	2.5E-09	1.2E-09	7.9E-10	4.3E-10	3.5E-10
Remainder	4.5E-08	4.0E-08	2.1E-08	1.2E-08	5.1E-10	4.2E-10
Effective Dose	1.7E-08	1.3E-08	7.4E-09	5.1E-09	3.5E-09	2.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-126 (T½ = 12.4 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.0E-09	4.1E-09	2.4E-09	1.4E-09	1.0E-09	8.6E-10
Bladder Wall	2.2E-09	1.7E-09	7.7E-10	5.5E-10	2.6E-10	2.2E-10
Bone Surface	2.9E-09	2.2E-09	1.1E-09	7.0E-10	5.0E-10	4.3E-10
Brain	5.0E-10	3.6E-10	2.2E-10	1.5E-10	1.1E-10	9.6E-11
Breast	4.0E-09	3.4E-09	2.3E-09	1.6E-09	9.6E-10	8.8E-10
GI-Tract						
Oesophagus	4.9E-09	4.0E-09	2.5E-09	1.7E-09	1.2E-09	1.1E-09
St Wall	5.1E-09	3.6E-09	1.9E-09	1.2E-09	8.9E-10	6.7E-10
SI Wall	8.1E-09	5.8E-09	2.8E-09	1.8E-09	9.8E-10	8.0E-10
ULI Wall	2.4E-08	1.6E-08	7.4E-09	4.7E-09	2.4E-09	2.0E-09
LLI Wall	5.6E-08	3.7E-08	1.6E-08	1.0E-08	5.2E-09	4.3E-09
Colon	3.8E-08	2.6E-08	1.1E-08	7.1E-09	3.6E-09	3.0E-09
Kidneys	2.6E-09	2.0E-09	1.1E-09	6.7E-10	4.6E-10	3.6E-10
Liver	4.2E-09	3.3E-09	1.9E-09	1.2E-09	9.3E-10	7.5E-10
Muscle	2.8E-09	2.2E-09	1.2E-09	7.6E-10	5.5E-10	4.5E-10
Ovaries	5.9E-09	4.5E-09	2.2E-09	1.5E-09	8.8E-10	6.7E-10
Pancreas	4.3E-09	3.3E-09	1.9E-09	1.2E-09	8.8E-10	6.7E-10
Red Marrow	2.2E-09	1.7E-09	1.1E-09	8.1E-10	6.4E-10	5.8E-10
Respiratory Tract						
ET Airways	8.8E-08	7.9E-08	4.2E-08	2.4E-08	1.4E-08	1.1E-08
Lungs	7.7E-08	6.0E-08	3.8E-08	2.7E-08	2.5E-08	2.0E-08
Skin	1.4E-09	1.1E-09	5.8E-10	3.6E-10	2.6E-10	2.2E-10
Spleen	3.9E-09	3.2E-09	1.7E-09	1.1E-09	8.1E-10	6.4E-10
Testes	1.0E-09	7.3E-10	3.2E-10	2.0E-10	8.9E-11	7.2E-11
Thymus	4.9E-09	4.0E-09	2.5E-09	1.7E-09	1.2E-09	1.1E-09
Thyroid	2.2E-09	1.8E-09	1.1E-09	6.4E-10	4.3E-10	3.7E-10
Uterus	3.2E-09	2.5E-09	1.2E-09	7.5E-10	4.0E-10	3.2E-10
Remainder	4.5E-08	4.0E-08	2.1E-08	7.4E-10	5.4E-10	4.4E-10
Effective Dose	1.9E-08	1.5E-08	8.2E-09	5.0E-09	4.0E-09	3.2E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.5(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-127 (T½ = 3.85 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	8.7E-10	5.9E-10	2.9E-10	1.9E-10	1.2E-10	1.0E-10
Bladder Wall	1.4E-09	1.0E-09	6.9E-10	5.3E-10	4.0E-10	3.2E-10
Bone Surface	4.4E-09	3.3E-09	2.0E-09	1.1E-09	6.4E-10	6.4E-10
Brain	7.5E-10	4.9E-10	2.4E-10	1.5E-10	9.1E-11	7.9E-11
Breast	7.0E-10	4.5E-10	2.1E-10	1.3E-10	7.7E-11	6.5E-11
GI-Tract						
Oesophagus	9.9E-10	6.6E-10	2.9E-10	1.7E-10	9.6E-11	8.0E-11
St Wall	1.5E-09	9.4E-10	4.2E-10	2.6E-10	1.5E-10	1.3E-10
SI Wall	2.5E-09	1.8E-09	8.1E-10	5.2E-10	2.7E-10	2.3E-10
ULI Wall	1.2E-08	8.8E-09	3.8E-09	2.3E-09	1.1E-09	9.2E-10
LLI Wall	3.1E-08	2.2E-08	9.3E-09	5.6E-09	2.7E-09	2.3E-09
Colon	2.0E-08	1.4E-08	6.1E-09	3.7E-09	1.8E-09	1.5E-09
Kidneys	8.4E-10	5.6E-10	2.8E-10	1.8E-10	1.1E-10	9.2E-11
Liver	2.2E-09	1.5E-09	6.9E-10	4.6E-10	2.8E-10	2.3E-10
Muscle	8.5E-10	5.7E-10	2.7E-10	1.7E-10	1.0E-10	8.6E-11
Ovaries	1.3E-09	9.3E-10	4.6E-10	3.1E-10	1.8E-10	1.5E-10
Pancreas	8.7E-10	5.8E-10	2.8E-10	1.8E-10	1.1E-10	9.4E-11
Red Marrow	8.4E-09	4.8E-09	2.1E-09	1.2E-09	6.8E-10	5.1E-10
Respiratory Tract						
ET Airways	2.8E-08	2.3E-08	1.2E-08	7.0E-09	4.0E-09	3.3E-09
Lungs	8.8E-10	5.9E-10	2.9E-10	1.9E-10	1.3E-10	1.0E-10
Skin	7.1E-10	4.6E-10	2.1E-10	1.3E-10	7.7E-11	6.7E-11
Spleen	8.1E-10	5.3E-10	2.5E-10	1.6E-10	9.5E-11	8.0E-11
Testes	7.4E-10	4.9E-10	2.3E-10	1.4E-10	8.5E-11	7.2E-11
Thymus	9.9E-10	6.6E-10	2.9E-10	1.7E-10	9.6E-11	8.0E-11
Thyroid	7.4E-10	4.9E-10	2.4E-10	1.5E-10	9.2E-11	8.0E-11
Uterus	9.9E-10	7.0E-10	3.5E-10	2.2E-10	1.3E-10	1.1E-10
Remainder	1.5E-08	1.2E-08	5.9E-09	3.6E-09	2.0E-09	1.7E-09
Effective Dose	5.1E-09	3.5E-09	1.6E-09	9.7E-10	5.2E-10	4.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.5(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-127 (T½ = 3.85 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.4E-10	4.1E-10	2.3E-10	1.4E-10	9.7E-11	8.0E-11
Bladder Wall	5.3E-10	3.9E-10	2.1E-10	1.5E-10	8.9E-11	7.4E-11
Bone Surface	8.1E-10	6.1E-10	3.5E-10	2.0E-10	1.2E-10	1.2E-10
Brain	1.4E-10	9.4E-11	5.1E-11	3.5E-11	2.3E-11	2.1E-11
Breast	4.2E-10	3.3E-10	2.1E-10	1.4E-10	8.2E-11	7.5E-11
GI-Tract						
Oesophagus	6.5E-10	4.9E-10	2.6E-10	1.6E-10	1.1E-10	9.2E-11
St Wall	1.9E-09	1.2E-09	5.2E-10	3.2E-10	1.9E-10	1.5E-10
SI Wall	4.3E-09	2.9E-09	1.3E-09	8.1E-10	4.0E-10	3.3E-10
ULI Wall	2.3E-08	1.5E-08	6.4E-09	4.0E-09	1.9E-09	1.5E-09
LLI Wall	6.0E-08	3.9E-08	1.7E-08	1.0E-08	4.8E-09	4.0E-09
Colon	3.9E-08	2.6E-08	1.1E-08	6.6E-09	3.1E-09	2.6E-09
Kidneys	3.8E-10	2.8E-10	1.4E-10	9.1E-11	5.8E-11	4.7E-11
Liver	6.6E-10	4.8E-10	2.5E-10	1.6E-10	1.1E-10	8.9E-11
Muscle	4.2E-10	3.1E-10	1.6E-10	1.0E-10	6.6E-11	5.4E-11
Ovaries	1.2E-09	8.9E-10	4.4E-10	3.0E-10	1.7E-10	1.3E-10
Pancreas	5.3E-10	3.9E-10	2.1E-10	1.3E-10	8.9E-11	7.0E-11
Red Marrow	1.2E-09	7.3E-10	3.6E-10	2.2E-10	1.4E-10	1.2E-10
Respiratory Tract						
ET Airways	3.2E-08	2.6E-08	1.3E-08	7.7E-09	4.4E-09	3.7E-09
Lungs	4.0E-08	3.1E-08	1.9E-08	1.4E-08	1.4E-08	1.1E-08
Skin	2.3E-10	1.6E-10	8.2E-11	5.1E-11	3.3E-11	2.8E-11
Spleen	4.7E-10	3.6E-10	1.8E-10	1.2E-10	7.9E-11	6.3E-11
Testes	2.5E-10	1.8E-10	7.8E-11	4.8E-11	2.4E-11	2.0E-11
Thymus	6.5E-10	4.9E-10	2.6E-10	1.6E-10	1.1E-10	9.2E-11
Thyroid	2.7E-10	2.0E-10	1.1E-10	7.2E-11	4.7E-11	4.1E-11
Uterus	6.6E-10	5.0E-10	2.4E-10	1.6E-10	8.3E-11	6.7E-11
Remainder	4.6E-10	3.3E-10	1.7E-10	1.1E-10	7.3E-11	6.0E-11
Effective Dose	1.0E-08	7.3E-09	3.9E-09	2.7E-09	2.1E-09	1.7E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.17.5(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Sb-127 ($T\frac{1}{2}$ = 3.85 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.1E-10	4.0E-10	2.2E-10	1.4E-10	9.6E-11	7.8E-11
Bladder Wall	4.3E-10	3.1E-10	1.5E-10	1.1E-10	5.1E-11	4.3E-11
Bone Surface	4.0E-10	2.7E-10	1.4E-10	8.7E-11	5.7E-11	5.0E-11
Brain	7.3E-11	4.8E-11	2.9E-11	2.1E-11	1.4E-11	1.3E-11
Breast	4.0E-10	3.2E-10	2.1E-10	1.4E-10	8.4E-11	7.7E-11
GI-Tract						
Oesophagus	6.2E-10	4.7E-10	2.6E-10	1.7E-10	1.1E-10	9.5E-11
St Wall	2.0E-09	1.2E-09	5.3E-10	3.2E-10	2.0E-10	1.6E-10
SI Wall	4.5E-09	3.0E-09	1.3E-09	8.4E-10	4.1E-10	3.4E-10
ULI Wall	2.4E-08	1.6E-08	6.7E-09	4.1E-09	1.9E-09	1.6E-09
LLI Wall	6.3E-08	4.1E-08	1.7E-08	1.0E-08	5.0E-09	4.1E-09
Colon	4.1E-08	2.7E-08	1.1E-08	6.9E-09	3.3E-09	2.7E-09
Kidneys	3.3E-10	2.4E-10	1.3E-10	8.1E-11	5.2E-11	4.2E-11
Liver	5.0E-10	3.7E-10	2.0E-10	1.3E-10	9.0E-11	7.2E-11
Muscle	3.8E-10	2.8E-10	1.5E-10	9.4E-11	6.2E-11	5.0E-11
Ovaries	1.2E-09	8.8E-10	4.3E-10	2.9E-10	1.7E-10	1.3E-10
Pancreas	5.0E-10	3.7E-10	2.1E-10	1.3E-10	8.8E-11	6.7E-11
Red Marrow	4.2E-10	2.5E-10	1.5E-10	1.1E-10	7.8E-11	6.9E-11
Respiratory Tract						
ET Airways	3.3E-08	2.6E-08	1.3E-08	7.8E-09	4.5E-09	3.8E-09
Lungs	4.6E-08	3.6E-08	2.2E-08	1.7E-08	1.6E-08	1.2E-08
Skin	1.8E-10	1.3E-10	6.6E-11	4.2E-11	2.8E-11	2.3E-11
Spleen	4.4E-10	3.4E-10	1.8E-10	1.1E-10	7.8E-11	6.2E-11
Testes	2.0E-10	1.4E-10	5.8E-11	3.6E-11	1.6E-11	1.3E-11
Thymus	6.2E-10	4.7E-10	2.6E-10	1.7E-10	1.1E-10	9.5E-11
Thyroid	2.2E-10	1.7E-10	1.0E-10	6.3E-11	4.2E-11	3.7E-11
Uterus	6.2E-10	4.7E-10	2.3E-10	1.5E-10	7.6E-11	6.1E-11
Remainder	4.1E-10	3.0E-10	1.6E-10	1.1E-10	6.9E-11	5.7E-11
Effective Dose	1.1E-08	7.9E-09	4.2E-09	3.0E-09	2.3E-09	1.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.18. Tellurium

(189) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides and nitrates of tellurium (Te) to inhalation Class W and all other compounds to Class D. In the absence of any relevant experimental data this classification was adopted in *ICRP Publication 30*, Part 1 (ICRP, 1979).

(190) Although many studies have been reported relating to the toxicity of tellurium, and to its biokinetics following ingestion and injection (Kron *et al.*, 1991; ICRP, 1993), no experimental studies of the behaviour of tellurium following deposition in the respiratory tract have been identified in the literature.

Absorption Types

(a) *Gases and vapours*

(191) In one study following accidental inhalation of tellurium in the form of hexafluoride gas and possibly also tellurium esters (Blackadder and Manderson, 1975), absorption to blood was described as rapid, but insufficient information was available to estimate the fraction deposited, or to indicate assignment to Type V or F. Tellurium in gas and vapour forms are assigned here to Class SR-1 (100% deposition) with Type F clearance.

(b) *Particulate aerosols*

(192) No direct information was found in the literature on the rate of absorption of tellurium following respiratory tract deposition of particulate compounds.

Dose coefficients

(193) Dose coefficients (in Table 5.18.2–5) were derived for the gases and vapours given in Tables 5.18.1a, and for particulate aerosols, using the f_1 values given in Table 5.18.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993) and Annexe C of this publication.

Table 5.18.1a. Classification and absorption Types for gas and vapour compounds of tellurium

Chemical form/origin	Deposition: Vapour Class	Deposition: Fraction deposited (%)	Absorption: Type	Absorption: f_1
Unspecified	SR-1	100	F	[a]

[a]As for Type F in Table 5.18.1b.

Table 5.18.1b. Values of f_1 for inhaled particulate compounds of tellurium

Absorption Type	f_1[a] 3 mo	f_1[a] 1 y–adult
F	0.6	0.3
M[b]	0.2	0.1
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type M is recommended for use in the absence of specific information.

Table 5.18.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-127m (T½ = 109 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	1.6E-09	9.8E-10	4.4E-10	2.6E-10	1.5E-10	1.3E-10
Bladder Wall	2.0E-09	1.2E-09	7.4E-10	5.4E-10	3.8E-10	3.0E-10
Bone Surface	1.8E-07	1.4E-07	9.2E-08	5.0E-08	2.8E-08	2.9E-08
Brain	1.6E-09	9.4E-10	4.2E-10	2.5E-10	1.5E-10	1.2E-10
Breast	1.5E-09	8.8E-10	3.9E-10	2.4E-10	1.3E-10	1.1E-10
GI-Tract						
Oesophagus	1.5E-09	9.0E-10	4.0E-10	2.4E-10	1.4E-10	1.1E-10
St Wall	1.7E-09	9.9E-10	4.4E-10	2.6E-10	1.5E-10	1.2E-10
SI Wall	1.8E-09	1.2E-09	5.3E-10	3.2E-10	1.7E-10	1.5E-10
ULI Wall	6.5E-09	5.3E-09	2.3E-09	1.4E-09	6.7E-10	5.6E-10
LLI Wall	1.8E-08	1.5E-08	6.6E-09	3.9E-09	1.9E-09	1.6E-09
Colon	1.2E-08	9.6E-09	4.1E-09	2.5E-09	1.2E-09	1.0E-09
Kidneys	1.9E-08	1.1E-08	5.6E-09	3.7E-09	2.5E-09	2.1E-09
Liver	1.5E-09	8.9E-10	4.0E-10	2.4E-10	1.3E-10	1.1E-10
Muscle	1.5E-09	9.2E-10	4.1E-10	2.5E-10	1.4E-10	1.2E-10
Ovaries	1.6E-09	9.6E-10	4.3E-10	2.6E-10	1.5E-10	1.2E-10
Pancreas	1.5E-09	9.0E-10	4.0E-10	2.4E-10	1.4E-10	1.2E-10
Red Marrow	1.2E-07	7.5E-08	3.3E-08	1.8E-08	1.0E-08	7.4E-09
Respiratory Tract						
ET Airways	1.3E-08	9.3E-09	4.0E-09	2.6E-09	1.4E-09	1.3E-09
Lungs	1.6E-09	9.7E-10	4.4E-10	2.7E-10	1.6E-10	1.4E-10
Skin	1.5E-09	8.9E-10	4.0E-10	2.4E-10	1.3E-10	1.1E-10
Spleen	1.5E-09	9.1E-10	4.1E-10	2.4E-10	1.4E-10	1.1E-10
Testes	1.5E-09	8.7E-10	3.9E-10	2.3E-10	1.3E-10	1.1E-10
Thymus	1.5E-09	9.0E-10	4.0E-10	2.4E-10	1.4E-10	1.1E-10
Thyroid	4.2E-08	3.4E-08	1.6E-08	6.9E-09	4.3E-09	2.8E-09
Uterus	1.5E-09	9.0E-10	4.1E-10	2.4E-10	1.4E-10	1.1E-10
Remainder	1.8E-09	1.1E-09	4.8E-10	2.9E-10	1.7E-10	1.4E-10
Effective Dose	2.1E-08	1.4E-08	6.5E-09	3.5E-09	2.0E-09	1.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-127m (T½ = 109 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	7.3E-10	4.3E-10	2.1E-10	1.2E-10	7.0E-11	5.8E-11
Bladder Wall	6.8E-10	3.8E-10	2.4E-10	1.7E-10	1.3E-10	1.0E-10
Bone Surface	6.2E-08	4.1E-08	2.7E-08	1.5E-08	8.6E-09	9.0E-09
Brain	5.3E-10	2.7E-10	1.3E-10	7.6E-11	4.6E-11	3.9E-11
Breast	6.4E-10	3.8E-10	2.0E-10	1.2E-10	6.2E-11	5.7E-11
GI-Tract						
Oesophagus	6.4E-10	3.8E-10	1.9E-10	1.1E-10	6.6E-11	5.5E-11
St Wall	1.1E-09	6.2E-10	2.8E-10	1.6E-10	1.0E-10	8.1E-11
SI Wall	1.9E-09	1.3E-09	5.6E-10	3.4E-10	1.8E-10	1.5E-10
ULI Wall	1.3E-08	9.1E-09	3.9E-09	2.4E-09	1.2E-09	9.6E-10
LLI Wall	4.2E-08	3.0E-08	1.3E-08	7.7E-09	3.8E-09	3.1E-09
Colon	2.5E-08	1.8E-08	7.7E-09	4.6E-09	2.3E-09	1.9E-09
Kidneys	6.3E-09	3.3E-09	1.7E-09	1.1E-09	7.7E-10	6.4E-10
Liver	6.4E-10	3.8E-10	1.8E-10	1.1E-10	7.0E-11	5.7E-11
Muscle	6.0E-10	3.3E-10	1.6E-10	9.5E-11	5.9E-11	4.9E-11
Ovaries	6.1E-10	3.4E-10	1.6E-10	9.7E-11	5.6E-11	4.6E-11
Pancreas	6.4E-10	3.7E-10	1.7E-10	9.6E-11	5.8E-11	4.7E-11
Red Marrow	3.9E-08	2.1E-08	9.9E-09	5.2E-09	3.1E-09	2.3E-09
Respiratory Tract						
ET Airways	4.5E-08	3.3E-08	1.4E-08	9.2E-09	5.1E-09	4.9E-09
Lungs	2.1E-07	1.7E-07	1.1E-07	7.7E-08	7.0E-08	5.6E-08
Skin	5.2E-10	2.8E-10	1.3E-10	7.6E-11	4.5E-11	3.8E-11
Spleen	6.5E-10	3.8E-10	1.8E-10	1.0E-10	6.1E-11	5.1E-11
Testes	5.0E-10	2.6E-10	1.2E-10	7.0E-11	4.1E-11	3.5E-11
Thymus	6.4E-10	3.8E-10	1.9E-10	1.1E-10	6.6E-11	5.5E-11
Thyroid	1.4E-08	9.8E-09	4.7E-09	2.0E-09	1.3E-09	8.6E-10
Uterus	5.4E-10	2.9E-10	1.3E-10	7.7E-11	4.5E-11	3.8E-11
Remainder	7.0E-10	3.9E-10	1.9E-10	1.1E-10	7.1E-11	5.9E-11
Effective Dose	3.5E-08	2.6E-08	1.5E-08	1.1E-08	9.2E-09	7.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-127m (T½ = 109 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.4E-10	2.6E-10	1.4E-10	7.2E-11	4.3E-11	3.4E-11
Bladder Wall	7.5E-11	3.9E-11	2.0E-11	1.4E-11	8.1E-12	6.3E-12
Bone Surface	4.6E-09	2.5E-09	1.5E-09	8.2E-10	4.6E-10	4.7E-10
Brain	4.0E-11	1.8E-11	8.3E-12	4.9E-12	2.9E-12	2.5E-12
Breast	2.8E-10	2.2E-10	1.4E-10	9.2E-11	3.8E-11	3.9E-11
GI-Tract						
Oesophagus	2.6E-10	2.1E-10	1.2E-10	7.5E-11	4.3E-11	3.4E-11
St Wall	7.8E-10	4.6E-10	2.1E-10	1.2E-10	7.8E-11	6.0E-11
SI Wall	1.9E-09	1.3E-09	5.6E-10	3.3E-10	1.7E-10	1.4E-10
ULI Wall	1.5E-08	1.0E-08	4.4E-09	2.6E-09	1.3E-09	1.1E-09
LLI Wall	5.1E-08	3.4E-08	1.5E-08	8.7E-09	4.3E-09	3.6E-09
Colon	3.1E-08	2.0E-08	8.8E-09	5.3E-09	2.6E-09	2.2E-09
Kidneys	5.1E-10	2.3E-10	1.1E-10	6.9E-11	4.5E-11	3.6E-11
Liver	2.7E-10	2.1E-10	1.1E-10	6.9E-11	5.0E-11	3.8E-11
Muscle	1.7E-10	1.3E-10	6.7E-11	4.1E-11	2.9E-11	2.3E-11
Ovaries	1.6E-10	1.0E-10	4.6E-11	2.9E-11	1.5E-11	1.1E-11
Pancreas	2.5E-10	1.9E-10	9.3E-11	4.5E-11	2.8E-11	2.0E-11
Red Marrow	2.8E-09	1.2E-09	5.3E-10	2.9E-10	1.6E-10	1.2E-10
Respiratory Tract						
ET Airways	6.8E-08	5.1E-08	2.2E-08	1.5E-08	8.1E-09	7.8E-09
Lungs	3.1E-07	2.5E-07	1.5E-07	1.1E-07	9.7E-08	7.9E-08
Skin	7.6E-11	4.6E-11	2.3E-11	1.3E-11	7.9E-12	7.1E-12
Spleen	2.7E-10	2.1E-10	1.0E-10	5.5E-11	3.4E-11	2.7E-11
Testes	4.4E-11	2.0E-11	8.2E-12	4.7E-12	2.4E-12	2.0E-12
Thymus	2.6E-10	2.1E-10	1.2E-10	7.5E-11	4.3E-11	3.4E-11
Thyroid	1.1E-09	5.9E-10	2.7E-10	1.2E-10	7.1E-11	4.8E-11
Uterus	8.4E-11	4.9E-11	2.0E-11	1.1E-11	5.1E-12	3.8E-12
Remainder	2.2E-10	1.5E-10	7.9E-11	5.0E-11	3.5E-11	2.9E-11
Effective Dose	4.1E-08	3.3E-08	2.0E-08	1.4E-08	1.2E-08	9.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-127m (T½ = 109 d).

Tellurium Gas or Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	4.2E-09	2.7E-09	1.3E-09	8.0E-10	4.8E-10	3.9E-10
Bladder Wall	5.0E-09	3.4E-09	2.3E-09	1.6E-09	1.2E-09	9.3E-10
Bone Surface	4.7E-07	3.9E-07	2.8E-07	1.5E-07	8.9E-08	8.9E-08
Brain	4.1E-09	2.6E-09	1.3E-09	7.7E-10	4.6E-10	3.7E-10
Breast	3.8E-09	2.4E-09	1.2E-09	7.2E-10	4.2E-10	3.4E-10
GI-Tract						
Oesophagus	3.9E-09	2.5E-09	1.2E-09	7.3E-10	4.3E-10	3.5E-10
St Wall	4.0E-09	2.5E-09	1.2E-09	7.4E-10	4.4E-10	3.5E-10
SI Wall	4.1E-09	2.7E-09	1.4E-09	8.2E-10	4.8E-10	3.9E-10
ULI Wall	1.2E-08	8.9E-09	4.4E-09	2.6E-09	1.5E-09	1.2E-09
LLI Wall	3.1E-08	2.3E-08	1.1E-08	6.8E-09	3.9E-09	3.1E-09
Colon	2.0E-08	1.5E-08	7.5E-09	4.4E-09	2.5E-09	2.0E-09
Kidneys	4.9E-08	3.1E-08	1.7E-08	1.1E-08	7.9E-09	6.3E-09
Liver	3.9E-09	2.5E-09	1.2E-09	7.3E-10	4.3E-10	3.5E-10
Muscle	3.9E-09	2.5E-09	1.2E-09	7.4E-10	4.4E-10	3.6E-10
Ovaries	4.0E-09	2.6E-09	1.3E-09	7.8E-10	4.6E-10	3.7E-10
Pancreas	3.9E-09	2.5E-09	1.2E-09	7.4E-10	4.3E-10	3.5E-10
Red Marrow	3.1E-07	2.1E-07	1.0E-07	5.4E-08	3.2E-08	2.3E-08
Respiratory Tract						
ET Airways	9.6E-09	6.5E-09	3.3E-09	2.1E-09	1.4E-09	1.2E-09
Lungs	4.6E-09	3.0E-09	1.6E-09	9.7E-10	6.1E-10	5.1E-10
Skin	3.9E-09	2.4E-09	1.2E-09	7.2E-10	4.2E-10	3.4E-10
Spleen	3.9E-09	2.5E-09	1.2E-09	7.4E-10	4.3E-10	3.5E-10
Testes	3.8E-09	2.4E-09	1.2E-09	7.0E-10	4.1E-10	3.3E-10
Thymus	3.9E-09	2.5E-09	1.2E-09	7.3E-10	4.3E-10	3.5E-10
Thyroid	1.1E-07	9.4E-08	4.8E-08	2.1E-08	1.4E-08	8.4E-09
Uterus	3.9E-09	2.5E-09	1.2E-09	7.3E-10	4.3E-10	3.5E-10
Remainder	4.5E-09	2.9E-09	1.4E-09	8.7E-10	5.2E-10	4.2E-10
Effective Dose	5.3E-08	3.7E-08	1.9E-08	1.0E-08	6.1E-09	4.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-129m (T½ = 33.6 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	2.7E-09	1.6E-09	7.2E-10	4.4E-10	2.5E-10	2.1E-10
Bladder Wall	3.5E-09	2.3E-09	1.4E-09	1.0E-09	7.6E-10	6.0E-10
Bone Surface	7.7E-08	5.7E-08	3.6E-08	2.0E-08	1.1E-08	1.1E-08
Brain	2.6E-09	1.5E-09	6.8E-10	4.1E-10	2.3E-10	2.0E-10
Breast	2.5E-09	1.4E-09	6.5E-10	3.9E-10	2.2E-10	1.9E-10
GI-Tract						
Oesophagus	2.5E-09	1.5E-09	6.7E-10	4.0E-10	2.3E-10	1.9E-10
St Wall	3.3E-09	1.9E-09	8.4E-10	5.0E-10	2.8E-10	2.4E-10
SI Wall	3.5E-09	2.7E-09	1.2E-09	7.1E-10	3.7E-10	3.1E-10
ULI Wall	1.5E-08	1.2E-08	5.2E-09	3.2E-09	1.5E-09	1.3E-09
LLI Wall	3.7E-08	3.2E-08	1.4E-08	8.1E-09	3.9E-09	3.3E-09
Colon	2.4E-08	2.1E-08	8.8E-09	5.3E-09	2.6E-09	2.2E-09
Kidneys	2.9E-08	1.7E-08	8.4E-09	5.6E-09	3.8E-09	3.1E-09
Liver	2.5E-09	1.5E-09	6.7E-10	4.0E-10	2.3E-10	1.9E-10
Muscle	2.5E-09	1.5E-09	6.8E-10	4.1E-10	2.3E-10	1.9E-10
Ovaries	2.6E-09	1.6E-09	7.2E-10	4.4E-10	2.5E-10	2.1E-10
Pancreas	2.6E-09	1.5E-09	6.8E-10	4.1E-10	2.4E-10	2.0E-10
Red Marrow	9.0E-08	5.1E-08	2.2E-08	1.2E-08	6.5E-09	4.8E-09
Respiratory Tract						
ET Airways	2.0E-08	1.4E-08	6.1E-09	3.9E-09	2.1E-09	2.0E-09
Lungs	2.6E-09	1.6E-09	7.2E-10	4.4E-10	2.6E-10	2.2E-10
Skin	2.5E-09	1.5E-09	6.5E-10	3.9E-10	2.2E-10	1.9E-10
Spleen	2.6E-09	1.5E-09	6.8E-10	4.1E-10	2.3E-10	2.0E-10
Testes	2.5E-09	1.4E-09	6.5E-10	3.9E-10	2.2E-10	1.9E-10
Thymus	2.5E-09	1.5E-09	6.7E-10	4.0E-10	2.3E-10	1.9E-10
Thyroid	6.4E-08	5.1E-08	2.4E-08	1.0E-08	6.4E-09	4.1E-09
Uterus	2.5E-09	1.5E-09	6.8E-10	4.1E-10	2.4E-10	2.0E-10
Remainder	2.9E-09	1.7E-09	7.8E-10	4.8E-10	2.7E-10	2.3E-10
Effective Dose	2.0E-08	1.3E-08	5.8E-09	3.1E-09	1.7E-09	1.3E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-129m ($T\frac{1}{2}$ = 33.6 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.0E-09	5.9E-10	2.9E-10	1.8E-10	1.1E-10	9.2E-11
Bladder Wall	1.1E-09	5.8E-10	3.5E-10	2.6E-10	1.9E-10	1.5E-10
Bone Surface	2.3E-08	1.4E-08	8.6E-09	4.7E-09	2.6E-09	2.7E-09
Brain	7.5E-10	3.6E-10	1.7E-10	1.0E-10	5.9E-11	5.0E-11
Breast	9.3E-10	5.3E-10	2.8E-10	1.8E-10	9.9E-11	8.8E-11
GI-Tract						
Oesophagus	9.7E-10	5.4E-10	2.8E-10	1.8E-10	1.1E-10	9.4E-11
St Wall	2.8E-09	1.5E-09	6.5E-10	3.8E-10	2.3E-10	1.8E-10
SI Wall	5.3E-09	3.7E-09	1.6E-09	9.5E-10	4.6E-10	3.9E-10
ULI Wall	3.1E-08	2.2E-08	9.4E-09	5.7E-09	2.7E-09	2.2E-09
LLI Wall	8.7E-08	6.1E-08	2.6E-08	1.6E-08	7.6E-09	6.3E-09
Colon	5.5E-08	3.9E-08	1.7E-08	1.0E-08	4.8E-09	4.0E-09
Kidneys	8.5E-09	4.1E-09	2.0E-09	1.3E-09	9.1E-10	7.6E-10
Liver	9.4E-10	5.2E-10	2.6E-10	1.6E-10	1.0E-10	8.4E-11
Muscle	8.7E-10	4.6E-10	2.2E-10	1.3E-10	8.2E-11	6.8E-11
Ovaries	9.5E-10	5.2E-10	2.4E-10	1.5E-10	8.7E-11	7.0E-11
Pancreas	9.5E-10	5.2E-10	2.5E-10	1.5E-10	9.5E-11	7.7E-11
Red Marrow	2.6E-08	1.2E-08	5.2E-09	2.8E-09	1.6E-09	1.2E-09
Respiratory Tract						
ET Airways	3.3E-08	2.4E-08	1.0E-08	6.7E-09	3.7E-09	3.5E-09
Lungs	1.9E-07	1.5E-07	9.2E-08	6.6E-08	5.9E-08	4.8E-08
Skin	7.7E-10	3.9E-10	1.8E-10	1.1E-10	6.3E-11	5.3E-11
Spleen	9.5E-10	5.2E-10	2.5E-10	1.5E-10	9.4E-11	7.7E-11
Testes	7.4E-10	3.6E-10	1.6E-10	9.7E-11	5.5E-11	4.6E-11
Thymus	9.7E-10	5.4E-10	2.8E-10	1.8E-10	1.1E-10	9.4E-11
Thyroid	1.9E-08	1.2E-08	5.7E-09	2.5E-09	1.5E-09	1.0E-09
Uterus	8.3E-10	4.3E-10	2.0E-10	1.2E-10	6.6E-11	5.5E-11
Remainder	1.0E-09	5.5E-10	2.6E-10	1.6E-10	9.9E-11	8.2E-11
Effective Dose	3.5E-08	2.6E-08	1.4E-08	9.8E-09	8.0E-09	6.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-129m (T½ = 33.6 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.2E-10	3.1E-10	1.7E-10	1.0E-10	7.0E-11	5.7E-11
Bladder Wall	1.6E-10	8.9E-11	4.5E-11	3.1E-11	1.7E-11	1.4E-11
Bone Surface	1.9E-09	9.5E-10	5.4E-10	3.0E-10	1.6E-10	1.6E-10
Brain	7.2E-11	3.4E-11	1.8E-11	1.1E-11	7.0E-12	6.0E-12
Breast	3.4E-10	2.7E-10	1.8E-10	1.2E-10	6.4E-11	6.1E-11
GI-Tract						
Oesophagus	3.6E-10	2.8E-10	1.7E-10	1.1E-10	7.8E-11	6.7E-11
St Wall	2.3E-09	1.3E-09	5.5E-10	3.2E-10	2.0E-10	1.6E-10
SI Wall	6.0E-09	3.9E-09	1.7E-09	1.0E-09	4.9E-10	4.0E-10
ULI Wall	3.8E-08	2.5E-08	1.1E-08	6.4E-09	3.0E-09	2.5E-09
LLI Wall	1.1E-07	6.9E-08	2.9E-08	1.8E-08	8.6E-09	7.1E-09
Colon	6.8E-08	4.4E-08	1.9E-08	1.1E-08	5.4E-09	4.5E-09
Kidneys	7.3E-10	3.3E-10	1.6E-10	1.0E-10	6.6E-11	5.3E-11
Liver	3.3E-10	2.5E-10	1.4E-10	8.8E-11	6.6E-11	5.2E-11
Muscle	2.3E-10	1.6E-10	8.4E-11	5.2E-11	3.8E-11	3.1E-11
Ovaries	3.2E-10	2.1E-10	1.0E-10	6.6E-11	3.7E-11	2.8E-11
Pancreas	3.3E-10	2.4E-10	1.3E-10	7.5E-11	5.4E-11	4.1E-11
Red Marrow	1.9E-09	7.3E-10	3.2E-10	1.8E-10	1.1E-10	8.5E-11
Respiratory Tract						
ET Airways	3.7E-08	2.7E-08	1.2E-08	7.6E-09	4.2E-09	4.0E-09
Lungs	2.4E-07	1.9E-07	1.2E-07	8.4E-08	7.4E-08	6.1E-08
Skin	1.2E-10	7.6E-11	4.0E-11	2.4E-11	1.6E-11	1.4E-11
Spleen	3.3E-10	2.4E-10	1.3E-10	7.7E-11	5.4E-11	4.3E-11
Testes	8.6E-11	4.4E-11	1.8E-11	1.1E-11	5.2E-12	4.2E-12
Thymus	3.6E-10	2.8E-10	1.7E-10	1.1E-10	7.8E-11	6.7E-11
Thyroid	1.4E-09	7.6E-10	3.5E-10	1.6E-10	9.7E-11	6.7E-11
Uterus	1.8E-10	1.2E-10	5.2E-11	3.0E-11	1.6E-11	1.2E-11
Remainder	3.3E-10	2.2E-10	1.1E-10	7.2E-11	4.8E-11	4.0E-11
Effective Dose	3.8E-08	2.9E-08	1.7E-08	1.2E-08	9.6E-09	7.9E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.3(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-129m (T½ = 33.6 d).

Tellurium Gas or Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	6.8E-09	4.3E-09	2.2E-09	1.3E-09	8.0E-10	6.5E-10
Bladder Wall	9.1E-09	6.2E-09	4.2E-09	3.1E-09	2.4E-09	1.8E-09
Bone Surface	2.0E-07	1.6E-07	1.1E-07	6.0E-08	3.4E-08	3.4E-08
Brain	6.6E-09	4.1E-09	2.1E-09	1.2E-09	7.4E-10	6.0E-10
Breast	6.3E-09	4.0E-09	2.0E-09	1.2E-09	7.0E-10	5.7E-10
GI-Tract						
Oesophagus	6.4E-09	4.0E-09	2.0E-09	1.2E-09	7.2E-10	5.8E-10
St Wall	7.0E-09	4.3E-09	2.2E-09	1.3E-09	7.8E-10	6.3E-10
SI Wall	7.3E-09	5.0E-09	2.5E-09	1.5E-09	9.0E-10	7.3E-10
ULI Wall	2.5E-08	1.9E-08	9.2E-09	5.5E-09	3.1E-09	2.5E-09
LLI Wall	5.9E-08	4.4E-08	2.2E-08	1.3E-08	7.5E-09	6.1E-09
Colon	4.0E-08	3.0E-08	1.5E-08	8.8E-09	5.0E-09	4.0E-09
Kidneys	7.5E-08	4.7E-08	2.6E-08	1.7E-08	1.2E-08	9.6E-09
Liver	6.5E-09	4.1E-09	2.0E-09	1.2E-09	7.2E-10	5.9E-10
Muscle	6.5E-09	4.1E-09	2.0E-09	1.2E-09	7.3E-10	5.9E-10
Ovaries	6.7E-09	4.2E-09	2.1E-09	1.3E-09	7.8E-10	6.3E-10
Pancreas	6.6E-09	4.1E-09	2.1E-09	1.2E-09	7.5E-10	6.1E-10
Red Marrow	2.3E-07	1.4E-07	6.7E-08	3.5E-08	2.1E-08	1.5E-08
Respiratory Tract						
ET Airways	1.5E-08	1.0E-08	5.3E-09	3.3E-09	2.2E-09	1.8E-09
Lungs	7.3E-09	4.7E-09	2.4E-09	1.5E-09	9.4E-10	7.9E-10
Skin	6.4E-09	4.0E-09	2.0E-09	1.2E-09	7.0E-10	5.7E-10
Spleen	6.6E-09	4.1E-09	2.1E-09	1.2E-09	7.4E-10	6.0E-10
Testes	6.3E-09	4.0E-09	2.0E-09	1.2E-09	7.0E-10	5.7E-10
Thymus	6.4E-09	4.0E-09	2.0E-09	1.2E-09	7.2E-10	5.8E-10
Thyroid	1.6E-07	1.4E-07	7.3E-08	3.2E-08	2.0E-08	1.3E-08
Uterus	6.5E-09	4.1E-09	2.1E-09	1.2E-09	7.4E-10	6.0E-10
Remainder	7.4E-09	4.7E-09	2.4E-09	1.4E-09	8.5E-10	6.9E-10
Effective Dose	4.8E-08	3.2E-08	1.6E-08	8.5E-09	5.1E-09	3.7E-09

GI-Tract Gastrointestinal Tract
St Stomach
SI Small Intestine
ULI Upper Large Intestine
LLI Lower Large Intestine
ET Airways Extrathoracic airways
Lungs Thoracic airways

Table 5.18.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-131m ($T½$ = 1.25 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	6.9E-10	4.6E-10	2.2E-10	1.4E-10	8.9E-11	7.6E-11
Bladder Wall	1.0E-09	7.7E-10	5.3E-10	4.0E-10	3.0E-10	2.4E-10
Bone Surface	3.3E-09	2.3E-09	1.4E-09	7.9E-10	4.4E-10	4.4E-10
Brain	5.7E-10	3.6E-10	1.8E-10	1.2E-10	7.3E-11	6.6E-11
Breast	5.3E-10	3.3E-10	1.6E-10	9.9E-11	5.7E-11	4.9E-11
GI-Tract						
Oesophagus	1.1E-09	7.1E-10	2.9E-10	1.7E-10	8.8E-11	7.2E-11
St Wall	1.3E-09	8.4E-10	3.8E-10	2.4E-10	1.4E-10	1.2E-10
SI Wall	1.6E-09	1.5E-09	6.8E-10	4.4E-10	2.3E-10	1.9E-10
ULI Wall	5.4E-09	5.1E-09	2.2E-09	1.4E-09	6.7E-10	5.7E-10
LLI Wall	9.6E-09	9.0E-09	3.9E-09	2.4E-09	1.2E-09	9.8E-10
Colon	7.2E-09	6.8E-09	2.9E-09	1.8E-09	8.8E-10	7.4E-10
Kidneys	1.7E-09	1.1E-09	5.3E-10	3.6E-10	2.3E-10	2.0E-10
Liver	6.5E-10	4.3E-10	2.1E-10	1.3E-10	7.7E-11	6.6E-11
Muscle	7.2E-10	4.9E-10	2.3E-10	1.5E-10	8.7E-11	7.5E-11
Ovaries	1.0E-09	8.4E-10	4.2E-10	2.8E-10	1.7E-10	1.4E-10
Pancreas	7.0E-10	4.7E-10	2.3E-10	1.5E-10	8.9E-11	7.6E-11
Red Marrow	2.0E-09	1.1E-09	5.2E-10	3.2E-10	1.9E-10	1.6E-10
Respiratory Tract						
ET Airways	3.5E-08	3.0E-08	1.6E-08	9.3E-09	5.4E-09	4.3E-09
Lungs	7.3E-10	4.9E-10	2.4E-10	1.6E-10	1.1E-10	9.1E-11
Skin	5.2E-10	3.3E-10	1.5E-10	9.6E-11	5.7E-11	5.0E-11
Spleen	6.5E-10	4.3E-10	2.1E-10	1.3E-10	8.0E-11	6.8E-11
Testes	5.5E-10	3.6E-10	1.8E-10	1.1E-10	6.6E-11	5.6E-11
Thymus	1.1E-09	7.1E-10	2.9E-10	1.7E-10	8.8E-11	7.2E-11
Thyroid	1.4E-07	1.2E-07	6.4E-08	3.3E-08	2.0E-08	1.3E-08
Uterus	8.0E-10	6.2E-10	3.1E-10	2.1E-10	1.2E-10	1.0E-10
Remainder	7.3E-10	5.0E-10	2.4E-10	1.6E-10	9.3E-11	8.0E-11
Effective Dose	8.7E-09	7.6E-09	3.9E-09	2.0E-09	1.2E-09	8.6E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-131m (T½ = 1.25 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	5.9E-10	4.3E-10	2.3E-10	1.4E-10	9.5E-11	7.7E-11
Bladder Wall	6.7E-10	4.8E-10	2.4E-10	1.8E-10	1.0E-10	8.4E-11
Bone Surface	1.1E-09	6.4E-10	3.5E-10	2.1E-10	1.2E-10	1.1E-10
Brain	1.9E-10	1.1E-10	6.0E-11	4.3E-11	2.8E-11	2.6E-11
Breast	4.6E-10	3.4E-10	2.0E-10	1.4E-10	7.8E-11	7.0E-11
GI-Tract						
Oesophagus	8.7E-10	6.2E-10	2.9E-10	1.8E-10	1.1E-10	9.2E-11
St Wall	2.0E-09	1.3E-09	5.6E-10	3.5E-10	2.1E-10	1.7E-10
SI Wall	3.7E-09	2.8E-09	1.3E-09	8.0E-10	4.0E-10	3.3E-10
ULI Wall	1.4E-08	1.0E-08	4.4E-09	2.7E-09	1.3E-09	1.1E-09
LLI Wall	2.6E-08	1.8E-08	7.9E-09	4.8E-09	2.3E-09	1.9E-09
Colon	1.9E-08	1.4E-08	5.9E-09	3.6E-09	1.7E-09	1.5E-09
Kidneys	7.0E-10	4.3E-10	2.2E-10	1.4E-10	8.9E-11	7.4E-11
Liver	5.9E-10	4.3E-10	2.2E-10	1.4E-10	9.0E-11	7.3E-11
Muscle	5.3E-10	3.8E-10	1.9E-10	1.2E-10	7.5E-11	6.1E-11
Ovaries	1.4E-09	1.1E-09	5.5E-10	3.8E-10	2.2E-10	1.7E-10
Pancreas	6.3E-10	4.5E-10	2.4E-10	1.5E-10	9.6E-11	7.5E-11
Red Marrow	6.8E-10	3.9E-10	2.1E-10	1.5E-10	1.0E-10	8.7E-11
Respiratory Tract						
ET Airways	3.8E-08	3.2E-08	1.7E-08	9.8E-09	5.7E-09	4.6E-09
Lungs	1.7E-08	1.3E-08	8.2E-09	6.1E-09	5.8E-09	4.6E-09
Skin	2.8E-10	1.8E-10	9.0E-11	5.8E-11	3.5E-11	3.1E-11
Spleen	5.5E-10	3.9E-10	2.0E-10	1.3E-10	8.3E-11	6.7E-11
Testes	3.1E-10	2.0E-10	9.5E-11	5.7E-11	2.8E-11	2.3E-11
Thymus	8.7E-10	6.2E-10	2.9E-10	1.8E-10	1.1E-10	9.2E-11
Thyroid	3.7E-08	2.5E-08	1.3E-08	6.6E-09	4.1E-09	2.7E-09
Uterus	8.5E-10	6.6E-10	3.2E-10	2.1E-10	1.1E-10	8.8E-11
Remainder	1.9E-08	1.6E-08	8.4E-09	5.0E-09	8.2E-11	6.8E-11
Effective Dose	7.9E-09	5.8E-09	3.0E-09	1.9E-09	1.2E-09	9.4E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-131m (T½ = 1.25 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.3E-10	4.1E-10	2.3E-10	1.4E-10	9.4E-11	7.5E-11
Bladder Wall	5.8E-10	4.3E-10	1.9E-10	1.4E-10	6.8E-11	5.6E-11
Bone Surface	4.3E-10	3.0E-10	1.5E-10	9.6E-11	6.2E-11	5.4E-11
Brain	8.5E-11	6.0E-11	3.7E-11	2.8E-11	1.9E-11	1.8E-11
Breast	4.1E-10	3.2E-10	2.0E-10	1.4E-10	7.9E-11	7.1E-11
GI-Tract						
Oesophagus	7.8E-10	5.8E-10	2.9E-10	1.8E-10	1.1E-10	9.3E-11
St Wall	2.1E-09	1.3E-09	5.8E-10	3.6E-10	2.2E-10	1.7E-10
SI Wall	4.6E-09	3.1E-09	1.4E-09	9.0E-10	4.5E-10	3.7E-10
ULI Wall	1.7E-08	1.2E-08	4.9E-09	3.1E-09	1.5E-09	1.2E-09
LLI Wall	3.2E-08	2.1E-08	8.9E-09	5.5E-09	2.6E-09	2.2E-09
Colon	2.4E-08	1.6E-08	6.7E-09	4.1E-09	2.0E-09	1.6E-09
Kidneys	4.2E-10	3.1E-10	1.6E-10	1.0E-10	6.2E-11	5.1E-11
Liver	5.5E-10	4.2E-10	2.2E-10	1.4E-10	9.1E-11	7.3E-11
Muscle	4.8E-10	3.6E-10	1.8E-10	1.2E-10	7.2E-11	5.9E-11
Ovaries	1.6E-09	1.2E-09	5.9E-10	4.1E-10	2.4E-10	1.8E-10
Pancreas	5.9E-10	4.3E-10	2.3E-10	1.5E-10	9.5E-11	7.3E-11
Red Marrow	3.2E-10	2.4E-10	1.5E-10	1.2E-10	8.3E-11	7.4E-11
Respiratory Tract						
ET Airways	3.8E-08	3.3E-08	1.7E-08	9.9E-09	5.8E-09	4.6E-09
Lungs	1.9E-08	1.5E-08	9.3E-09	6.9E-09	6.5E-09	5.2E-09
Skin	2.1E-10	1.5E-10	7.6E-11	5.0E-11	3.1E-11	2.7E-11
Spleen	5.0E-10	3.7E-10	1.9E-10	1.3E-10	8.2E-11	6.5E-11
Testes	2.5E-10	1.8E-10	8.0E-11	4.8E-11	2.2E-11	1.7E-11
Thymus	7.8E-10	5.8E-10	2.9E-10	1.8E-10	1.1E-10	9.3E-11
Thyroid	2.9E-09	1.6E-09	8.0E-10	4.2E-10	2.5E-10	1.7E-10
Uterus	9.1E-10	6.9E-10	3.2E-10	2.2E-10	1.1E-10	8.8E-11
Remainder	1.9E-08	1.6E-08	8.5E-09	5.0E-09	8.0E-11	6.6E-11
Effective Dose	7.0E-09	5.1E-09	2.6E-09	1.8E-09	1.1E-09	9.1E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.4(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-131m (T½ = 1.25 d).

Tellurium Gas or Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	1.7E-09	1.1E-09	6.3E-10	4.1E-10	2.7E-10	2.2E-10
Bladder Wall	2.5E-09	1.8E-09	1.5E-09	1.1E-09	9.0E-10	7.1E-10
Bone Surface	8.3E-09	6.2E-09	4.2E-09	2.4E-09	1.4E-09	1.3E-09
Brain	1.4E-09	9.0E-10	4.9E-10	3.1E-10	2.0E-10	1.7E-10
Breast	1.2E-09	7.9E-10	4.2E-10	2.6E-10	1.7E-10	1.4E-10
GI-Tract						
Oesophagus	1.8E-09	1.2E-09	6.1E-10	3.7E-10	2.3E-10	1.8E-10
St Wall	2.0E-09	1.3E-09	7.0E-10	4.3E-10	2.9E-10	2.4E-10
SI Wall	2.4E-09	1.9E-09	1.1E-09	6.9E-10	4.4E-10	3.6E-10
ULI Wall	7.6E-09	6.2E-09	3.2E-09	2.0E-09	1.2E-09	9.4E-10
LLI Wall	1.3E-08	1.1E-08	5.4E-09	3.3E-09	1.9E-09	1.6E-09
Colon	1.0E-08	8.0E-09	4.2E-09	2.5E-09	1.5E-09	1.2E-09
Kidneys	4.3E-09	2.8E-09	1.5E-09	1.0E-09	7.2E-10	5.9E-10
Liver	1.5E-09	1.0E-09	5.6E-10	3.5E-10	2.2E-10	1.9E-10
Muscle	1.5E-09	1.0E-09	5.5E-10	3.5E-10	2.3E-10	1.9E-10
Ovaries	2.0E-09	1.5E-09	8.6E-10	5.7E-10	3.8E-10	3.1E-10
Pancreas	1.6E-09	1.1E-09	6.0E-10	3.9E-10	2.5E-10	2.1E-10
Red Marrow	5.0E-09	2.9E-09	1.5E-09	8.9E-10	5.7E-10	4.4E-10
Respiratory Tract						
ET Airways	1.8E-08	1.6E-08	9.7E-09	5.6E-09	4.1E-09	3.1E-09
Lungs	2.2E-09	1.6E-09	9.2E-10	6.3E-10	4.4E-10	3.8E-10
Skin	1.2E-09	7.9E-10	4.1E-10	2.6E-10	1.6E-10	1.4E-10
Spleen	1.5E-09	1.0E-09	5.6E-10	3.6E-10	2.3E-10	1.9E-10
Testes	1.3E-09	8.9E-10	4.9E-10	3.1E-10	2.0E-10	1.6E-10
Thymus	1.8E-09	1.2E-09	6.1E-10	3.7E-10	2.3E-10	1.8E-10
Thyroid	3.5E-07	3.3E-07	1.9E-07	9.6E-08	6.3E-08	4.0E-08
Uterus	1.7E-09	1.2E-09	7.3E-10	4.7E-10	3.0E-10	2.5E-10
Remainder	1.5E-09	1.0E-09	5.7E-10	3.7E-10	2.4E-10	2.0E-10
Effective Dose	2.1E-08	1.9E-08	1.1E-08	5.6E-09	3.7E-09	2.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.5(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-132 (T½ = 3.26 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	1.9E-09	1.2E-09	6.0E-10	3.8E-10	2.3E-10	2.0E-10
Bladder Wall	8.4E-09	6.2E-09	4.5E-09	3.8E-09	3.1E-09	2.4E-09
Bone Surface	7.3E-09	5.1E-09	3.0E-09	1.7E-09	9.7E-10	9.6E-10
Brain	1.7E-09	1.1E-09	5.3E-10	3.4E-10	2.1E-10	1.8E-10
Breast	1.6E-09	9.8E-10	4.6E-10	2.9E-10	1.7E-10	1.4E-10
GI-Tract						
Oesophagus	2.9E-09	1.9E-09	8.1E-10	4.8E-10	2.5E-10	2.1E-10
St Wall	2.4E-09	1.5E-09	7.2E-10	4.4E-10	2.7E-10	2.3E-10
SI Wall	2.8E-09	2.2E-09	1.1E-09	7.2E-10	4.1E-10	3.5E-10
ULI Wall	1.0E-08	9.4E-09	4.1E-09	2.6E-09	1.3E-09	1.1E-09
LLI Wall	2.5E-08	2.3E-08	1.0E-08	6.2E-09	3.0E-09	2.6E-09
Colon	1.7E-08	1.5E-08	6.7E-09	4.1E-09	2.0E-09	1.7E-09
Kidneys	2.8E-09	1.8E-09	8.7E-10	5.7E-10	3.6E-10	3.1E-10
Liver	1.9E-09	1.2E-09	6.0E-10	3.7E-10	2.2E-10	1.9E-10
Muscle	2.1E-09	1.4E-09	6.7E-10	4.2E-10	2.5E-10	2.1E-10
Ovaries	2.8E-09	2.3E-09	1.2E-09	7.8E-10	4.7E-10	3.8E-10
Pancreas	2.0E-09	1.3E-09	6.3E-10	4.0E-10	2.4E-10	2.1E-10
Red Marrow	3.1E-09	1.8E-09	9.0E-10	5.7E-10	3.5E-10	2.9E-10
Respiratory Tract						
ET Airways	6.1E-08	5.4E-08	2.9E-08	1.7E-08	9.7E-09	7.7E-09
Lungs	1.9E-09	1.2E-09	6.0E-10	3.9E-10	2.4E-10	2.0E-10
Skin	1.5E-09	9.6E-10	4.5E-10	2.8E-10	1.7E-10	1.5E-10
Spleen	1.9E-09	1.2E-09	5.8E-10	3.7E-10	2.2E-10	1.9E-10
Testes	1.8E-09	1.2E-09	6.4E-10	4.0E-10	2.4E-10	2.0E-10
Thymus	2.9E-09	1.9E-09	8.1E-10	4.8E-10	2.5E-10	2.1E-10
Thyroid	3.6E-07	2.9E-07	1.4E-07	6.1E-08	3.8E-08	2.5E-08
Uterus	2.5E-09	1.8E-09	1.0E-09	6.8E-10	3.9E-10	3.4E-10
Remainder	2.1E-09	1.4E-09	6.7E-10	4.3E-10	2.6E-10	2.2E-10
Effective Dose	2.2E-08	1.8E-08	8.5E-09	4.2E-09	2.6E-09	1.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.5(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-132 (T½ = 3.26 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.8E-09	1.3E-09	7.0E-10	4.2E-10	2.9E-10	2.4E-10
Bladder Wall	3.1E-09	1.9E-09	1.2E-09	9.4E-10	6.5E-10	5.2E-10
Bone Surface	2.6E-09	1.6E-09	8.6E-10	5.1E-10	3.1E-10	2.8E-10
Brain	5.6E-10	3.0E-10	1.6E-10	1.1E-10	7.1E-11	6.4E-11
Breast	1.4E-09	1.0E-09	6.4E-10	4.3E-10	2.5E-10	2.3E-10
GI-Tract						
Oesophagus	2.2E-09	1.6E-09	8.1E-10	5.2E-10	3.4E-10	2.8E-10
St Wall	2.8E-09	1.8E-09	8.6E-10	5.4E-10	3.5E-10	2.7E-10
SI Wall	6.1E-09	4.6E-09	2.1E-09	1.4E-09	7.2E-10	5.9E-10
ULI Wall	2.7E-08	2.0E-08	8.6E-09	5.4E-09	2.6E-09	2.1E-09
LLI Wall	6.4E-08	4.6E-08	2.0E-08	1.2E-08	5.8E-09	4.9E-09
Colon	4.3E-08	3.1E-08	1.3E-08	8.3E-09	4.0E-09	3.3E-09
Kidneys	1.5E-09	9.5E-10	4.8E-10	3.1E-10	1.9E-10	1.6E-10
Liver	1.6E-09	1.2E-09	6.2E-10	4.0E-10	2.7E-10	2.2E-10
Muscle	1.4E-09	9.9E-10	5.0E-10	3.2E-10	2.1E-10	1.7E-10
Ovaries	3.5E-09	2.8E-09	1.4E-09	9.3E-10	5.4E-10	4.2E-10
Pancreas	1.7E-09	1.2E-09	6.3E-10	3.9E-10	2.7E-10	2.0E-10
Red Marrow	1.4E-09	8.5E-10	4.9E-10	3.6E-10	2.5E-10	2.2E-10
Respiratory Tract						
ET Airways	6.4E-08	5.6E-08	2.9E-08	1.7E-08	1.0E-08	7.9E-09
Lungs	4.0E-08	3.0E-08	1.9E-08	1.4E-08	1.3E-08	1.0E-08
Skin	7.9E-10	5.0E-10	2.5E-10	1.6E-10	1.0E-10	8.7E-11
Spleen	1.5E-09	1.1E-09	5.6E-10	3.6E-10	2.4E-10	1.9E-10
Testes	8.8E-10	5.7E-10	2.7E-10	1.7E-10	8.3E-11	6.8E-11
Thymus	2.2E-09	1.6E-09	8.1E-10	5.2E-10	3.4E-10	2.8E-10
Thyroid	8.7E-08	5.3E-08	2.4E-08	1.1E-08	6.6E-09	4.3E-09
Uterus	2.1E-09	1.6E-09	7.7E-10	5.0E-10	2.7E-10	2.1E-10
Remainder	1.4E-09	2.9E-08	1.5E-08	8.7E-09	2.1E-10	1.8E-10
Effective Dose	1.6E-08	1.3E-08	6.4E-09	4.0E-09	2.6E-09	2.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.5(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-132 (T½ = 3.26 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.6E-09	1.2E-09	6.8E-10	4.1E-10	2.9E-10	2.3E-10
Bladder Wall	1.5E-09	1.1E-09	5.0E-10	3.7E-10	1.8E-10	1.5E-10
Bone Surface	1.2E-09	8.3E-10	4.1E-10	2.6E-10	1.7E-10	1.5E-10
Brain	2.1E-10	1.4E-10	8.6E-11	6.4E-11	4.4E-11	4.1E-11
Breast	1.2E-09	9.8E-10	6.4E-10	4.4E-10	2.5E-10	2.3E-10
GI-Tract						
Oesophagus	1.9E-09	1.5E-09	7.8E-10	5.0E-10	3.4E-10	2.9E-10
St Wall	2.7E-09	1.8E-09	8.6E-10	5.5E-10	3.5E-10	2.7E-10
SI Wall	7.4E-09	5.2E-09	2.4E-09	1.5E-09	7.9E-10	6.5E-10
ULI Wall	3.4E-08	2.3E-08	9.7E-09	6.1E-09	2.9E-09	2.4E-09
LLI Wall	7.9E-08	5.2E-08	2.2E-08	1.4E-08	6.6E-09	5.5E-09
Colon	5.3E-08	3.5E-08	1.5E-08	9.4E-09	4.5E-09	3.7E-09
Kidneys	1.0E-09	7.7E-10	4.0E-10	2.5E-10	1.6E-10	1.3E-10
Liver	1.5E-09	1.1E-09	6.0E-10	3.9E-10	2.7E-10	2.2E-10
Muscle	1.2E-09	8.9E-10	4.5E-10	2.9E-10	1.9E-10	1.6E-10
Ovaries	3.9E-09	2.9E-09	1.4E-09	9.8E-10	5.7E-10	4.3E-10
Pancreas	1.5E-09	1.1E-09	6.1E-10	3.8E-10	2.6E-10	2.0E-10
Red Marrow	8.0E-10	6.3E-10	4.0E-10	3.1E-10	2.2E-10	2.0E-10
Respiratory Tract						
ET Airways	6.4E-08	5.6E-08	2.9E-08	1.7E-08	1.0E-08	8.0E-09
Lungs	4.4E-08	3.4E-08	2.1E-08	1.5E-08	1.4E-08	1.1E-08
Skin	5.4E-10	3.9E-10	2.0E-10	1.3E-10	8.4E-11	7.3E-11
Spleen	1.3E-09	1.0E-09	5.4E-10	3.4E-10	2.4E-10	1.9E-10
Testes	6.3E-10	4.4E-10	2.0E-10	1.2E-10	5.5E-11	4.4E-11
Thymus	1.9E-09	1.5E-09	7.8E-10	5.0E-10	3.4E-10	2.9E-10
Thyroid	7.0E-09	3.5E-09	1.6E-09	7.9E-10	4.6E-10	3.2E-10
Uterus	2.0E-09	1.5E-09	7.3E-10	4.8E-10	2.5E-10	2.0E-10
Remainder	3.3E-08	2.9E-08	1.5E-08	8.7E-09	2.0E-10	1.7E-10
Effective Dose	1.5E-08	1.1E-08	5.8E-09	3.8E-09	2.5E-09	2.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.18.5(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Te-132 (T½ = 3.26 d).

Tellurium Gas or Vapour						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.6	0.3	0.3	0.3	0.3	0.3
Adrenals	4.7E-09	3.2E-09	1.7E-09	1.1E-09	7.1E-10	5.9E-10
Bladder Wall	2.1E-08	1.6E-08	1.3E-08	1.1E-08	9.5E-09	7.3E-09
Bone Surface	1.8E-08	1.4E-08	9.1E-09	5.1E-09	3.0E-09	2.9E-09
Brain	4.2E-09	2.7E-09	1.5E-09	9.3E-10	5.8E-10	4.9E-10
Breast	3.8E-09	2.4E-09	1.3E-09	7.9E-10	5.1E-10	4.2E-10
GI-Tract						
Oesophagus	5.6E-09	3.7E-09	1.9E-09	1.1E-09	7.0E-10	5.6E-10
St Wall	4.8E-09	3.1E-09	1.7E-09	1.1E-09	7.0E-10	5.8E-10
SI Wall	5.8E-09	4.2E-09	2.4E-09	1.6E-09	1.0E-09	8.2E-10
ULI Wall	1.6E-08	1.3E-08	6.7E-09	4.1E-09	2.4E-09	2.0E-09
LLI Wall	3.7E-08	2.9E-08	1.5E-08	9.2E-09	5.4E-09	4.4E-09
Colon	2.5E-08	2.0E-08	1.0E-08	6.3E-09	3.7E-09	3.0E-09
Kidneys	7.0E-09	4.6E-09	2.5E-09	1.6E-09	1.1E-09	9.0E-10
Liver	4.6E-09	3.1E-09	1.7E-09	1.1E-09	6.6E-10	5.5E-10
Muscle	4.6E-09	3.1E-09	1.7E-09	1.1E-09	6.9E-10	5.8E-10
Ovaries	6.1E-09	4.5E-09	2.7E-09	1.7E-09	1.2E-09	9.3E-10
Pancreas	4.9E-09	3.2E-09	1.8E-09	1.1E-09	7.2E-10	6.0E-10
Red Marrow	7.7E-09	4.8E-09	2.5E-09	1.6E-09	1.0E-09	8.2E-10
Respiratory Tract						
ET Airways	3.3E-08	2.8E-08	1.8E-08	1.0E-08	7.5E-09	5.6E-09
Lungs	4.9E-09	3.3E-09	1.8E-09	1.2E-09	7.9E-10	6.6E-10
Skin	3.7E-09	2.4E-09	1.3E-09	7.8E-10	5.0E-10	4.2E-10
Spleen	4.6E-09	3.0E-09	1.6E-09	1.0E-09	6.7E-10	5.5E-10
Testes	4.5E-09	3.0E-09	1.8E-09	1.1E-09	7.1E-10	5.8E-10
Thymus	5.6E-09	3.7E-09	1.9E-09	1.1E-09	7.0E-10	5.6E-10
Thyroid	9.1E-07	7.8E-07	4.1E-07	1.8E-07	1.2E-07	7.6E-08
Uterus	5.8E-09	4.1E-09	2.7E-09	1.8E-09	1.1E-09	9.2E-10
Remainder	4.6E-09	3.1E-09	1.7E-09	1.1E-09	7.0E-10	5.8E-10
Effective Dose	5.4E-08	4.5E-08	2.4E-08	1.2E-08	7.6E-09	5.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.19. Iodine

(194) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned halides (including iodides) of elements in Periodic Table Group 1a (alkali metals) and Group 7a (halogens) to inhalation Class D, and most others to Class W. In *ICRP Publication 30*, Part 1 (ICRP, 1979), all compounds of iodine (I) were assigned to Class D. This classification was supported by the results of experiments in which elemental iodine vapour was inhaled by mice, sheep, rats and dogs, and ^{131}I-labelled silver iodide was inhaled by mice and sheep (Willard and Bair, 1961; Bair *et al.*, 1963). Silver iodide had been studied because it is one of the most insoluble iodine compounds in water, but nevertheless the ^{131}I was rapidly absorbed from the lungs.

Absorption Types

(a) *Gases and vapours*

(195) *Elemental iodine.* Detailed studies have been conducted in human volunteers of the deposition and subsequent biokinetics of iodine inhaled as elemental iodine (Black and Hounam, 1968; Morgan *et al.*, 1968). Almost all the inhaled activity was retained. It was inferred that it mainly deposited in the conducting airways, most parts of which cleared with a half-time of the order of 10 min. This confirmed the rapid absorption seen previously in animal experiments. The measurements also showed, however, that much of the activity was swallowed and subsequently absorbed from the GI tract. Elemental iodine is therefore assigned to Class SR-1 (100% deposition), with Type F clearance.

(196) *Methyl iodide.* Detailed studies have been conducted in human volunteers of the deposition and subsequent biokinetics of iodine inhaled as CH_3I (Morgan *et al.*, 1967a, 1967b; Morgan and Morgan, 1967). The amount retained varied from 50 to 90% (average 70%), increasing with decreasing number of breaths per minute. It was inferred that most of it deposited in the alveoli. Absorption to blood of the deposited activity was very rapid (estimated half-time about 5 s). Subsequent biokinetics were very similar to those of injected iodide, suggesting that the CH_3I is rapidly metabolized. Methyl iodide is therefore assigned to Class SR-1 (70% deposition), with Type V clearance.

(b) *Particulate aerosols*

(197) As with silver iodide (see above), iodine inhaled as sodium iodide is also rapidly absorbed into blood. A half-time of the order of 10 min was inferred from studies on monkeys (Thiéblemont *et al.*, 1965; Perrault *et al.*, 1967), and a similar result was obtained in isolated perfused rabbit lung (Dawson *et al.*, 1985). Rapid uptake of iodine, consistent with assignment to Type F, was also observed following inhalation of ^{131}I associated with caesium chloride vector aerosols by rats (Thomas *et al.*, 1970) and dogs (McClellan and Rupprecht, 1968).

Dose coefficients

(198) Dose coefficients (given in Tables 5.19.2–8) were derived for the gases and vapours given in Table 5.19.1a, and for particulate aerosols using the f_1 values given in Table 5.19.1b, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993). For completeness, dose coefficients are given for particulate materials of all three absorption Types, although no experimental data were found indicating Type M or S behaviour for any form of iodine.

Table 5.19.1a. Classification and absorption Types for gas and vapour compounds of iodine[a]

	Deposition		Absorption	
Chemical form/origin	Vapour Class	Fraction deposited (%)	Type	f_1
Elemental iodine, I_2	SR-1	100[b]	F	1.0
Methyl iodide, CH_3I	SR-1	70[c]	V	[d]

[a] For iodine in unspecified gas or vapour form, the parameters given in Table 5.19.1a for elemental iodine are recommended.

[b] 10% ET_1, 40% ET_2, 50% BB.

[c] Deposited beyond ET_1, i.e. in ET_2 and the lungs.

[d] Not applicable, since all activity deposited in the respiratory tract is instantaneously absorbed.

Table 5.19.1b. Values of f_1 for inhaled particulate compounds of iodine

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F[b]	1	1
M	0.2	0.1
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type F is recommended for use in the absence of specific information.

Table 5.19.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-125 (T½ = 60.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	4.7E-11	3.4E-11	1.7E-11	1.4E-11	7.8E-12	9.0E-12
Bladder Wall	1.4E-10	1.2E-10	9.8E-11	7.8E-11	6.0E-11	4.9E-11
Bone Surface	2.4E-10	1.7E-10	9.5E-11	8.6E-11	5.7E-11	6.0E-11
Brain	5.5E-11	4.0E-11	2.1E-11	1.9E-11	1.2E-11	1.2E-11
Breast	5.5E-11	4.3E-11	1.8E-11	1.2E-11	6.8E-12	7.3E-12
GI-Tract						
Oesophagus	7.5E-10	6.0E-10	2.0E-10	8.3E-11	2.4E-11	1.8E-11
St Wall	1.0E-10	6.4E-11	2.9E-11	2.0E-11	1.1E-11	1.1E-11
SI Wall	6.2E-11	4.5E-11	2.2E-11	1.5E-11	8.4E-12	9.2E-12
ULI Wall	1.7E-10	1.2E-10	5.0E-11	2.6E-11	1.4E-11	1.2E-11
LLI Wall	3.9E-10	2.6E-10	1.1E-10	4.9E-11	2.5E-11	2.1E-11
Colon	2.7E-10	1.8E-10	7.5E-11	3.6E-11	1.9E-11	1.6E-11
Kidneys	4.2E-11	3.2E-11	1.6E-11	1.3E-11	7.4E-12	8.6E-12
Liver	4.8E-11	3.5E-11	1.8E-11	1.4E-11	7.7E-12	8.9E-12
Muscle	2.2E-10	1.9E-10	1.1E-10	1.0E-10	5.6E-11	4.7E-11
Ovaries	7.1E-11	5.1E-11	2.6E-11	1.7E-11	9.5E-12	9.9E-12
Pancreas	5.1E-11	3.6E-11	1.8E-11	1.4E-11	8.1E-12	9.3E-12
Red Marrow	5.3E-11	3.9E-11	2.1E-11	1.8E-11	1.2E-11	1.2E-11
Respiratory Tract						
ET Airways	6.3E-09	5.6E-09	3.0E-09	1.7E-09	9.8E-10	7.6E-10
Lungs	1.3E-10	1.0E-10	4.9E-11	3.6E-11	1.5E-11	1.5E-11
Skin	5.4E-11	3.9E-11	1.9E-11	1.8E-11	1.2E-11	1.2E-11
Spleen	4.8E-11	3.6E-11	1.7E-11	1.4E-11	7.7E-12	9.0E-12
Testes	3.8E-11	2.9E-11	1.6E-11	1.2E-11	6.9E-12	7.9E-12
Thymus	7.5E-10	6.0E-10	2.0E-10	8.3E-11	2.4E-11	1.8E-11
Thyroid	4.0E-07	4.5E-07	2.9E-07	2.2E-07	1.4E-07	1.0E-07
Uterus	5.6E-11	4.2E-11	2.5E-11	1.8E-11	9.4E-12	1.0E-11
Remainder	1.9E-10	1.6E-10	9.6E-11	9.0E-11	5.1E-11	4.4E-11
Effective Dose	2.0E-08	2.3E-08	1.5E-08	1.1E-08	7.2E-09	5.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-125 (T½ = 60.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.8E-10	3.5E-10	1.8E-10	9.1E-11	5.0E-11	3.8E-11
Bladder Wall	1.0E-10	7.0E-11	3.9E-11	2.7E-11	1.7E-11	1.4E-11
Bone Surface	8.5E-10	5.9E-10	2.4E-10	1.3E-10	7.3E-11	6.2E-11
Brain	1.9E-11	9.8E-12	5.0E-12	4.2E-12	2.6E-12	2.8E-12
Breast	3.8E-10	3.0E-10	1.9E-10	1.2E-10	4.4E-11	4.6E-11
GI-Tract						
Oesophagus	5.6E-10	4.1E-10	2.0E-10	1.1E-10	5.1E-11	3.8E-11
St Wall	3.6E-10	2.4E-10	1.1E-10	5.9E-11	3.9E-11	2.8E-11
SI Wall	4.2E-10	3.1E-10	1.4E-10	8.6E-11	4.2E-11	3.4E-11
ULI Wall	1.4E-09	1.1E-09	4.6E-10	2.9E-10	1.4E-10	1.2E-10
LLI Wall	3.5E-09	2.6E-09	1.1E-09	7.0E-10	3.5E-10	2.9E-10
Colon	2.3E-09	1.7E-09	7.5E-10	4.7E-10	2.3E-10	1.9E-10
Kidneys	1.3E-10	9.0E-11	3.1E-11	1.5E-11	7.5E-12	5.4E-12
Liver	3.8E-10	3.0E-10	1.5E-10	9.1E-11	6.5E-11	4.8E-11
Muscle	2.9E-10	2.1E-10	1.1E-10	7.4E-11	5.0E-11	4.0E-11
Ovaries	3.2E-10	2.5E-10	1.1E-10	7.0E-11	3.6E-11	2.7E-11
Pancreas	3.5E-10	2.7E-10	1.2E-10	5.4E-11	3.1E-11	2.0E-11
Red Marrow	1.2E-10	8.9E-11	4.7E-11	3.0E-11	1.8E-11	1.7E-11
Respiratory Tract						
ET Airways	7.0E-09	6.2E-09	3.2E-09	1.9E-09	1.1E-09	8.2E-10
Lungs	8.2E-09	6.4E-09	3.8E-09	2.5E-09	2.0E-09	1.6E-09
Skin	7.6E-11	5.1E-11	2.4E-11	1.4E-11	8.6E-12	8.4E-12
Spleen	3.8E-10	2.9E-10	1.3E-10	7.0E-11	4.1E-11	3.2E-11
Testes	3.2E-11	1.9E-11	7.7E-12	4.2E-12	2.2E-12	2.1E-12
Thymus	5.6E-10	4.1E-10	2.0E-10	1.1E-10	5.1E-11	3.8E-11
Thyroid	1.1E-07	9.0E-08	6.0E-08	4.5E-08	3.1E-08	2.2E-08
Uterus	1.3E-10	9.6E-11	3.6E-11	1.9E-11	8.1E-12	6.0E-12
Remainder	2.4E-10	1.8E-10	9.8E-11	6.8E-11	4.7E-11	3.8E-11
Effective Dose	6.9E-09	5.6E-09	3.6E-09	2.6E-09	1.8E-09	1.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-125 (T½ = 60.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	6.7E-10	5.1E-10	2.6E-10	1.3E-10	7.1E-11	5.4E-11
Bladder Wall	9.1E-11	5.7E-11	2.4E-11	1.4E-11	5.4E-12	4.0E-12
Bone Surface	1.1E-09	8.0E-10	3.3E-10	1.6E-10	9.0E-11	7.3E-11
Brain	6.5E-12	3.2E-12	1.1E-12	7.0E-13	3.2E-13	2.9E-13
Breast	5.3E-10	4.4E-10	2.7E-10	1.7E-10	6.3E-11	6.6E-11
GI-Tract						
Oesophagus	5.3E-10	4.2E-10	2.3E-10	1.3E-10	6.8E-11	5.1E-11
St Wall	4.5E-10	3.1E-10	1.4E-10	7.5E-11	5.0E-11	3.5E-11
SI Wall	5.4E-10	3.7E-10	1.6E-10	9.9E-11	4.8E-11	3.8E-11
ULI Wall	1.8E-09	1.2E-09	5.4E-10	3.3E-10	1.7E-10	1.4E-10
LLI Wall	4.5E-09	3.0E-09	1.3E-09	8.2E-10	4.2E-10	3.4E-10
Colon	3.0E-09	2.0E-09	8.8E-10	5.5E-10	2.7E-10	2.3E-10
Kidneys	1.7E-10	1.2E-10	4.0E-11	1.8E-11	8.6E-12	5.2E-12
Liver	5.3E-10	4.3E-10	2.2E-10	1.3E-10	9.4E-11	6.9E-11
Muscle	3.3E-10	2.5E-10	1.3E-10	7.8E-11	5.6E-11	4.3E-11
Ovaries	4.0E-10	2.8E-10	1.3E-10	7.9E-11	4.1E-11	3.0E-11
Pancreas	4.9E-10	3.8E-10	1.7E-10	7.5E-11	4.3E-11	2.7E-11
Red Marrow	1.5E-10	1.2E-10	6.2E-11	3.8E-11	2.3E-11	2.1E-11
Respiratory Tract						
ET Airways	7.3E-09	6.5E-09	3.4E-09	1.9E-09	1.1E-09	8.6E-10
Lungs	1.1E-08	9.2E-09	5.5E-09	3.6E-09	2.8E-09	2.3E-09
Skin	8.9E-11	6.2E-11	2.9E-11	1.6E-11	9.0E-12	8.5E-12
Spleen	5.3E-10	4.1E-10	1.9E-10	9.9E-11	5.9E-11	4.5E-11
Testes	2.9E-11	1.7E-11	5.5E-12	2.2E-12	9.3E-13	5.2E-13
Thymus	5.3E-10	4.2E-10	2.3E-10	1.3E-10	6.8E-11	5.1E-11
Thyroid	7.6E-09	4.9E-09	3.1E-09	2.3E-09	1.5E-09	1.1E-09
Uterus	1.5E-10	1.0E-10	3.7E-11	1.9E-11	7.4E-12	4.7E-12
Remainder	2.7E-10	2.1E-10	1.1E-10	7.2E-11	5.2E-11	4.1E-11
Effective Dose	2.4E-09	1.8E-09	1.0E-09	6.7E-10	4.8E-10	3.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.2(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-125 (T½ = 60.1 d).

Elemental Iodine Age at intake f1	3 Months 1.0	1 Year 1.0	5 Years 1.0	10 Years 1.0	15 Years 1.0	Adult 1.0
Adrenals	1.1E-10	7.7E-11	4.4E-11	3.5E-11	2.2E-11	2.4E-11
Bladder Wall	3.3E-10	2.7E-10	2.5E-10	2.0E-10	1.7E-10	1.3E-10
Bone Surface	5.2E-10	3.7E-10	2.4E-10	2.2E-10	1.6E-10	1.6E-10
Brain	1.2E-10	8.9E-11	5.5E-11	4.8E-11	3.2E-11	3.2E-11
Breast	1.2E-10	9.5E-11	4.5E-11	3.1E-11	1.9E-11	2.0E-11
GI-Tract						
Oesophagus	1.6E-09	1.3E-09	4.8E-10	2.1E-10	6.4E-11	4.7E-11
St Wall	1.9E-10	1.2E-10	6.5E-11	4.4E-11	3.0E-11	2.9E-11
SI Wall	1.4E-10	1.0E-10	5.6E-11	3.9E-11	2.3E-11	2.4E-11
ULI Wall	4.0E-10	2.6E-10	1.3E-10	6.7E-11	3.8E-11	3.3E-11
LLI Wall	8.9E-10	5.8E-10	2.7E-10	1.2E-10	6.9E-11	5.6E-11
Colon	6.1E-10	4.0E-10	1.9E-10	9.0E-11	5.1E-11	4.3E-11
Kidneys	9.7E-11	7.1E-11	4.1E-11	3.3E-11	2.1E-11	2.3E-11
Liver	1.1E-10	7.9E-11	4.5E-11	3.6E-11	2.1E-11	2.4E-11
Muscle	4.9E-10	4.1E-10	2.7E-10	2.5E-10	1.5E-10	1.2E-10
Ovaries	1.6E-10	1.2E-10	6.6E-11	4.4E-11	2.6E-11	2.6E-11
Pancreas	1.1E-10	8.1E-11	4.6E-11	3.6E-11	2.2E-11	2.5E-11
Red Marrow	1.2E-10	8.6E-11	5.2E-11	4.6E-11	3.2E-11	3.1E-11
Respiratory Tract						
ET Airways	3.1E-09	2.8E-09	1.8E-09	1.0E-09	7.4E-10	5.4E-10
Lungs	2.8E-10	2.2E-10	1.2E-10	9.0E-11	4.1E-11	3.9E-11
Skin	1.2E-10	8.5E-11	4.8E-11	4.6E-11	3.2E-11	3.3E-11
Spleen	1.1E-10	8.0E-11	4.3E-11	3.5E-11	2.1E-11	2.4E-11
Testes	8.9E-11	6.5E-11	4.1E-11	3.1E-11	1.9E-11	2.1E-11
Thymus	1.6E-09	1.3E-09	4.8E-10	2.1E-10	6.4E-11	4.7E-11
Thyroid	9.3E-07	1.0E-06	7.5E-07	5.6E-07	4.0E-07	2.7E-07
Uterus	1.3E-10	9.5E-11	6.3E-11	4.5E-11	2.6E-11	2.7E-11
Remainder	4.1E-10	3.4E-10	2.4E-10	2.2E-10	1.4E-10	1.2E-10
Effective Dose	4.7E-08	5.2E-08	3.7E-08	2.8E-08	2.0E-08	1.4E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.2(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-125 (T½ = 60.1 d).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	8.2E-11	5.9E-11	3.4E-11	2.7E-11	1.7E-11	1.9E-11
Bladder Wall	2.5E-10	2.1E-10	2.0E-10	1.6E-10	1.3E-10	1.0E-10
Bone Surface	4.0E-10	2.8E-10	1.8E-10	1.7E-10	1.2E-10	1.2E-10
Brain	9.6E-11	6.9E-11	4.2E-11	3.7E-11	2.5E-11	2.5E-11
Breast	9.4E-11	7.3E-11	3.5E-11	2.4E-11	1.5E-11	1.5E-11
GI-Tract						
Oesophagus	1.2E-09	9.8E-10	3.7E-10	1.6E-10	5.0E-11	3.6E-11
St Wall	8.1E-11	5.6E-11	3.1E-11	2.3E-11	1.5E-11	1.6E-11
SI Wall	1.1E-10	7.6E-11	4.3E-11	3.0E-11	1.8E-11	1.9E-11
ULI Wall	3.0E-10	2.0E-10	9.6E-11	5.0E-11	2.8E-11	2.5E-11
LLI Wall	6.7E-10	4.3E-10	2.0E-10	9.0E-11	5.1E-11	4.1E-11
Colon	4.6E-10	3.0E-10	1.4E-10	6.7E-11	3.8E-11	3.2E-11
Kidneys	7.5E-11	5.5E-11	3.2E-11	2.6E-11	1.6E-11	1.8E-11
Liver	8.3E-11	6.0E-11	3.5E-11	2.8E-11	1.6E-11	1.8E-11
Muscle	3.7E-10	3.2E-10	2.1E-10	1.9E-10	1.2E-10	9.6E-11
Ovaries	1.2E-10	8.9E-11	5.1E-11	3.4E-11	2.0E-11	2.0E-11
Pancreas	8.5E-11	6.0E-11	3.4E-11	2.7E-11	1.7E-11	1.9E-11
Red Marrow	9.1E-11	6.6E-11	4.0E-11	3.6E-11	2.5E-11	2.4E-11
Respiratory Tract						
ET Airways	1.0E-10	7.1E-11	4.3E-11	3.7E-11	2.5E-11	2.5E-11
Lungs	2.1E-10	1.7E-10	9.2E-11	6.8E-11	3.1E-11	3.0E-11
Skin	9.3E-11	6.6E-11	3.7E-11	3.6E-11	2.4E-11	2.6E-11
Spleen	8.2E-11	6.1E-11	3.3E-11	2.7E-11	1.6E-11	1.8E-11
Testes	6.9E-11	5.1E-11	3.2E-11	2.4E-11	1.5E-11	1.6E-11
Thymus	1.2E-09	9.8E-10	3.7E-10	1.6E-10	5.0E-11	3.6E-11
Thyroid	7.3E-07	8.1E-07	5.8E-07	4.4E-07	3.1E-07	2.1E-07
Uterus	1.0E-10	7.4E-11	4.9E-11	3.5E-11	2.0E-11	2.1E-11
Remainder	3.1E-10	2.6E-10	1.8E-10	1.7E-10	1.1E-10	8.9E-11
Effective Dose	3.7E-08	4.0E-08	2.9E-08	2.2E-08	1.6E-08	1.1E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-129 (T½ = 1.57E+07 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	8.3E-11	6.4E-11	3.7E-11	4.7E-11	2.9E-11	4.2E-11
Bladder Wall	3.2E-10	2.7E-10	2.3E-10	2.1E-10	1.7E-10	1.5E-10
Bone Surface	2.3E-10	1.8E-10	1.1E-10	1.5E-10	1.1E-10	1.4E-10
Brain	9.0E-11	7.0E-11	4.2E-11	5.6E-11	3.7E-11	4.9E-11
Breast	9.1E-11	7.4E-11	4.0E-11	4.6E-11	2.8E-11	3.9E-11
GI-Tract						
Oesophagus	5.7E-10	5.0E-10	2.1E-10	1.5E-10	5.7E-11	5.9E-11
St Wall	2.2E-10	1.4E-10	6.6E-11	6.2E-11	3.8E-11	4.7E-11
SI Wall	9.4E-11	7.3E-11	4.2E-11	4.9E-11	3.0E-11	4.2E-11
ULI Wall	5.0E-10	3.5E-10	1.7E-10	1.2E-10	6.8E-11	7.3E-11
LLI Wall	1.3E-09	8.8E-10	4.0E-10	2.6E-10	1.4E-10	1.4E-10
Colon	8.3E-10	5.8E-10	2.7E-10	1.8E-10	1.0E-10	1.0E-10
Kidneys	7.9E-11	6.2E-11	3.6E-11	4.5E-11	2.9E-11	4.1E-11
Liver	8.3E-11	6.5E-11	3.8E-11	4.7E-11	2.9E-11	4.1E-11
Muscle	2.0E-10	1.8E-10	1.2E-10	1.6E-10	9.7E-11	1.0E-10
Ovaries	9.8E-11	7.6E-11	4.4E-11	5.1E-11	3.2E-11	4.3E-11
Pancreas	8.5E-11	6.6E-11	3.8E-11	4.7E-11	3.0E-11	4.2E-11
Red Marrow	9.0E-11	7.1E-11	4.2E-11	5.5E-11	3.7E-11	4.8E-11
Respiratory Tract						
ET Airways	5.6E-09	4.4E-09	2.1E-09	1.3E-09	7.6E-10	6.7E-10
Lungs	1.8E-10	1.5E-10	8.5E-11	9.3E-11	5.4E-11	6.3E-11
Skin	9.0E-11	7.0E-11	4.0E-11	5.4E-11	3.6E-11	4.8E-11
Spleen	8.3E-11	6.6E-11	3.7E-11	4.6E-11	2.9E-11	4.1E-11
Testes	7.6E-11	6.0E-11	3.6E-11	4.4E-11	2.8E-11	3.9E-11
Thymus	5.7E-10	5.0E-10	2.1E-10	1.5E-10	5.7E-11	5.9E-11
Thyroid	1.4E-06	1.7E-06	1.2E-06	1.3E-06	9.2E-07	7.1E-07
Uterus	8.8E-11	7.0E-11	4.3E-11	4.9E-11	3.1E-11	4.2E-11
Remainder	1.8E-10	1.6E-10	1.0E-10	1.4E-10	9.0E-11	9.7E-11
Effective Dose	7.2E-08	8.6E-08	6.1E-08	6.7E-08	4.6E-08	3.6E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-129 (T½ = 1.57E+07 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	6.3E-10	5.1E-10	2.8E-10	1.5E-10	9.1E-11	7.7E-11
Bladder Wall	1.6E-10	1.1E-10	8.6E-11	7.4E-11	6.0E-11	5.4E-11
Bone Surface	1.1E-09	8.3E-10	3.8E-10	2.2E-10	1.4E-10	1.3E-10
Brain	3.6E-11	2.3E-11	1.5E-11	1.8E-11	1.3E-11	1.7E-11
Breast	5.2E-10	4.5E-10	2.9E-10	1.9E-10	8.2E-11	8.9E-11
GI-Tract						
Oesophagus	6.7E-10	5.5E-10	3.1E-10	1.9E-10	1.0E-10	8.3E-11
St Wall	6.1E-10	4.1E-10	1.9E-10	1.1E-10	7.7E-11	6.2E-11
SI Wall	7.2E-10	5.3E-10	2.4E-10	1.5E-10	7.6E-11	6.8E-11
ULI Wall	3.6E-09	2.7E-09	1.2E-09	7.1E-10	3.5E-10	2.9E-10
LLI Wall	1.0E-08	7.3E-09	3.2E-09	1.9E-09	9.7E-10	8.1E-10
Colon	6.4E-09	4.7E-09	2.0E-09	1.2E-09	6.2E-10	5.2E-10
Kidneys	1.9E-10	1.4E-10	5.6E-11	3.5E-11	2.0E-11	2.1E-11
Liver	5.0E-10	4.2E-10	2.3E-10	1.5E-10	1.1E-10	8.9E-11
Muscle	3.3E-10	2.7E-10	1.6E-10	1.2E-10	8.7E-11	7.9E-11
Ovaries	2.1E-10	1.6E-10	7.8E-11	5.6E-11	3.2E-11	3.1E-11
Pancreas	4.8E-10	4.0E-10	1.9E-10	9.8E-11	6.1E-11	4.7E-11
Red Marrow	1.7E-10	1.3E-10	7.6E-11	5.6E-11	3.8E-11	4.0E-11
Respiratory Tract						
ET Airways	2.5E-08	2.0E-08	8.7E-09	5.7E-09	3.2E-09	3.0E-09
Lungs	7.5E-08	6.0E-08	3.7E-08	2.6E-08	2.3E-08	1.9E-08
Skin	1.1E-10	8.2E-11	4.3E-11	3.3E-11	2.3E-11	2.6E-11
Spleen	5.0E-10	4.1E-10	2.1E-10	1.2E-10	7.5E-11	6.5E-11
Testes	4.1E-11	2.7E-11	1.5E-11	1.5E-11	1.0E-11	1.4E-11
Thymus	6.7E-10	5.5E-10	3.1E-10	1.9E-10	1.0E-10	8.3E-11
Thyroid	5.3E-07	4.9E-07	3.9E-07	4.1E-07	3.2E-07	2.5E-07
Uterus	1.1E-10	8.0E-11	3.5E-11	2.6E-11	1.5E-11	1.8E-11
Remainder	3.0E-10	2.4E-10	1.4E-10	1.1E-10	8.3E-11	7.6E-11
Effective Dose	3.6E-08	3.3E-08	2.4E-08	2.4E-08	1.9E-08	1.5E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-129 (T½ = 1.57E+07 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.6E-09	2.5E-09	1.5E-09	8.4E-10	6.0E-10	5.5E-10
Bladder Wall	8.2E-11	5.7E-11	2.8E-11	1.9E-11	1.1E-11	1.0E-11
Bone Surface	4.0E-09	3.5E-09	1.9E-09	1.0E-09	7.6E-10	7.2E-10
Brain	1.9E-11	1.4E-11	7.6E-12	5.2E-12	3.8E-12	4.1E-12
Breast	2.4E-09	2.4E-09	1.7E-09	1.0E-09	6.4E-10	6.8E-10
GI-Tract						
Oesophagus	2.2E-09	2.2E-09	1.5E-09	8.7E-10	6.1E-10	5.6E-10
St Wall	1.5E-09	1.2E-09	7.0E-10	4.1E-10	3.2E-10	2.7E-10
SI Wall	1.0E-09	7.2E-10	3.2E-10	1.9E-10	9.8E-11	8.2E-11
ULI Wall	5.0E-09	3.4E-09	1.5E-09	9.1E-10	4.8E-10	4.0E-10
LLI Wall	1.4E-08	9.2E-09	4.2E-09	2.5E-09	1.3E-09	1.1E-09
Colon	8.7E-09	5.9E-09	2.7E-09	1.6E-09	8.4E-10	7.2E-10
Kidneys	5.8E-10	5.0E-10	2.3E-10	1.1E-10	6.9E-11	5.7E-11
Liver	2.2E-09	2.1E-09	1.4E-09	8.8E-10	7.3E-10	6.6E-10
Muscle	1.2E-09	1.1E-09	7.3E-10	4.8E-10	4.1E-10	3.8E-10
Ovaries	2.6E-10	1.9E-10	9.3E-11	5.7E-11	3.3E-11	2.6E-11
Pancreas	1.9E-09	1.8E-09	9.8E-10	4.9E-10	3.4E-10	2.9E-10
Red Marrow	6.1E-10	5.8E-10	3.8E-10	2.4E-10	2.0E-10	2.0E-10
Respiratory Tract						
ET Airways	9.1E-08	7.7E-08	3.9E-08	2.7E-08	1.7E-08	1.6E-08
Lungs	2.0E-07	1.8E-07	1.2E-07	8.2E-08	7.2E-08	6.5E-08
Skin	3.3E-10	3.0E-10	1.8E-10	1.1E-10	8.5E-11	8.6E-11
Spleen	2.0E-09	1.9E-09	1.1E-09	6.5E-10	4.9E-10	4.5E-10
Testes	2.4E-11	1.5E-11	6.2E-12	3.4E-12	2.3E-12	2.3E-12
Thymus	2.2E-09	2.2E-09	1.5E-09	8.7E-10	6.1E-10	5.6E-10
Thyroid	6.1E-08	5.5E-08	4.8E-08	4.5E-08	3.8E-08	3.4E-08
Uterus	1.3E-10	9.2E-11	3.5E-11	1.8E-11	8.4E-12	6.6E-12
Remainder	1.0E-09	9.5E-10	6.4E-10	4.4E-10	3.8E-10	3.6E-10
Effective Dose	2.9E-08	2.6E-08	1.8E-08	1.3E-08	1.1E-08	9.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.3(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-129 (T½ = 1.57E+07 y).

Elemental Iodine Age at intake f1	3 Months 1.0	1 Year 1.0	5 Years 1.0	10 Years 1.0	15 Years 1.0	Adult 1.0
Adrenals	1.9E-10	1.5E-10	9.6E-11	1.2E-10	8.1E-11	1.1E-10
Bladder Wall	7.5E-10	6.2E-10	5.9E-10	5.4E-10	4.6E-10	3.9E-10
Bone Surface	5.1E-10	3.9E-10	2.9E-10	3.9E-10	3.1E-10	3.7E-10
Brain	2.1E-10	1.6E-10	1.1E-10	1.4E-10	1.0E-10	1.3E-10
Breast	2.1E-10	1.7E-10	1.0E-10	1.2E-10	7.8E-11	1.0E-10
GI-Tract						
Oesophagus	1.3E-09	1.1E-09	5.2E-10	3.8E-10	1.6E-10	1.6E-10
St Wall	4.0E-10	2.6E-10	1.5E-10	1.4E-10	1.0E-10	1.2E-10
SI Wall	2.2E-10	1.6E-10	1.1E-10	1.2E-10	8.4E-11	1.1E-10
ULI Wall	1.1E-09	8.0E-10	4.2E-10	3.1E-10	1.9E-10	1.9E-10
LLI Wall	2.9E-09	2.0E-09	1.0E-09	6.6E-10	3.9E-10	3.6E-10
Colon	1.9E-09	1.3E-09	6.8E-10	4.6E-10	2.8E-10	2.7E-10
Kidneys	1.8E-10	1.4E-10	9.3E-11	1.2E-10	8.0E-11	1.1E-10
Liver	1.9E-10	1.5E-10	9.7E-11	1.2E-10	8.1E-11	1.1E-10
Muscle	4.5E-10	3.9E-10	2.9E-10	4.0E-10	2.7E-10	2.7E-10
Ovaries	2.3E-10	1.7E-10	1.1E-10	1.3E-10	8.8E-11	1.2E-10
Pancreas	2.0E-10	1.5E-10	9.8E-11	1.2E-10	8.2E-11	1.1E-10
Red Marrow	2.0E-10	1.6E-10	1.1E-10	1.4E-10	1.0E-10	1.3E-10
Respiratory Tract						
ET Airways	3.2E-09	2.5E-09	1.4E-09	9.6E-10	6.8E-10	6.0E-10
Lungs	1.1E-09	8.6E-10	5.6E-10	5.0E-10	3.4E-10	3.5E-10
Skin	2.0E-10	1.6E-10	1.0E-10	1.4E-10	1.0E-10	1.3E-10
Spleen	1.9E-10	1.5E-10	9.5E-11	1.2E-10	8.1E-11	1.1E-10
Testes	1.8E-10	1.4E-10	9.2E-11	1.1E-10	7.7E-11	1.0E-10
Thymus	1.3E-09	1.1E-09	5.2E-10	3.8E-10	1.6E-10	1.6E-10
Thyroid	3.3E-06	3.9E-06	3.1E-06	3.4E-06	2.5E-06	1.9E-06
Uterus	2.0E-10	1.6E-10	1.1E-10	1.3E-10	8.5E-11	1.1E-10
Remainder	3.9E-10	3.4E-10	2.6E-10	3.6E-10	2.5E-10	2.6E-10
Effective Dose	1.7E-07	2.0E-07	1.6E-07	1.7E-07	1.3E-07	9.6E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.3(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-129 (T½ = 1.57E+07 y).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	1.5E-10	1.1E-10	7.5E-11	9.3E-11	6.3E-11	8.7E-11
Bladder Wall	5.9E-10	4.8E-10	4.6E-10	4.2E-10	3.6E-10	3.0E-10
Bone Surface	3.9E-10	3.0E-10	2.2E-10	3.1E-10	2.4E-10	2.8E-10
Brain	1.6E-10	1.2E-10	8.5E-11	1.1E-10	8.0E-11	1.0E-10
Breast	1.6E-10	1.3E-10	7.9E-11	9.2E-11	6.1E-11	8.0E-11
GI-Tract						
Oesophagus	9.6E-10	8.3E-10	4.0E-10	3.0E-10	1.2E-10	1.2E-10
St Wall	1.5E-10	1.1E-10	7.2E-11	8.8E-11	6.1E-11	8.2E-11
SI Wall	1.6E-10	1.3E-10	8.2E-11	9.6E-11	6.5E-11	8.7E-11
ULI Wall	8.7E-10	6.1E-10	3.2E-10	2.4E-10	1.4E-10	1.5E-10
LLI Wall	2.2E-09	1.5E-09	7.7E-10	5.0E-10	3.0E-10	2.8E-10
Colon	1.4E-09	9.9E-10	5.2E-10	3.5E-10	2.1E-10	2.0E-10
Kidneys	1.4E-10	1.1E-10	7.3E-11	9.0E-11	6.2E-11	8.5E-11
Liver	1.5E-10	1.1E-10	7.5E-11	9.3E-11	6.3E-11	8.6E-11
Muscle	3.4E-10	3.0E-10	2.3E-10	3.1E-10	2.1E-10	2.1E-10
Ovaries	1.7E-10	1.3E-10	8.8E-11	1.0E-10	6.8E-11	9.0E-11
Pancreas	1.5E-10	1.1E-10	7.5E-11	9.3E-11	6.4E-11	8.7E-11
Red Marrow	1.6E-10	1.2E-10	8.4E-11	1.1E-10	8.0E-11	1.0E-10
Respiratory Tract						
ET Airways	1.6E-10	1.2E-10	8.5E-11	1.1E-10	8.0E-11	1.0E-10
Lungs	2.5E-10	2.1E-10	1.3E-10	1.6E-10	9.0E-11	1.1E-10
Skin	1.6E-10	1.2E-10	8.0E-11	1.1E-10	7.8E-11	1.0E-10
Spleen	1.5E-10	1.1E-10	7.4E-11	9.2E-11	6.3E-11	8.6E-11
Testes	1.4E-10	1.1E-10	7.2E-11	8.7E-11	6.0E-11	8.2E-11
Thymus	9.6E-10	8.3E-10	4.0E-10	3.0E-10	1.2E-10	1.2E-10
Thyroid	2.6E-06	3.0E-06	2.4E-06	2.7E-06	2.0E-06	1.5E-06
Uterus	1.6E-10	1.2E-10	8.5E-11	9.8E-11	6.6E-11	8.8E-11
Remainder	3.0E-10	2.6E-10	2.0E-10	2.8E-10	1.9E-10	2.0E-10
Effective Dose	1.3E-07	1.5E-07	1.2E-07	1.3E-07	9.9E-08	7.4E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-131 (T½ = 8.04 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	2.0E-10	1.4E-10	6.4E-11	3.8E-11	2.0E-11	1.7E-11
Bladder Wall	7.5E-10	6.0E-10	5.1E-10	4.1E-10	3.3E-10	2.6E-10
Bone Surface	2.6E-10	1.9E-10	1.1E-10	7.5E-11	4.9E-11	4.6E-11
Brain	2.3E-10	1.6E-10	9.7E-11	7.7E-11	5.5E-11	5.4E-11
Breast	2.5E-10	1.8E-10	9.0E-11	5.6E-11	2.6E-11	2.1E-11
GI-Tract						
Oesophagus	1.1E-09	8.2E-10	3.4E-10	1.9E-10	8.0E-11	5.7E-11
St Wall	5.9E-10	3.6E-10	1.5E-10	8.7E-11	4.8E-11	4.0E-11
SI Wall	1.9E-10	1.3E-10	5.6E-11	3.5E-11	1.8E-11	1.6E-11
ULI Wall	5.8E-10	3.4E-10	1.2E-10	5.1E-11	2.5E-11	2.0E-11
LLI Wall	1.2E-09	6.8E-10	2.4E-10	8.4E-11	4.1E-11	3.2E-11
Colon	8.5E-10	4.9E-10	1.7E-10	6.5E-11	3.2E-11	2.5E-11
Kidneys	1.7E-10	1.2E-10	5.6E-11	3.1E-11	1.8E-11	1.5E-11
Liver	1.9E-10	1.4E-10	6.2E-11	3.6E-11	2.0E-11	1.7E-11
Muscle	3.8E-10	3.0E-10	1.5E-10	9.9E-11	5.7E-11	4.7E-11
Ovaries	1.9E-10	1.3E-10	6.1E-11	3.4E-11	1.9E-11	1.7E-11
Pancreas	2.0E-10	1.4E-10	6.7E-11	4.0E-11	2.1E-11	1.8E-11
Red Marrow	2.2E-10	1.6E-10	8.4E-11	6.0E-11	4.0E-11	3.7E-11
Respiratory Tract						
ET Airways	1.8E-08	1.5E-08	7.3E-09	4.4E-09	2.6E-09	2.1E-09
Lungs	3.9E-10	2.9E-10	1.6E-10	1.1E-10	7.3E-11	6.0E-11
Skin	2.0E-10	1.5E-10	6.8E-11	4.7E-11	2.9E-11	2.5E-11
Spleen	1.9E-10	1.3E-10	6.1E-11	3.8E-11	2.0E-11	1.7E-11
Testes	1.5E-10	1.0E-10	5.0E-11	2.9E-11	1.6E-11	1.4E-11
Thymus	1.1E-09	8.2E-10	3.4E-10	1.9E-10	8.0E-11	5.7E-11
Thyroid	1.4E-06	1.4E-06	7.3E-07	3.7E-07	2.2E-07	1.5E-07
Uterus	1.8E-10	1.3E-10	6.8E-11	4.0E-11	2.2E-11	1.9E-11
Remainder	3.6E-10	2.7E-10	1.4E-10	9.7E-11	5.6E-11	4.7E-11
Effective Dose	7.2E-08	7.2E-08	3.7E-08	1.9E-08	1.1E-08	7.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-131 (T½ = 8.04 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.6E-10	3.6E-10	2.0E-10	1.3E-10	9.0E-11	7.4E-11
Bladder Wall	3.8E-10	2.6E-10	1.6E-10	1.2E-10	7.7E-11	6.2E-11
Bone Surface	3.0E-10	2.2E-10	1.1E-10	7.4E-11	5.3E-11	4.5E-11
Brain	8.6E-11	5.3E-11	3.2E-11	2.4E-11	1.7E-11	1.6E-11
Breast	3.8E-10	3.1E-10	2.0E-10	1.4E-10	8.0E-11	7.4E-11
GI-Tract						
Oesophagus	6.6E-10	4.7E-10	2.6E-10	1.7E-10	1.1E-10	9.5E-11
St Wall	1.2E-09	7.3E-10	3.3E-10	2.1E-10	1.3E-10	1.0E-10
SI Wall	2.0E-09	1.5E-09	6.6E-10	4.2E-10	2.1E-10	1.7E-10
ULI Wall	9.2E-09	6.7E-09	2.8E-09	1.7E-09	8.3E-10	6.8E-10
LLI Wall	2.3E-08	1.7E-08	7.1E-09	4.3E-09	2.1E-09	1.7E-09
Colon	1.5E-08	1.1E-08	4.7E-09	2.9E-09	1.4E-09	1.1E-09
Kidneys	2.6E-10	1.9E-10	1.0E-10	6.3E-11	4.2E-11	3.3E-11
Liver	3.9E-10	3.1E-10	1.7E-10	1.1E-10	8.0E-11	6.5E-11
Muscle	3.3E-10	2.5E-10	1.3E-10	8.3E-11	5.7E-11	4.6E-11
Ovaries	6.4E-10	5.3E-10	2.6E-10	1.8E-10	1.0E-10	7.6E-11
Pancreas	4.2E-10	3.2E-10	1.8E-10	1.1E-10	7.7E-11	6.0E-11
Red Marrow	2.2E-10	1.7E-10	1.1E-10	8.0E-11	6.2E-11	5.6E-11
Respiratory Tract						
ET Airways	2.2E-08	1.8E-08	8.5E-09	5.2E-09	3.0E-09	2.6E-09
Lungs	3.5E-08	2.7E-08	1.7E-08	1.3E-08	1.2E-08	9.6E-09
Skin	1.6E-10	1.1E-10	5.9E-11	3.7E-11	2.5E-11	2.2E-11
Spleen	3.8E-10	3.0E-10	1.6E-10	1.0E-10	7.1E-11	5.6E-11
Testes	1.3E-10	9.4E-11	3.8E-11	2.5E-11	1.1E-11	9.3E-12
Thymus	6.6E-10	4.7E-10	2.6E-10	1.7E-10	1.1E-10	9.5E-11
Thyroid	3.2E-07	2.1E-07	1.1E-07	5.5E-08	3.4E-08	2.2E-08
Uterus	3.6E-10	2.9E-10	1.4E-10	9.0E-11	4.7E-11	3.8E-11
Remainder	3.3E-10	2.4E-10	1.3E-10	8.6E-11	5.9E-11	4.8E-11
Effective Dose	2.2E-08	1.5E-08	8.2E-09	4.7E-09	3.4E-09	2.4E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-131 (T½ = 8.04 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	5.0E-10	4.0E-10	2.3E-10	1.4E-10	1.0E-10	8.4E-11
Bladder Wall	2.9E-10	2.1E-10	1.0E-10	7.2E-11	3.5E-11	2.9E-11
Bone Surface	3.0E-10	2.3E-10	1.2E-10	7.3E-11	5.3E-11	4.5E-11
Brain	4.8E-11	3.5E-11	2.1E-11	1.5E-11	1.1E-11	9.8E-12
Breast	3.9E-10	3.3E-10	2.2E-10	1.5E-10	8.9E-11	8.3E-11
GI-Tract						
Oesophagus	5.2E-10	4.2E-10	2.5E-10	1.7E-10	1.2E-10	1.0E-10
St Wall	1.3E-09	7.8E-10	3.6E-10	2.2E-10	1.4E-10	1.1E-10
SI Wall	2.5E-09	1.7E-09	7.6E-10	4.8E-10	2.4E-10	2.0E-10
ULI Wall	1.2E-08	7.8E-09	3.3E-09	2.0E-09	9.6E-10	7.9E-10
LLI Wall	3.0E-08	1.9E-08	8.2E-09	5.0E-09	2.4E-09	2.0E-09
Colon	1.9E-08	1.3E-08	5.4E-09	3.3E-09	1.6E-09	1.3E-09
Kidneys	2.7E-10	2.0E-10	1.1E-10	6.8E-11	4.6E-11	3.6E-11
Liver	4.2E-10	3.3E-10	1.9E-10	1.2E-10	9.1E-11	7.3E-11
Muscle	3.1E-10	2.4E-10	1.3E-10	8.0E-11	5.7E-11	4.6E-11
Ovaries	7.7E-10	5.9E-10	2.9E-10	2.0E-10	1.1E-10	8.6E-11
Pancreas	4.5E-10	3.5E-10	2.0E-10	1.2E-10	8.7E-11	6.7E-11
Red Marrow	2.1E-10	1.7E-10	1.1E-10	8.4E-11	6.5E-11	5.9E-11
Respiratory Tract						
ET Airways	2.3E-08	1.8E-08	8.7E-09	5.4E-09	3.1E-09	2.6E-09
Lungs	4.0E-08	3.1E-08	2.0E-08	1.5E-08	1.4E-08	1.1E-08
Skin	1.4E-10	1.1E-10	5.7E-11	3.5E-11	2.5E-11	2.1E-11
Spleen	4.0E-10	3.2E-10	1.7E-10	1.1E-10	7.9E-11	6.2E-11
Testes	1.3E-10	9.2E-11	3.7E-11	2.4E-11	1.0E-11	8.6E-12
Thymus	5.2E-10	4.2E-10	2.5E-10	1.7E-10	1.2E-10	1.0E-10
Thyroid	2.3E-08	1.2E-08	5.9E-09	3.0E-09	1.7E-09	1.1E-09
Uterus	4.1E-10	3.1E-10	1.5E-10	9.8E-11	5.1E-11	4.1E-11
Remainder	3.1E-10	2.3E-10	1.3E-10	8.5E-11	5.9E-11	4.9E-11
Effective Dose	8.8E-09	6.2E-09	3.5E-09	2.4E-09	2.0E-09	1.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.4(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-131 (T½ = 8.04 d).

Elemental Iodine						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	4.4E-10	3.0E-10	1.6E-10	9.4E-11	5.4E-11	4.4E-11
Bladder Wall	1.7E-09	1.4E-09	1.3E-09	1.1E-09	9.1E-10	6.9E-10
Bone Surface	5.6E-10	4.1E-10	2.6E-10	1.8E-10	1.3E-10	1.2E-10
Brain	4.9E-10	3.5E-10	2.3E-10	1.8E-10	1.4E-10	1.3E-10
Breast	5.3E-10	3.9E-10	2.2E-10	1.3E-10	6.8E-11	5.5E-11
GI-Tract						
Oesophagus	2.2E-09	1.6E-09	8.0E-10	4.3E-10	2.1E-10	1.4E-10
St Wall	1.0E-09	6.3E-10	3.2E-10	1.8E-10	1.2E-10	9.4E-11
SI Wall	4.2E-10	2.8E-10	1.4E-10	8.6E-11	5.0E-11	4.1E-11
ULI Wall	1.3E-09	7.4E-10	3.1E-10	1.2E-10	6.8E-11	5.3E-11
LLI Wall	2.7E-09	1.5E-09	5.8E-10	2.0E-10	1.1E-10	8.0E-11
Colon	1.9E-09	1.1E-09	4.3E-10	1.5E-10	8.6E-11	6.5E-11
Kidneys	3.8E-10	2.6E-10	1.4E-10	7.8E-11	4.8E-11	4.0E-11
Liver	4.3E-10	3.0E-10	1.5E-10	8.9E-11	5.3E-11	4.4E-11
Muscle	8.0E-10	6.1E-10	3.6E-10	2.3E-10	1.5E-10	1.2E-10
Ovaries	4.2E-10	2.8E-10	1.5E-10	8.7E-11	5.3E-11	4.4E-11
Pancreas	4.5E-10	3.1E-10	1.6E-10	9.7E-11	5.6E-11	4.7E-11
Red Marrow	4.7E-10	3.4E-10	2.0E-10	1.4E-10	1.1E-10	9.3E-11
Respiratory Tract						
ET Airways	1.1E-08	8.6E-09	5.0E-09	3.1E-09	2.2E-09	1.8E-09
Lungs	2.7E-09	2.1E-09	1.4E-09	1.0E-09	7.4E-10	6.9E-10
Skin	4.4E-10	3.1E-10	1.7E-10	1.1E-10	7.5E-11	6.4E-11
Spleen	4.2E-10	2.9E-10	1.5E-10	9.3E-11	5.5E-11	4.4E-11
Testes	3.4E-10	2.3E-10	1.3E-10	7.3E-11	4.3E-11	3.6E-11
Thymus	2.2E-09	1.6E-09	8.0E-10	4.3E-10	2.1E-10	1.4E-10
Thyroid	3.3E-06	3.2E-06	1.9E-06	9.5E-07	6.2E-07	3.9E-07
Uterus	4.1E-10	2.8E-10	1.7E-10	1.0E-10	6.1E-11	5.2E-11
Remainder	7.4E-10	5.6E-10	3.3E-10	2.2E-10	1.4E-10	1.2E-10
Effective Dose	1.7E-07	1.6E-07	9.4E-08	4.8E-08	3.1E-08	2.0E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.4(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-131 ($T½$ = 8.04 d).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	3.3E-10	2.3E-10	1.2E-10	7.2E-11	4.1E-11	3.4E-11
Bladder Wall	1.4E-09	1.1E-09	1.0E-09	8.3E-10	7.1E-10	5.3E-10
Bone Surface	4.3E-10	3.1E-10	2.0E-10	1.4E-10	9.8E-11	8.8E-11
Brain	3.8E-10	2.7E-10	1.8E-10	1.4E-10	1.1E-10	1.0E-10
Breast	4.0E-10	2.9E-10	1.6E-10	1.0E-10	5.2E-11	4.2E-11
GI-Tract						
Oesophagus	1.6E-09	1.2E-09	6.0E-10	3.3E-10	1.6E-10	1.1E-10
St Wall	3.2E-10	2.1E-10	1.1E-10	6.2E-11	3.7E-11	3.0E-11
SI Wall	3.1E-10	2.1E-10	1.0E-10	6.3E-11	3.7E-11	3.0E-11
ULI Wall	9.3E-10	5.3E-10	2.2E-10	8.1E-11	4.5E-11	3.5E-11
LLI Wall	1.9E-09	1.0E-09	4.0E-10	1.2E-10	6.5E-11	4.7E-11
Colon	1.4E-09	7.5E-10	3.0E-10	9.8E-11	5.4E-11	4.0E-11
Kidneys	3.0E-10	2.0E-10	1.1E-10	6.0E-11	3.6E-11	3.1E-11
Liver	3.3E-10	2.3E-10	1.2E-10	6.8E-11	4.1E-11	3.3E-11
Muscle	6.1E-10	4.6E-10	2.7E-10	1.8E-10	1.1E-10	8.9E-11
Ovaries	3.2E-10	2.2E-10	1.2E-10	6.6E-11	4.1E-11	3.4E-11
Pancreas	3.3E-10	2.3E-10	1.2E-10	7.2E-11	4.1E-11	3.5E-11
Red Marrow	3.6E-10	2.6E-10	1.5E-10	1.1E-10	8.1E-11	7.1E-11
Respiratory Tract						
ET Airways	3.9E-10	2.8E-10	1.8E-10	1.4E-10	1.1E-10	1.0E-10
Lungs	5.1E-10	3.8E-10	2.3E-10	1.5E-10	8.8E-11	7.2E-11
Skin	3.4E-10	2.4E-10	1.3E-10	8.6E-11	5.8E-11	4.9E-11
Spleen	3.2E-10	2.2E-10	1.1E-10	7.0E-11	4.1E-11	3.3E-11
Testes	2.6E-10	1.8E-10	9.9E-11	5.7E-11	3.4E-11	2.8E-11
Thymus	1.6E-09	1.2E-09	6.0E-10	3.3E-10	1.6E-10	1.1E-10
Thyroid	2.6E-06	2.5E-06	1.5E-06	7.4E-07	4.8E-07	3.1E-07
Uterus	3.2E-10	2.2E-10	1.3E-10	7.8E-11	4.7E-11	4.0E-11
Remainder	5.5E-10	4.2E-10	2.5E-10	1.7E-10	1.1E-10	8.7E-11
Effective Dose	1.3E-07	1.3E-07	7.4E-08	3.7E-08	2.4E-08	1.5E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.5(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-132 (T½ = 2.30 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	9.6E-11	6.8E-11	3.3E-11	2.1E-11	1.3E-11	1.1E-11
Bladder Wall	4.0E-10	3.2E-10	2.3E-10	1.9E-10	1.6E-10	1.2E-10
Bone Surface	9.7E-11	6.8E-11	3.4E-11	2.2E-11	1.4E-11	1.2E-11
Brain	8.7E-11	6.1E-11	3.1E-11	2.1E-11	1.3E-11	1.2E-11
Breast	9.0E-11	6.3E-11	3.0E-11	1.8E-11	1.0E-11	8.6E-12
GI-Tract						
Oesophagus	2.4E-10	1.7E-10	6.5E-11	3.7E-11	1.7E-11	1.4E-11
St Wall	9.4E-10	5.4E-10	2.3E-10	1.4E-10	7.8E-11	6.4E-11
SI Wall	1.1E-10	7.8E-11	3.7E-11	2.4E-11	1.4E-11	1.2E-11
ULI Wall	1.2E-10	7.9E-11	3.9E-11	2.4E-11	1.4E-11	1.2E-11
LLI Wall	9.4E-11	6.5E-11	3.5E-11	2.2E-11	1.3E-11	1.2E-11
Colon	1.1E-10	7.3E-11	3.7E-11	2.3E-11	1.3E-11	1.2E-11
Kidneys	8.9E-11	6.2E-11	3.0E-11	1.9E-11	1.1E-11	9.9E-12
Liver	9.6E-11	6.8E-11	3.2E-11	2.0E-11	1.2E-11	9.8E-12
Muscle	1.2E-10	8.5E-11	4.1E-11	2.6E-11	1.4E-11	1.2E-11
Ovaries	9.2E-11	6.5E-11	3.4E-11	2.2E-11	1.3E-11	1.1E-11
Pancreas	1.2E-10	8.7E-11	4.3E-11	2.9E-11	1.7E-11	1.4E-11
Red Marrow	8.6E-11	6.1E-11	3.0E-11	2.1E-11	1.3E-11	1.1E-11
Respiratory Tract						
ET Airways	1.0E-08	8.8E-09	4.6E-09	2.7E-09	1.6E-09	1.2E-09
Lungs	2.0E-10	1.5E-10	8.0E-11	5.6E-11	4.5E-11	3.6E-11
Skin	7.8E-11	5.4E-11	2.5E-11	1.6E-11	9.3E-12	8.2E-12
Spleen	1.0E-10	7.2E-11	3.5E-11	2.3E-11	1.3E-11	1.2E-11
Testes	7.8E-11	5.5E-11	2.9E-11	1.9E-11	1.1E-11	9.1E-12
Thymus	2.4E-10	1.7E-10	6.5E-11	3.7E-11	1.7E-11	1.4E-11
Thyroid	1.8E-08	1.6E-08	7.6E-09	3.4E-09	2.1E-09	1.4E-09
Uterus	1.0E-10	7.3E-11	4.2E-11	2.8E-11	1.6E-11	1.4E-11
Remainder	1.2E-10	8.4E-11	4.1E-11	2.6E-11	1.5E-11	1.3E-11
Effective Dose	1.1E-09	9.6E-10	4.5E-10	2.2E-10	1.3E-10	9.4E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.5(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-132 (T½ = 2.30 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	8.5E-11	6.3E-11	3.4E-11	2.1E-11	1.3E-11	1.1E-11
Bladder Wall	1.1E-10	7.6E-11	4.3E-11	3.2E-11	2.2E-11	1.7E-11
Bone Surface	6.3E-11	4.5E-11	2.2E-11	1.4E-11	9.0E-12	8.0E-12
Brain	2.7E-11	1.8E-11	1.1E-11	8.4E-12	5.6E-12	5.3E-12
Breast	6.8E-11	5.1E-11	2.8E-11	1.9E-11	1.0E-11	8.7E-12
GI-Tract						
Oesophagus	1.9E-10	1.3E-10	5.5E-11	3.2E-11	1.6E-11	1.3E-11
St Wall	1.7E-09	9.6E-10	4.0E-10	2.5E-10	1.4E-10	1.1E-10
SI Wall	1.5E-09	1.1E-09	4.6E-10	2.9E-10	1.3E-10	1.1E-10
ULI Wall	1.9E-09	1.4E-09	5.9E-10	3.8E-10	1.8E-10	1.5E-10
LLI Wall	7.0E-10	4.9E-10	2.1E-10	1.3E-10	6.4E-11	5.4E-11
Colon	1.4E-09	1.0E-09	4.3E-10	2.7E-10	1.3E-10	1.1E-10
Kidneys	7.7E-11	5.8E-11	3.0E-11	2.0E-11	1.1E-11	9.5E-12
Liver	9.9E-11	7.3E-11	3.6E-11	2.2E-11	1.3E-11	1.0E-11
Muscle	9.2E-11	6.8E-11	3.2E-11	2.1E-11	1.2E-11	9.8E-12
Ovaries	1.9E-10	1.5E-10	7.1E-11	4.8E-11	2.6E-11	2.2E-11
Pancreas	1.4E-10	1.0E-10	5.2E-11	3.6E-11	2.1E-11	1.7E-11
Red Marrow	5.1E-11	3.9E-11	2.3E-11	1.8E-11	1.2E-11	1.1E-11
Respiratory Tract						
ET Airways	1.2E-08	1.0E-08	5.1E-09	3.0E-09	1.8E-09	1.4E-09
Lungs	1.2E-09	8.8E-10	5.5E-10	4.0E-10	3.7E-10	3.0E-10
Skin	4.2E-11	2.9E-11	1.4E-11	9.3E-12	5.4E-12	4.7E-12
Spleen	9.7E-11	7.2E-11	3.7E-11	2.5E-11	1.5E-11	1.3E-11
Testes	3.1E-11	2.1E-11	9.5E-12	5.7E-12	2.7E-12	2.1E-12
Thymus	1.9E-10	1.3E-10	5.5E-11	3.2E-11	1.6E-11	1.3E-11
Thyroid	2.3E-09	1.6E-09	7.6E-10	3.4E-10	2.1E-10	1.4E-10
Uterus	1.5E-10	1.2E-10	5.6E-11	3.8E-11	1.9E-11	1.6E-11
Remainder	6.0E-09	5.1E-09	2.6E-09	1.5E-09	8.9E-10	7.2E-10
Effective Dose	9.9E-10	7.3E-10	3.6E-10	2.2E-10	1.4E-10	1.1E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.5(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-132 (T½ = 2.30 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	8.4E-11	6.3E-11	3.4E-11	2.1E-11	1.3E-11	1.1E-11
Bladder Wall	7.0E-11	5.1E-11	2.3E-11	1.5E-11	7.5E-12	5.9E-12
Bone Surface	5.8E-11	4.2E-11	2.0E-11	1.4E-11	8.5E-12	7.5E-12
Brain	1.9E-11	1.4E-11	8.7E-12	7.0E-12	4.8E-12	4.7E-12
Breast	6.5E-11	5.0E-11	2.8E-11	1.9E-11	1.0E-11	8.7E-12
GI-Tract						
Oesophagus	1.8E-10	1.3E-10	5.4E-11	3.2E-11	1.6E-11	1.3E-11
St Wall	1.8E-09	1.0E-09	4.2E-10	2.6E-10	1.5E-10	1.2E-10
SI Wall	1.8E-09	1.2E-09	5.0E-10	3.1E-10	1.5E-10	1.2E-10
ULI Wall	2.2E-09	1.5E-09	6.5E-10	4.1E-10	1.9E-10	1.6E-10
LLI Wall	8.0E-10	5.4E-10	2.3E-10	1.4E-10	6.9E-11	5.8E-11
Colon	1.6E-09	1.1E-09	4.7E-10	3.0E-10	1.4E-10	1.2E-10
Kidneys	7.5E-11	5.7E-11	3.0E-11	2.0E-11	1.1E-11	9.5E-12
Liver	1.0E-10	7.4E-11	3.7E-11	2.3E-11	1.3E-11	1.0E-11
Muscle	8.9E-11	6.6E-11	3.2E-11	2.0E-11	1.2E-11	9.6E-12
Ovaries	2.0E-10	1.5E-10	7.4E-11	5.0E-11	2.7E-11	2.3E-11
Pancreas	1.4E-10	1.0E-10	5.3E-11	3.7E-11	2.1E-11	1.7E-11
Red Marrow	4.6E-11	3.7E-11	2.2E-11	1.7E-11	1.2E-11	1.1E-11
Respiratory Tract						
ET Airways	1.2E-08	1.0E-08	5.2E-09	3.1E-09	1.8E-09	1.4E-09
Lungs	1.3E-09	9.6E-10	6.0E-10	4.4E-10	4.1E-10	3.3E-10
Skin	3.6E-11	2.7E-11	1.3E-11	8.6E-12	5.0E-12	4.3E-12
Spleen	9.6E-11	7.2E-11	3.7E-11	2.5E-11	1.5E-11	1.3E-11
Testes	2.5E-11	1.8E-11	7.4E-12	4.4E-12	1.9E-12	1.4E-12
Thymus	1.8E-10	1.3E-10	5.4E-11	3.2E-11	1.6E-11	1.3E-11
Thyroid	1.4E-10	8.0E-11	4.0E-11	2.2E-11	1.3E-11	1.1E-11
Uterus	1.6E-10	1.2E-10	5.8E-11	3.9E-11	1.9E-11	1.6E-11
Remainder	6.1E-09	5.1E-09	2.6E-09	1.5E-09	9.0E-10	7.3E-10
Effective Dose	9.3E-10	6.8E-10	3.4E-10	2.1E-10	1.4E-10	1.1E-10

GI-Tract Gastrointestinal Tract
St Stomach
SI Small Intestine
ULI Upper Large Intestine
LLI Lower Large Intestine
ET Airways Extrathoracic airways
Lungs Thoracic airways

Table 5.19.5(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-132 (T½ = 2.30 h).

Elemental Iodine Age at intake f1	3 Months 1.0	1 Year 1.0	5 Years 1.0	10 Years 1.0	15 Years 1.0	Adult 1.0
Adrenals	2.1E-10	1.5E-10	8.2E-11	5.2E-11	3.4E-11	2.8E-11
Bladder Wall	9.5E-10	7.5E-10	6.0E-10	5.0E-10	4.3E-10	3.3E-10
Bone Surface	2.0E-10	1.4E-10	7.6E-11	4.9E-11	3.2E-11	2.8E-11
Brain	1.8E-10	1.2E-10	6.7E-11	4.3E-11	2.8E-11	2.3E-11
Breast	1.8E-10	1.2E-10	6.5E-11	4.1E-11	2.6E-11	2.1E-11
GI-Tract						
Oesophagus	3.1E-10	2.1E-10	1.0E-10	6.3E-11	3.7E-11	2.9E-11
St Wall	1.5E-09	8.6E-10	4.4E-10	2.6E-10	1.8E-10	1.5E-10
SI Wall	2.4E-10	1.6E-10	9.1E-11	5.9E-11	3.7E-11	3.0E-11
ULI Wall	2.4E-10	1.6E-10	9.2E-11	5.7E-11	3.6E-11	3.0E-11
LLI Wall	2.1E-10	1.4E-10	8.8E-11	5.6E-11	3.5E-11	3.1E-11
Colon	2.3E-10	1.5E-10	9.0E-11	5.6E-11	3.5E-11	3.0E-11
Kidneys	2.0E-10	1.4E-10	7.5E-11	4.8E-11	3.1E-11	2.6E-11
Liver	2.1E-10	1.4E-10	7.9E-11	4.9E-11	3.1E-11	2.6E-11
Muscle	2.1E-10	1.5E-10	8.1E-11	5.1E-11	3.3E-11	2.7E-11
Ovaries	2.1E-10	1.5E-10	8.8E-11	5.6E-11	3.7E-11	3.0E-11
Pancreas	2.5E-10	1.8E-10	1.0E-10	6.6E-11	4.3E-11	3.6E-11
Red Marrow	1.8E-10	1.2E-10	7.0E-11	4.7E-11	3.1E-11	2.7E-11
Respiratory Tract						
ET Airways	7.1E-09	5.8E-09	3.5E-09	2.1E-09	1.5E-09	1.2E-09
Lungs	2.2E-09	1.7E-09	1.1E-09	8.5E-10	6.4E-10	6.0E-10
Skin	1.6E-10	1.1E-10	5.7E-11	3.6E-11	2.3E-11	1.9E-11
Spleen	2.2E-10	1.5E-10	8.4E-11	5.5E-11	3.6E-11	3.0E-11
Testes	1.8E-10	1.3E-10	7.6E-11	4.8E-11	3.0E-11	2.4E-11
Thymus	3.1E-10	2.1E-10	1.0E-10	6.3E-11	3.7E-11	2.9E-11
Thyroid	4.3E-08	3.8E-08	2.0E-08	8.9E-09	5.8E-09	3.6E-09
Uterus	2.3E-10	1.6E-10	1.1E-10	7.1E-11	4.5E-11	3.7E-11
Remainder	2.1E-10	1.5E-10	8.1E-11	5.1E-11	3.3E-11	2.8E-11
Effective Dose	2.8E-09	2.3E-09	1.3E-09	6.4E-10	4.3E-10	3.1E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.5(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-132 (T½ = 2.30 h).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	1.6E-10	1.1E-10	6.1E-11	3.9E-11	2.5E-11	2.1E-11
Bladder Wall	8.2E-10	6.5E-10	5.2E-10	4.4E-10	3.8E-10	2.9E-10
Bone Surface	1.6E-10	1.1E-10	6.0E-11	3.9E-11	2.5E-11	2.1E-11
Brain	1.5E-10	1.0E-10	5.4E-11	3.4E-11	2.1E-11	1.8E-11
Breast	1.3E-10	8.9E-11	4.7E-11	2.9E-11	1.9E-11	1.6E-11
GI-Tract						
Oesophagus	1.9E-10	1.3E-10	6.7E-11	4.1E-11	2.5E-11	2.1E-11
St Wall	1.5E-10	9.8E-11	5.5E-11	3.3E-11	2.3E-11	1.9E-11
SI Wall	1.7E-10	1.1E-10	6.5E-11	4.2E-11	2.7E-11	2.2E-11
ULI Wall	1.6E-10	1.1E-10	6.1E-11	3.8E-11	2.4E-11	2.1E-11
LLI Wall	1.6E-10	1.1E-10	6.9E-11	4.4E-11	2.8E-11	2.5E-11
Colon	1.6E-10	1.1E-10	6.5E-11	4.1E-11	2.6E-11	2.3E-11
Kidneys	1.6E-10	1.1E-10	5.9E-11	3.7E-11	2.4E-11	2.0E-11
Liver	1.6E-10	1.1E-10	5.9E-11	3.8E-11	2.4E-11	2.0E-11
Muscle	1.6E-10	1.1E-10	6.0E-11	3.8E-11	2.4E-11	2.0E-11
Ovaries	1.7E-10	1.2E-10	7.3E-11	4.7E-11	3.0E-11	2.5E-11
Pancreas	1.7E-10	1.2E-10	6.3E-11	4.0E-11	2.6E-11	2.2E-11
Red Marrow	1.4E-10	9.9E-11	5.6E-11	3.7E-11	2.4E-11	2.0E-11
Respiratory Tract						
ET Airways	1.7E-10	1.1E-10	6.2E-11	3.9E-11	2.4E-11	2.0E-11
Lungs	1.6E-10	1.1E-10	5.6E-11	3.6E-11	2.3E-11	1.9E-11
Skin	1.3E-10	8.7E-11	4.6E-11	2.8E-11	1.8E-11	1.5E-11
Spleen	1.6E-10	1.1E-10	5.8E-11	3.7E-11	2.4E-11	2.0E-11
Testes	1.6E-10	1.1E-10	6.6E-11	4.2E-11	2.6E-11	2.1E-11
Thymus	1.9E-10	1.3E-10	6.7E-11	4.1E-11	2.5E-11	2.1E-11
Thyroid	3.7E-08	3.3E-08	1.7E-08	7.7E-09	5.0E-09	3.2E-09
Uterus	1.9E-10	1.4E-10	9.1E-11	6.0E-11	3.8E-11	3.2E-11
Remainder	1.6E-10	1.1E-10	5.9E-11	3.8E-11	2.4E-11	2.0E-11
Effective Dose	2.0E-09	1.8E-09	9.5E-10	4.4E-10	2.9E-10	1.9E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.6(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-133 (T½ = 20.8 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	1.6E-10	1.1E-10	5.0E-11	3.0E-11	1.7E-11	1.4E-11
Bladder Wall	1.0E-09	8.4E-10	7.2E-10	6.1E-10	4.9E-10	3.8E-10
Bone Surface	1.8E-10	1.2E-10	5.8E-11	3.7E-11	2.2E-11	2.0E-11
Brain	1.7E-10	1.1E-10	5.6E-11	3.8E-11	2.3E-11	2.1E-11
Breast	1.7E-10	1.2E-10	5.3E-11	3.2E-11	1.6E-11	1.4E-11
GI-Tract						
Oesophagus	4.6E-10	3.2E-10	1.3E-10	6.7E-11	3.0E-11	2.3E-11
St Wall	9.8E-10	5.6E-10	2.3E-10	1.4E-10	7.5E-11	6.2E-11
SI Wall	1.7E-10	1.2E-10	5.3E-11	3.4E-11	1.8E-11	1.5E-11
ULI Wall	2.7E-10	1.7E-10	7.2E-11	4.2E-11	2.2E-11	1.9E-11
LLI Wall	3.3E-10	2.0E-10	8.9E-11	5.2E-11	2.7E-11	2.3E-11
Colon	2.9E-10	1.8E-10	8.0E-11	4.6E-11	2.4E-11	2.1E-11
Kidneys	1.5E-10	1.0E-10	4.6E-11	2.8E-11	1.6E-11	1.3E-11
Liver	1.6E-10	1.1E-10	4.9E-11	2.9E-11	1.6E-11	1.4E-11
Muscle	2.2E-10	1.5E-10	7.2E-11	4.5E-11	2.5E-11	2.1E-11
Ovaries	1.6E-10	1.1E-10	5.2E-11	3.3E-11	1.9E-11	1.6E-11
Pancreas	1.7E-10	1.2E-10	5.3E-11	3.3E-11	1.8E-11	1.6E-11
Red Marrow	1.6E-10	1.1E-10	5.3E-11	3.5E-11	2.1E-11	1.8E-11
Respiratory Tract						
ET Airways	1.5E-08	1.3E-08	6.4E-09	3.8E-09	2.2E-09	1.8E-09
Lungs	2.8E-10	2.0E-10	1.1E-10	7.1E-11	5.3E-11	4.2E-11
Skin	1.5E-10	1.0E-10	4.6E-11	2.9E-11	1.7E-11	1.4E-11
Spleen	1.6E-10	1.1E-10	4.9E-11	3.1E-11	1.7E-11	1.4E-11
Testes	1.4E-10	9.6E-11	4.8E-11	2.9E-11	1.6E-11	1.4E-11
Thymus	4.6E-10	3.2E-10	1.3E-10	6.7E-11	3.0E-11	2.3E-11
Thyroid	3.8E-07	3.5E-07	1.6E-07	7.4E-08	4.4E-08	2.8E-08
Uterus	1.6E-10	1.1E-10	6.3E-11	3.9E-11	2.2E-11	1.9E-11
Remainder	2.2E-10	1.5E-10	7.2E-11	4.5E-11	2.5E-11	2.1E-11
Effective Dose	1.9E-08	1.8E-08	8.3E-09	3.8E-09	2.2E-09	1.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.6(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-133 (T½ = 20.8 h).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.5E-10	1.1E-10	5.9E-11	3.6E-11	2.3E-11	1.9E-11
Bladder Wall	3.4E-10	2.2E-10	1.4E-10	1.2E-10	7.9E-11	6.3E-11
Bone Surface	1.2E-10	8.4E-11	4.0E-11	2.6E-11	1.7E-11	1.5E-11
Brain	5.1E-11	3.0E-11	1.7E-11	1.2E-11	8.2E-12	7.8E-12
Breast	1.2E-10	9.0E-11	5.3E-11	3.5E-11	1.9E-11	1.7E-11
GI-Tract						
Oesophagus	2.9E-10	2.0E-10	9.0E-11	5.2E-11	2.9E-11	2.4E-11
St Wall	1.8E-09	1.0E-09	4.3E-10	2.6E-10	1.5E-10	1.2E-10
SI Wall	3.0E-09	2.2E-09	9.4E-10	5.9E-10	2.8E-10	2.3E-10
ULI Wall	1.2E-08	8.5E-09	3.5E-09	2.2E-09	1.0E-09	8.3E-10
LLI Wall	1.8E-08	1.3E-08	5.4E-09	3.3E-09	1.6E-09	1.3E-09
Colon	1.4E-08	1.0E-08	4.4E-09	2.7E-09	1.2E-09	1.0E-09
Kidneys	1.3E-10	9.1E-11	4.7E-11	3.0E-11	1.8E-11	1.5E-11
Liver	1.7E-10	1.2E-10	6.2E-11	3.8E-11	2.3E-11	1.9E-11
Muscle	1.6E-10	1.2E-10	5.6E-11	3.6E-11	2.1E-11	1.7E-11
Ovaries	4.4E-10	3.6E-10	1.8E-10	1.2E-10	6.8E-11	5.3E-11
Pancreas	1.8E-10	1.3E-10	6.7E-11	4.2E-11	2.6E-11	2.0E-11
Red Marrow	1.0E-10	7.5E-11	4.5E-11	3.5E-11	2.4E-11	2.1E-11
Respiratory Tract						
ET Airways	1.7E-08	1.4E-08	7.0E-09	4.2E-09	2.4E-09	2.0E-09
Lungs	7.0E-09	5.4E-09	3.3E-09	2.4E-09	2.3E-09	1.8E-09
Skin	8.0E-11	5.2E-11	2.5E-11	1.6E-11	9.7E-12	8.3E-12
Spleen	1.5E-10	1.1E-10	5.4E-11	3.5E-11	2.2E-11	1.7E-11
Testes	8.8E-11	6.1E-11	2.6E-11	1.7E-11	7.4E-12	6.2E-12
Thymus	2.9E-10	2.0E-10	9.0E-11	5.2E-11	2.9E-11	2.4E-11
Thyroid	7.3E-08	4.5E-08	2.1E-08	9.3E-09	5.5E-09	3.6E-09
Uterus	2.7E-10	2.1E-10	1.0E-10	6.7E-11	3.4E-11	2.8E-11
Remainder	2.0E-10	1.4E-10	7.0E-11	4.6E-11	2.7E-11	2.2E-11
Effective Dose	6.6E-09	4.4E-09	2.1E-09	1.2E-09	7.4E-10	5.5E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.6(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-133 (T½ = 20.8 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.5E-10	1.1E-10	6.0E-11	3.7E-11	2.4E-11	1.9E-11
Bladder Wall	1.9E-10	1.4E-10	6.6E-11	4.9E-11	2.3E-11	1.9E-11
Bone Surface	1.1E-10	7.8E-11	3.8E-11	2.5E-11	1.6E-11	1.4E-11
Brain	2.6E-11	1.8E-11	1.1E-11	8.9E-12	6.1E-12	5.9E-12
Breast	1.1E-10	8.6E-11	5.2E-11	3.5E-11	1.9E-11	1.7E-11
GI-Tract						
Oesophagus	2.5E-10	1.8E-10	8.4E-11	4.9E-11	2.9E-11	2.3E-11
St Wall	1.9E-09	1.1E-09	4.5E-10	2.7E-10	1.5E-10	1.2E-10
SI Wall	3.8E-09	2.5E-09	1.1E-09	6.7E-10	3.2E-10	2.6E-10
ULI Wall	1.5E-08	9.7E-09	4.0E-09	2.5E-09	1.1E-09	9.5E-10
LLI Wall	2.3E-08	1.5E-08	6.2E-09	3.8E-09	1.8E-09	1.5E-09
Colon	1.8E-08	1.2E-08	5.0E-09	3.1E-09	1.4E-09	1.2E-09
Kidneys	1.2E-10	9.0E-11	4.7E-11	3.1E-11	1.8E-11	1.5E-11
Liver	1.7E-10	1.2E-10	6.3E-11	4.0E-11	2.4E-11	1.9E-11
Muscle	1.5E-10	1.1E-10	5.4E-11	3.5E-11	2.1E-11	1.7E-11
Ovaries	5.2E-10	4.0E-10	2.0E-10	1.3E-10	7.6E-11	5.9E-11
Pancreas	1.8E-10	1.3E-10	6.9E-11	4.3E-11	2.7E-11	2.1E-11
Red Marrow	8.8E-11	7.0E-11	4.4E-11	3.5E-11	2.4E-11	2.2E-11
Respiratory Tract						
ET Airways	1.7E-08	1.4E-08	7.0E-09	4.2E-09	2.4E-09	2.0E-09
Lungs	7.8E-09	6.0E-09	3.7E-09	2.7E-09	2.5E-09	2.0E-09
Skin	6.3E-11	4.5E-11	2.2E-11	1.4E-11	8.8E-12	7.4E-12
Spleen	1.4E-10	1.1E-10	5.4E-11	3.6E-11	2.2E-11	1.8E-11
Testes	7.9E-11	5.7E-11	2.3E-11	1.5E-11	6.2E-12	5.3E-12
Thymus	2.5E-10	1.8E-10	8.4E-11	4.9E-11	2.9E-11	2.3E-11
Thyroid	5.2E-09	2.5E-09	1.1E-09	5.1E-10	2.8E-10	1.8E-10
Uterus	3.0E-10	2.3E-10	1.1E-10	7.2E-11	3.6E-11	2.9E-11
Remainder	2.0E-10	7.2E-09	3.5E-09	2.1E-09	2.8E-11	2.3E-11
Effective Dose	3.8E-09	2.9E-09	1.4E-09	9.0E-10	5.3E-10	4.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.6(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-133 (T½ = 20.8 h).

Elemental Iodine						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	3.6E-10	2.4E-10	1.2E-10	7.4E-11	4.5E-11	3.7E-11
Bladder Wall	2.4E-09	1.9E-09	1.9E-09	1.6E-09	1.4E-09	1.0E-09
Bone Surface	3.7E-10	2.5E-10	1.3E-10	8.4E-11	5.5E-11	4.7E-11
Brain	3.5E-10	2.3E-10	1.3E-10	8.2E-11	5.5E-11	4.8E-11
Breast	3.6E-10	2.3E-10	1.2E-10	7.2E-11	4.2E-11	3.4E-11
GI-Tract						
Oesophagus	7.5E-10	5.1E-10	2.4E-10	1.3E-10	6.9E-11	5.2E-11
St Wall	1.6E-09	9.3E-10	4.6E-10	2.7E-10	1.8E-10	1.4E-10
SI Wall	3.8E-10	2.5E-10	1.3E-10	8.2E-11	5.0E-11	4.0E-11
ULI Wall	5.5E-10	3.4E-10	1.7E-10	9.7E-11	5.8E-11	4.7E-11
LLI Wall	6.6E-10	4.0E-10	2.0E-10	1.2E-10	7.1E-11	5.9E-11
Colon	6.0E-10	3.6E-10	1.8E-10	1.1E-10	6.4E-11	5.3E-11
Kidneys	3.4E-10	2.2E-10	1.2E-10	7.0E-11	4.3E-11	3.5E-11
Liver	3.6E-10	2.3E-10	1.2E-10	7.2E-11	4.4E-11	3.6E-11
Muscle	4.3E-10	2.9E-10	1.6E-10	9.5E-11	5.9E-11	4.8E-11
Ovaries	3.6E-10	2.3E-10	1.3E-10	8.2E-11	5.2E-11	4.2E-11
Pancreas	3.8E-10	2.5E-10	1.3E-10	8.0E-11	4.9E-11	4.0E-11
Red Marrow	3.5E-10	2.3E-10	1.2E-10	8.0E-11	5.3E-11	4.4E-11
Respiratory Tract						
ET Airways	9.5E-09	7.6E-09	4.5E-09	2.7E-09	1.9E-09	1.5E-09
Lungs	2.5E-09	2.0E-09	1.3E-09	9.3E-10	7.0E-10	6.5E-10
Skin	3.3E-10	2.2E-10	1.1E-10	6.7E-11	4.2E-11	3.5E-11
Spleen	3.6E-10	2.3E-10	1.2E-10	7.4E-11	4.6E-11	3.7E-11
Testes	3.3E-10	2.2E-10	1.2E-10	7.5E-11	4.5E-11	3.6E-11
Thymus	7.5E-10	5.1E-10	2.4E-10	1.3E-10	6.9E-11	5.2E-11
Thyroid	8.9E-07	8.0E-07	4.2E-07	1.9E-07	1.2E-07	7.6E-08
Uterus	3.7E-10	2.5E-10	1.6E-10	1.0E-10	6.1E-11	5.1E-11
Remainder	4.2E-10	2.8E-10	1.5E-10	9.5E-11	5.9E-11	4.8E-11
Effective Dose	4.5E-08	4.1E-08	2.1E-08	9.7E-09	6.3E-09	4.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.6(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-133 (T½ = 20.8 h).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	2.7E-10	1.8E-10	9.2E-11	5.6E-11	3.4E-11	2.8E-11
Bladder Wall	1.9E-09	1.5E-09	1.5E-09	1.2E-09	1.1E-09	8.1E-10
Bone Surface	2.9E-10	1.9E-10	1.0E-10	6.4E-11	4.1E-11	3.5E-11
Brain	2.7E-10	1.8E-10	9.7E-11	6.2E-11	4.1E-11	3.5E-11
Breast	2.7E-10	1.8E-10	9.0E-11	5.4E-11	3.2E-11	2.6E-11
GI-Tract						
Oesophagus	5.2E-10	3.6E-10	1.7E-10	9.3E-11	5.0E-11	3.8E-11
St Wall	2.6E-10	1.7E-10	8.6E-11	5.1E-11	3.2E-11	2.6E-11
SI Wall	2.7E-10	1.8E-10	9.4E-11	5.8E-11	3.6E-11	2.9E-11
ULI Wall	3.3E-10	2.0E-10	9.8E-11	5.5E-11	3.4E-11	2.8E-11
LLI Wall	3.6E-10	2.1E-10	1.1E-10	6.3E-11	3.8E-11	3.2E-11
Colon	3.4E-10	2.0E-10	1.0E-10	5.8E-11	3.6E-11	3.0E-11
Kidneys	2.6E-10	1.7E-10	8.9E-11	5.4E-11	3.3E-11	2.7E-11
Liver	2.7E-10	1.8E-10	9.1E-11	5.5E-11	3.3E-11	2.7E-11
Muscle	3.2E-10	2.2E-10	1.1E-10	7.0E-11	4.3E-11	3.5E-11
Ovaries	2.8E-10	1.8E-10	1.0E-10	6.3E-11	4.0E-11	3.2E-11
Pancreas	2.8E-10	1.8E-10	9.4E-11	5.7E-11	3.5E-11	2.9E-11
Red Marrow	2.7E-10	1.8E-10	9.4E-11	6.0E-11	3.9E-11	3.3E-11
Respiratory Tract						
ET Airways	2.9E-10	1.9E-10	1.0E-10	6.6E-11	4.3E-11	3.7E-11
Lungs	3.0E-10	2.0E-10	1.1E-10	6.4E-11	3.9E-11	3.2E-11
Skin	2.5E-10	1.6E-10	8.4E-11	5.1E-11	3.2E-11	2.6E-11
Spleen	2.7E-10	1.7E-10	8.9E-11	5.5E-11	3.3E-11	2.7E-11
Testes	2.6E-10	1.7E-10	9.7E-11	5.9E-11	3.6E-11	2.9E-11
Thymus	5.2E-10	3.6E-10	1.7E-10	9.3E-11	5.0E-11	3.8E-11
Thyroid	7.0E-07	6.3E-07	3.3E-07	1.5E-07	9.6E-08	6.0E-08
Uterus	2.9E-10	2.0E-10	1.2E-10	7.8E-11	4.8E-11	4.0E-11
Remainder	3.1E-10	2.1E-10	1.1E-10	6.9E-11	4.3E-11	3.5E-11
Effective Dose	3.5E-08	3.2E-08	1.7E-08	7.6E-09	4.9E-09	3.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.7(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-134 (T½ = 0.876 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	4.8E-11	3.4E-11	1.7E-11	1.1E-11	6.5E-12	5.6E-12
Bladder Wall	1.6E-10	1.3E-10	7.4E-11	6.1E-11	4.9E-11	3.9E-11
Bone Surface	4.7E-11	3.3E-11	1.6E-11	1.1E-11	6.4E-12	5.8E-12
Brain	4.1E-11	2.8E-11	1.5E-11	9.8E-12	5.9E-12	5.4E-12
Breast	4.5E-11	3.1E-11	1.5E-11	9.3E-12	5.2E-12	4.4E-12
GI-Tract						
Oesophagus	1.1E-10	7.7E-11	3.1E-11	1.8E-11	8.4E-12	6.9E-12
St Wall	7.7E-10	4.4E-10	1.8E-10	1.1E-10	6.2E-11	5.1E-11
SI Wall	6.1E-11	4.2E-11	2.0E-11	1.3E-11	7.0E-12	6.0E-12
ULI Wall	5.5E-11	3.8E-11	1.8E-11	1.2E-11	6.5E-12	5.6E-12
LLI Wall	4.3E-11	2.9E-11	1.5E-11	9.6E-12	5.4E-12	5.0E-12
Colon	5.0E-11	3.4E-11	1.7E-11	1.1E-11	6.0E-12	5.4E-12
Kidneys	4.4E-11	3.1E-11	1.5E-11	9.8E-12	5.8E-12	5.0E-12
Liver	4.9E-11	3.4E-11	1.6E-11	1.0E-11	5.9E-12	5.0E-12
Muscle	5.7E-11	4.1E-11	1.9E-11	1.2E-11	6.9E-12	5.8E-12
Ovaries	4.4E-11	3.1E-11	1.5E-11	1.0E-11	5.9E-12	5.0E-12
Pancreas	6.8E-11	4.9E-11	2.4E-11	1.7E-11	9.5E-12	8.2E-12
Red Marrow	4.1E-11	2.9E-11	1.5E-11	1.0E-11	6.2E-12	5.5E-12
Respiratory Tract						
ET Airways	5.7E-09	4.8E-09	2.5E-09	1.5E-09	8.4E-10	6.8E-10
Lungs	1.4E-10	1.1E-10	6.1E-11	4.4E-11	3.7E-11	3.0E-11
Skin	3.8E-11	2.6E-11	1.2E-11	7.7E-12	4.5E-12	4.0E-12
Spleen	5.3E-11	3.8E-11	1.9E-11	1.3E-11	7.4E-12	6.5E-12
Testes	3.6E-11	2.5E-11	1.3E-11	8.0E-12	4.7E-12	4.0E-12
Thymus	1.1E-10	7.7E-11	3.1E-11	1.8E-11	8.4E-12	6.9E-12
Thyroid	3.4E-09	3.1E-09	1.4E-09	6.5E-10	3.9E-10	2.6E-10
Uterus	4.7E-11	3.4E-11	1.8E-11	1.2E-11	6.7E-12	5.8E-12
Remainder	2.9E-09	2.4E-09	1.2E-09	7.3E-10	4.3E-10	3.4E-10
Effective Dose	4.6E-10	3.7E-10	1.8E-10	9.7E-11	5.9E-11	4.5E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.7(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-134 (T½ = 0.876 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	3.8E-11	2.8E-11	1.5E-11	9.9E-12	6.2E-12	5.2E-12
Bladder Wall	3.6E-11	2.5E-11	1.3E-11	9.6E-12	6.4E-12	5.1E-12
Bone Surface	2.7E-11	2.0E-11	9.6E-12	6.4E-12	4.0E-12	3.6E-12
Brain	1.3E-11	8.7E-12	5.3E-12	4.2E-12	2.8E-12	2.7E-12
Breast	3.3E-11	2.5E-11	1.4E-11	8.8E-12	4.7E-12	4.1E-12
GI-Tract						
Oesophagus	9.3E-11	6.7E-11	2.7E-11	1.6E-11	7.7E-12	6.2E-12
St Wall	1.3E-09	7.5E-10	3.1E-10	1.9E-10	1.1E-10	8.7E-11
SI Wall	6.7E-10	4.6E-10	1.9E-10	1.2E-10	5.5E-11	4.6E-11
ULI Wall	4.2E-10	3.0E-10	1.3E-10	8.3E-11	3.9E-11	3.3E-11
LLI Wall	9.0E-11	6.3E-11	2.9E-11	1.8E-11	9.0E-12	7.7E-12
Colon	2.8E-10	2.0E-10	8.5E-11	5.5E-11	2.6E-11	2.2E-11
Kidneys	3.2E-11	2.4E-11	1.3E-11	8.4E-12	4.9E-12	4.1E-12
Liver	4.3E-11	3.2E-11	1.6E-11	9.5E-12	5.5E-12	4.3E-12
Muscle	4.2E-11	3.1E-11	1.5E-11	9.4E-12	5.4E-12	4.4E-12
Ovaries	6.1E-11	4.6E-11	2.2E-11	1.5E-11	7.9E-12	6.7E-12
Pancreas	7.3E-11	5.4E-11	2.8E-11	2.0E-11	1.1E-11	9.4E-12
Red Marrow	2.2E-11	1.7E-11	9.5E-12	7.3E-12	4.9E-12	4.5E-12
Respiratory Tract						
ET Airways	7.2E-09	5.9E-09	2.9E-09	1.8E-09	1.0E-09	8.4E-10
Lungs	5.2E-10	4.0E-10	2.5E-10	1.8E-10	1.7E-10	1.3E-10
Skin	1.9E-11	1.3E-11	6.2E-12	4.2E-12	2.5E-12	2.2E-12
Spleen	4.8E-11	3.6E-11	1.9E-11	1.3E-11	7.8E-12	6.8E-12
Testes	1.1E-11	7.3E-12	3.2E-12	2.0E-12	9.3E-13	7.3E-13
Thymus	9.3E-11	6.7E-11	2.7E-11	1.6E-11	7.7E-12	6.2E-12
Thyroid	3.6E-10	2.8E-10	1.4E-10	6.3E-11	3.9E-11	2.6E-11
Uterus	5.5E-11	4.2E-11	2.0E-11	1.3E-11	6.5E-12	5.4E-12
Remainder	3.6E-09	3.0E-09	1.5E-09	8.9E-10	5.1E-10	4.2E-10
Effective Dose	4.8E-10	3.4E-10	1.7E-10	1.0E-10	6.7E-11	5.4E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.7(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-134 (T½ = 0.876 h).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.7E-11	2.8E-11	1.5E-11	9.8E-12	6.2E-12	5.1E-12
Bladder Wall	2.2E-11	1.6E-11	7.5E-12	4.6E-12	2.2E-12	1.7E-12
Bone Surface	2.5E-11	1.8E-11	9.0E-12	6.0E-12	3.8E-12	3.4E-12
Brain	9.5E-12	6.9E-12	4.4E-12	3.6E-12	2.5E-12	2.4E-12
Breast	3.1E-11	2.4E-11	1.4E-11	8.8E-12	4.7E-12	4.1E-12
GI-Tract						
Oesophagus	9.1E-11	6.6E-11	2.7E-11	1.6E-11	7.6E-12	6.2E-12
St Wall	1.4E-09	7.8E-10	3.2E-10	2.0E-10	1.1E-10	9.0E-11
SI Wall	7.4E-10	4.9E-10	2.1E-10	1.3E-10	5.8E-11	4.9E-11
ULI Wall	4.6E-10	3.1E-10	1.4E-10	8.8E-11	4.1E-11	3.5E-11
LLI Wall	9.5E-11	6.5E-11	3.0E-11	1.9E-11	9.1E-12	7.8E-12
Colon	3.0E-10	2.1E-10	9.0E-11	5.8E-11	2.7E-11	2.3E-11
Kidneys	3.1E-11	2.4E-11	1.2E-11	8.2E-12	4.8E-12	4.0E-12
Liver	4.2E-11	3.1E-11	1.5E-11	9.5E-12	5.4E-12	4.3E-12
Muscle	4.0E-11	3.0E-11	1.4E-11	9.1E-12	5.2E-12	4.2E-12
Ovaries	6.3E-11	4.7E-11	2.2E-11	1.5E-11	8.0E-12	6.7E-12
Pancreas	7.3E-11	5.4E-11	2.8E-11	2.0E-11	1.1E-11	9.6E-12
Red Marrow	2.0E-11	1.6E-11	9.0E-12	7.1E-12	4.8E-12	4.4E-12
Respiratory Tract						
ET Airways	7.3E-09	6.0E-09	3.0E-09	1.8E-09	1.0E-09	8.5E-10
Lungs	5.6E-10	4.3E-10	2.7E-10	2.0E-10	1.8E-10	1.5E-10
Skin	1.6E-11	1.2E-11	5.6E-12	3.9E-12	2.3E-12	2.0E-12
Spleen	4.7E-11	3.6E-11	1.9E-11	1.3E-11	7.8E-12	6.8E-12
Testes	8.1E-12	5.5E-12	2.3E-12	1.4E-12	5.5E-13	4.1E-13
Thymus	9.1E-11	6.6E-11	2.7E-11	1.6E-11	7.6E-12	6.2E-12
Thyroid	2.7E-11	1.8E-11	1.0E-11	6.6E-12	4.3E-12	3.8E-12
Uterus	5.6E-11	4.2E-11	1.9E-11	1.3E-11	6.4E-12	5.3E-12
Remainder	3.7E-09	3.0E-09	1.5E-09	9.0E-10	5.2E-10	4.3E-10
Effective Dose	4.8E-10	3.4E-10	1.7E-10	1.1E-10	6.8E-11	5.5E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.7(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-134 (T½ = 0.876 h).

Elemental Iodine						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	1.1E-10	7.6E-11	4.2E-11	2.7E-11	1.8E-11	1.5E-11
Bladder Wall	3.9E-10	3.0E-10	2.0E-10	1.6E-10	1.4E-10	1.1E-10
Bone Surface	9.9E-11	6.7E-11	3.7E-11	2.4E-11	1.5E-11	1.3E-11
Brain	8.6E-11	5.8E-11	3.2E-11	2.0E-11	1.3E-11	1.1E-11
Breast	9.2E-11	6.2E-11	3.4E-11	2.1E-11	1.3E-11	1.1E-11
GI-Tract						
Oesophagus	1.4E-10	9.9E-11	5.0E-11	3.0E-11	1.8E-11	1.5E-11
St Wall	1.2E-09	6.9E-10	3.5E-10	2.1E-10	1.4E-10	1.1E-10
SI Wall	1.3E-10	8.7E-11	4.7E-11	3.0E-11	1.9E-11	1.5E-11
ULI Wall	1.2E-10	7.8E-11	4.4E-11	2.7E-11	1.7E-11	1.4E-11
LLI Wall	9.8E-11	6.5E-11	3.9E-11	2.4E-11	1.5E-11	1.3E-11
Colon	1.1E-10	7.3E-11	4.2E-11	2.6E-11	1.6E-11	1.4E-11
Kidneys	1.0E-10	6.8E-11	3.8E-11	2.4E-11	1.6E-11	1.3E-11
Liver	1.1E-10	7.5E-11	4.0E-11	2.5E-11	1.6E-11	1.3E-11
Muscle	1.0E-10	7.1E-11	3.9E-11	2.4E-11	1.6E-11	1.3E-11
Ovaries	1.0E-10	7.0E-11	4.0E-11	2.5E-11	1.6E-11	1.3E-11
Pancreas	1.4E-10	9.7E-11	5.6E-11	3.8E-11	2.4E-11	2.0E-11
Red Marrow	8.8E-11	6.0E-11	3.4E-11	2.3E-11	1.5E-11	1.3E-11
Respiratory Tract						
ET Airways	4.9E-09	3.8E-09	2.3E-09	1.3E-09	9.7E-10	7.7E-10
Lungs	1.9E-09	1.5E-09	1.0E-09	7.5E-10	5.7E-10	5.3E-10
Skin	8.0E-11	5.3E-11	2.8E-11	1.7E-11	1.1E-11	9.4E-12
Spleen	1.2E-10	8.0E-11	4.5E-11	3.0E-11	1.9E-11	1.7E-11
Testes	8.7E-11	5.9E-11	3.3E-11	2.1E-11	1.3E-11	1.1E-11
Thymus	1.4E-10	9.9E-11	5.0E-11	3.0E-11	1.8E-11	1.5E-11
Thyroid	8.2E-09	7.3E-09	3.8E-09	1.7E-09	1.1E-09	7.0E-10
Uterus	1.1E-10	7.6E-11	4.6E-11	3.0E-11	1.9E-11	1.5E-11
Remainder	1.0E-10	7.1E-11	3.9E-11	2.5E-11	1.6E-11	3.9E-10
Effective Dose	8.7E-10	6.9E-10	3.9E-10	2.2E-10	1.6E-10	1.5E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.7(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-134 (T½ = 0.876 h).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	8.9E-11	6.1E-11	3.3E-11	2.1E-11	1.3E-11	1.1E-11
Bladder Wall	3.9E-10	2.9E-10	2.0E-10	1.6E-10	1.4E-10	1.1E-10
Bone Surface	8.7E-11	5.8E-11	3.2E-11	2.0E-11	1.3E-11	1.1E-11
Brain	8.1E-11	5.4E-11	2.9E-11	1.8E-11	1.1E-11	9.1E-12
Breast	7.3E-11	4.8E-11	2.5E-11	1.6E-11	1.0E-11	8.4E-12
GI-Tract						
Oesophagus	9.2E-11	6.2E-11	3.3E-11	2.0E-11	1.3E-11	1.1E-11
St Wall	8.2E-11	5.4E-11	3.0E-11	1.8E-11	1.2E-11	1.0E-11
SI Wall	9.1E-11	6.2E-11	3.4E-11	2.2E-11	1.4E-11	1.2E-11
ULI Wall	8.6E-11	5.8E-11	3.2E-11	2.0E-11	1.3E-11	1.1E-11
LLI Wall	8.8E-11	5.8E-11	3.5E-11	2.2E-11	1.4E-11	1.2E-11
Colon	8.7E-11	5.8E-11	3.3E-11	2.1E-11	1.3E-11	1.2E-11
Kidneys	8.7E-11	5.9E-11	3.2E-11	2.0E-11	1.3E-11	1.1E-11
Liver	8.7E-11	5.9E-11	3.2E-11	2.0E-11	1.3E-11	1.1E-11
Muscle	8.4E-11	5.7E-11	3.1E-11	1.9E-11	1.2E-11	1.0E-11
Ovaries	9.3E-11	6.4E-11	3.7E-11	2.4E-11	1.5E-11	1.3E-11
Pancreas	9.2E-11	6.2E-11	3.4E-11	2.2E-11	1.4E-11	1.2E-11
Red Marrow	7.9E-11	5.3E-11	3.0E-11	1.9E-11	1.3E-11	1.1E-11
Respiratory Tract						
ET Airways	9.0E-11	6.1E-11	3.3E-11	2.0E-11	1.3E-11	1.0E-11
Lungs	8.3E-11	5.6E-11	3.0E-11	1.9E-11	1.2E-11	9.9E-12
Skin	7.1E-11	4.7E-11	2.5E-11	1.5E-11	9.6E-12	8.1E-12
Spleen	8.7E-11	5.9E-11	3.1E-11	2.0E-11	1.3E-11	1.1E-11
Testes	8.5E-11	5.8E-11	3.3E-11	2.1E-11	1.3E-11	1.1E-11
Thymus	9.2E-11	6.2E-11	3.3E-11	2.0E-11	1.3E-11	1.1E-11
Thyroid	8.2E-09	7.3E-09	3.8E-09	1.7E-09	1.1E-09	7.0E-10
Uterus	1.0E-10	7.0E-11	4.3E-11	2.8E-11	1.8E-11	1.5E-11
Remainder	8.4E-11	5.7E-11	3.0E-11	1.9E-11	1.2E-11	1.0E-11
Effective Dose	5.1E-10	4.3E-10	2.3E-10	1.1E-10	7.4E-11	5.0E-11

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.8(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-135 (T½ = 6.61 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	1.3E-10	9.4E-11	4.5E-11	2.9E-11	1.7E-11	1.4E-11
Bladder Wall	6.5E-10	5.3E-10	4.4E-10	3.7E-10	3.0E-10	2.3E-10
Bone Surface	1.4E-10	1.0E-10	5.0E-11	3.3E-11	2.0E-11	1.8E-11
Brain	1.3E-10	9.1E-11	4.7E-11	3.2E-11	2.0E-11	1.8E-11
Breast	1.3E-10	9.4E-11	4.4E-11	2.7E-11	1.5E-11	1.3E-11
GI-Tract						
Oesophagus	3.9E-10	2.7E-10	1.0E-10	6.2E-11	2.7E-11	2.2E-11
St Wall	8.7E-10	5.0E-10	2.1E-10	1.3E-10	7.3E-11	6.0E-11
SI Wall	1.5E-10	1.0E-10	4.9E-11	3.2E-11	1.8E-11	1.5E-11
ULI Wall	1.7E-10	1.2E-10	5.6E-11	3.5E-11	1.9E-11	1.7E-11
LLI Wall	1.6E-10	1.1E-10	5.7E-11	3.6E-11	2.0E-11	1.8E-11
Colon	1.7E-10	1.1E-10	5.6E-11	3.6E-11	2.0E-11	1.7E-11
Kidneys	1.2E-10	8.7E-11	4.2E-11	2.7E-11	1.5E-11	1.3E-11
Liver	1.3E-10	9.3E-11	4.4E-11	2.8E-11	1.6E-11	1.3E-11
Muscle	1.8E-10	1.3E-10	6.2E-11	3.9E-11	2.2E-11	1.9E-11
Ovaries	1.3E-10	9.2E-11	5.0E-11	3.2E-11	1.9E-11	1.6E-11
Pancreas	1.6E-10	1.1E-10	5.3E-11	3.5E-11	2.0E-11	1.7E-11
Red Marrow	1.3E-10	8.9E-11	4.5E-11	3.1E-11	1.9E-11	1.7E-11
Respiratory Tract						
ET Airways	1.5E-08	1.3E-08	6.7E-09	3.9E-09	2.3E-09	1.8E-09
Lungs	2.4E-10	1.8E-10	9.5E-11	6.6E-11	5.0E-11	4.0E-11
Skin	1.2E-10	8.1E-11	3.8E-11	2.4E-11	1.4E-11	1.3E-11
Spleen	1.4E-10	9.5E-11	4.6E-11	3.0E-11	1.7E-11	1.5E-11
Testes	1.1E-10	8.0E-11	4.4E-11	2.8E-11	1.6E-11	1.3E-11
Thymus	3.9E-10	2.7E-10	1.0E-10	6.2E-11	2.7E-11	2.2E-11
Thyroid	7.7E-08	7.0E-08	3.3E-08	1.5E-08	8.8E-09	5.7E-09
Uterus	1.4E-10	1.0E-10	6.3E-11	4.2E-11	2.4E-11	2.0E-11
Remainder	1.8E-10	1.3E-10	6.3E-11	4.0E-11	2.3E-11	1.9E-11
Effective Dose	4.1E-09	3.7E-09	1.7E-09	7.9E-10	4.8E-10	3.2E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.8(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-135 (T½ = 6.61 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.4E-10	1.0E-10	5.5E-11	3.3E-11	2.1E-11	1.7E-11
Bladder Wall	2.3E-10	1.6E-10	9.3E-11	7.2E-11	4.8E-11	3.8E-11
Bone Surface	1.1E-10	7.7E-11	3.7E-11	2.5E-11	1.5E-11	1.4E-11
Brain	4.6E-11	2.9E-11	1.7E-11	1.3E-11	8.9E-12	8.4E-12
Breast	1.1E-10	8.3E-11	4.7E-11	3.1E-11	1.7E-11	1.5E-11
GI-Tract						
Oesophagus	2.9E-10	2.1E-10	8.5E-11	5.2E-11	2.6E-11	2.2E-11
St Wall	1.6E-09	9.3E-10	3.9E-10	2.4E-10	1.4E-10	1.1E-10
SI Wall	2.2E-09	1.6E-09	6.8E-10	4.3E-10	2.1E-10	1.7E-10
ULI Wall	5.2E-09	3.7E-09	1.6E-09	1.0E-09	4.7E-10	3.9E-10
LLI Wall	4.1E-09	2.9E-09	1.2E-09	7.6E-10	3.6E-10	3.0E-10
Colon	4.7E-09	3.4E-09	1.4E-09	9.0E-10	4.2E-10	3.5E-10
Kidneys	1.3E-10	9.6E-11	4.9E-11	3.2E-11	1.8E-11	1.6E-11
Liver	1.6E-10	1.2E-10	6.1E-11	3.8E-11	2.2E-11	1.8E-11
Muscle	1.5E-10	1.1E-10	5.4E-11	3.5E-11	2.0E-11	1.7E-11
Ovaries	3.8E-10	3.0E-10	1.5E-10	1.0E-10	5.7E-11	4.6E-11
Pancreas	1.9E-10	1.4E-10	7.1E-11	4.7E-11	2.8E-11	2.2E-11
Red Marrow	8.9E-11	6.8E-11	4.1E-11	3.1E-11	2.1E-11	1.9E-11
Respiratory Tract						
ET Airways	1.7E-08	1.4E-08	7.3E-09	4.3E-09	2.5E-09	2.0E-09
Lungs	2.6E-09	1.9E-09	1.2E-09	9.0E-10	8.4E-10	6.7E-10
Skin	7.2E-11	5.0E-11	2.4E-11	1.6E-11	9.3E-12	8.4E-12
Spleen	1.4E-10	1.1E-10	5.4E-11	3.6E-11	2.2E-11	1.8E-11
Testes	6.7E-11	4.6E-11	2.2E-11	1.3E-11	6.4E-12	4.9E-12
Thymus	2.9E-10	2.1E-10	8.5E-11	5.2E-11	2.6E-11	2.2E-11
Thyroid	1.3E-08	8.0E-09	3.7E-09	1.7E-09	1.0E-09	6.5E-10
Uterus	2.7E-10	2.1E-10	9.8E-11	6.7E-11	3.4E-11	2.8E-11
Remainder	8.4E-09	7.1E-09	3.7E-09	2.2E-09	1.3E-09	1.0E-09
Effective Dose	2.2E-09	1.6E-09	7.8E-10	4.7E-10	3.0E-10	2.4E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.8(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-135 (T½ = 6.61 h).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.4E-10	1.0E-10	5.6E-11	3.3E-11	2.2E-11	1.7E-11
Bladder Wall	1.6E-10	1.1E-10	5.1E-11	3.6E-11	1.8E-11	1.5E-11
Bone Surface	1.0E-10	7.4E-11	3.5E-11	2.3E-11	1.5E-11	1.3E-11
Brain	3.0E-11	2.1E-11	1.4E-11	1.1E-11	7.5E-12	7.2E-12
Breast	1.1E-10	8.2E-11	4.7E-11	3.2E-11	1.7E-11	1.5E-11
GI-Tract						
Oesophagus	2.7E-10	2.0E-10	8.2E-11	5.1E-11	2.6E-11	2.2E-11
St Wall	1.7E-09	9.8E-10	4.1E-10	2.5E-10	1.4E-10	1.2E-10
SI Wall	2.7E-09	1.8E-09	7.7E-10	4.8E-10	2.3E-10	1.9E-10
ULI Wall	6.3E-09	4.2E-09	1.8E-09	1.1E-09	5.3E-10	4.4E-10
LLI Wall	5.0E-09	3.3E-09	1.4E-09	8.6E-10	4.0E-10	3.4E-10
Colon	5.7E-09	3.8E-09	1.6E-09	1.0E-09	4.7E-10	4.0E-10
Kidneys	1.3E-10	9.7E-11	5.0E-11	3.3E-11	1.9E-11	1.6E-11
Liver	1.7E-10	1.3E-10	6.3E-11	3.9E-11	2.3E-11	1.8E-11
Muscle	1.5E-10	1.1E-10	5.3E-11	3.5E-11	2.0E-11	1.6E-11
Ovaries	4.4E-10	3.3E-10	1.6E-10	1.1E-10	6.2E-11	5.0E-11
Pancreas	1.9E-10	1.4E-10	7.3E-11	4.8E-11	2.9E-11	2.2E-11
Red Marrow	8.2E-11	6.5E-11	4.0E-11	3.2E-11	2.1E-11	1.9E-11
Respiratory Tract						
ET Airways	1.7E-08	1.4E-08	7.3E-09	4.3E-09	2.5E-09	2.0E-09
Lungs	2.8E-09	2.1E-09	1.3E-09	9.9E-10	9.2E-10	7.4E-10
Skin	6.3E-11	4.6E-11	2.2E-11	1.5E-11	8.7E-12	7.9E-12
Spleen	1.4E-10	1.1E-10	5.5E-11	3.6E-11	2.2E-11	1.8E-11
Testes	6.0E-11	4.1E-11	1.9E-11	1.1E-11	5.3E-12	3.9E-12
Thymus	2.7E-10	2.0E-10	8.2E-11	5.1E-11	2.6E-11	2.2E-11
Thyroid	8.4E-10	4.2E-10	1.9E-10	9.3E-11	5.3E-11	3.8E-11
Uterus	3.0E-10	2.3E-10	1.0E-10	7.1E-11	3.5E-11	2.9E-11
Remainder	8.5E-09	7.2E-09	3.7E-09	2.2E-09	1.3E-09	1.0E-09
Effective Dose	1.8E-09	1.3E-09	6.5E-10	4.2E-10	2.7E-10	2.2E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.8(d).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-135 (T½ = 6.61 h).

Elemental Iodine Age at intake f1	3 Months 1.0	1 Year 1.0	5 Years 1.0	10 Years 1.0	15 Years 1.0	Adult 1.0
Adrenals	2.9E-10	2.0E-10	1.1E-10	7.0E-11	4.4E-11	3.7E-11
Bladder Wall	1.5E-09	1.2E-09	1.1E-09	9.5E-10	8.2E-10	6.3E-10
Bone Surface	2.9E-10	2.0E-10	1.1E-10	7.2E-11	4.8E-11	4.1E-11
Brain	2.7E-10	1.8E-10	1.0E-10	6.6E-11	4.4E-11	3.8E-11
Breast	2.6E-10	1.8E-10	9.5E-11	5.9E-11	3.7E-11	3.0E-11
GI-Tract						
Oesophagus	5.3E-10	3.7E-10	1.7E-10	1.0E-10	5.7E-11	4.5E-11
St Wall	1.4E-09	8.2E-10	4.2E-10	2.5E-10	1.7E-10	1.4E-10
SI Wall	3.1E-10	2.1E-10	1.2E-10	7.9E-11	4.9E-11	4.0E-11
ULI Wall	3.5E-10	2.3E-10	1.3E-10	8.3E-11	5.1E-11	4.3E-11
LLI Wall	3.3E-10	2.2E-10	1.4E-10	8.7E-11	5.4E-11	4.7E-11
Colon	3.4E-10	2.3E-10	1.3E-10	8.5E-11	5.2E-11	4.5E-11
Kidneys	2.8E-10	1.9E-10	1.0E-10	6.5E-11	4.1E-11	3.5E-11
Liver	2.9E-10	2.0E-10	1.1E-10	6.7E-11	4.2E-11	3.5E-11
Muscle	3.3E-10	2.3E-10	1.2E-10	7.8E-11	5.0E-11	4.1E-11
Ovaries	2.9E-10	2.0E-10	1.3E-10	8.1E-11	5.2E-11	4.3E-11
Pancreas	3.3E-10	2.3E-10	1.2E-10	8.1E-11	5.2E-11	4.3E-11
Red Marrow	2.6E-10	1.8E-10	1.0E-10	6.8E-11	4.6E-11	3.8E-11
Respiratory Tract						
ET Airways	9.3E-09	7.7E-09	4.7E-09	2.7E-09	2.0E-09	1.5E-09
Lungs	2.3E-09	1.8E-09	1.2E-09	8.9E-10	6.7E-10	6.2E-10
Skin	2.4E-10	1.6E-10	8.6E-11	5.4E-11	3.4E-11	2.9E-11
Spleen	2.9E-10	2.0E-10	1.1E-10	7.1E-11	4.5E-11	3.8E-11
Testes	2.6E-10	1.8E-10	1.1E-10	7.2E-11	4.4E-11	3.6E-11
Thymus	5.3E-10	3.7E-10	1.7E-10	1.0E-10	5.7E-11	4.5E-11
Thyroid	1.8E-07	1.6E-07	8.4E-08	3.8E-08	2.4E-08	1.5E-08
Uterus	3.2E-10	2.3E-10	1.6E-10	1.1E-10	6.6E-11	5.4E-11
Remainder	3.2E-10	2.2E-10	1.2E-10	7.8E-11	5.0E-11	4.2E-11
Effective Dose	9.7E-09	8.5E-09	4.5E-09	2.1E-09	1.4E-09	9.2E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.19.8(e).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for I-135 (T½ = 6.61 h).

Methyl Iodide Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
Adrenals	2.2E-10	1.5E-10	8.2E-11	5.2E-11	3.3E-11	2.7E-11
Bladder Wall	1.2E-09	9.9E-10	9.2E-10	7.7E-10	6.7E-10	5.1E-10
Bone Surface	2.2E-10	1.5E-10	8.4E-11	5.4E-11	3.5E-11	3.0E-11
Brain	2.1E-10	1.4E-10	7.7E-11	4.9E-11	3.2E-11	2.7E-11
Breast	1.9E-10	1.3E-10	6.8E-11	4.2E-11	2.7E-11	2.2E-11
GI-Tract						
Oesophagus	3.5E-10	2.4E-10	1.1E-10	6.9E-11	3.9E-11	3.1E-11
St Wall	2.1E-10	1.3E-10	7.6E-11	4.5E-11	3.0E-11	2.5E-11
SI Wall	2.2E-10	1.5E-10	8.7E-11	5.6E-11	3.5E-11	2.9E-11
ULI Wall	2.2E-10	1.4E-10	8.2E-11	5.2E-11	3.3E-11	2.8E-11
LLI Wall	2.2E-10	1.5E-10	9.6E-11	6.1E-11	3.8E-11	3.4E-11
Colon	2.2E-10	1.5E-10	8.8E-11	5.6E-11	3.5E-11	3.0E-11
Kidneys	2.1E-10	1.4E-10	7.8E-11	5.0E-11	3.1E-11	2.6E-11
Liver	2.2E-10	1.5E-10	8.0E-11	5.0E-11	3.2E-11	2.6E-11
Muscle	2.4E-10	1.6E-10	9.0E-11	5.6E-11	3.6E-11	3.0E-11
Ovaries	2.3E-10	1.6E-10	9.9E-11	6.3E-11	4.1E-11	3.4E-11
Pancreas	2.3E-10	1.5E-10	8.3E-11	5.3E-11	3.4E-11	2.8E-11
Red Marrow	2.0E-10	1.4E-10	7.7E-11	5.1E-11	3.4E-11	2.8E-11
Respiratory Tract						
ET Airways	2.3E-10	1.6E-10	8.6E-11	5.5E-11	3.6E-11	3.0E-11
Lungs	2.2E-10	1.5E-10	8.2E-11	5.2E-11	3.3E-11	2.7E-11
Skin	1.8E-10	1.2E-10	6.5E-11	4.1E-11	2.6E-11	2.2E-11
Spleen	2.1E-10	1.4E-10	7.8E-11	5.0E-11	3.1E-11	2.6E-11
Testes	2.1E-10	1.5E-10	9.2E-11	5.8E-11	3.6E-11	2.9E-11
Thymus	3.5E-10	2.4E-10	1.1E-10	6.9E-11	3.9E-11	3.1E-11
Thyroid	1.5E-07	1.3E-07	6.8E-08	3.1E-08	2.0E-08	1.3E-08
Uterus	2.5E-10	1.8E-10	1.3E-10	8.5E-11	5.3E-11	4.3E-11
Remainder	2.3E-10	1.6E-10	8.8E-11	5.6E-11	3.5E-11	3.0E-11
Effective Dose	7.5E-09	6.7E-09	3.5E-09	1.6E-09	1.1E-09	6.8E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.20. Caesium

(199) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned all compounds of caesium (Cs) to inhalation Class D. This was endorsed by ICRP in *ICRP Publication 30*, Part 1 (ICRP, 1979), which referred to supporting experimental evidence relating to inhalation of chloride, nitrate and sulphate (Lie, 1964; Miller, 1964; Boecker, 1969).

Absorption Types

(200) The results of a human study following accidental inhalation of caesium sulphate (Miller, 1964) indicate Type F behaviour. Animal experiments have also shown that simple ionic compounds (chloride and nitrate) of caesium are rapidly and completely absorbed from the respiratory tract, consistent with assignment to Type F (Lie, 1964; Stara, 1965; Boecker, 1969; Cuddihy and Ozog, 1973).

(201) Studies of caesium associated with irradiated fuel fragments, including particles released from the Chernobyl accident, indicate that much of the caesium is rapidly absorbed (within days), but a fraction may be retained with the particle matrix and absorbed over a period of months. The results of a human study following accidental inhalation of irradiated uranium indicate Type F behaviour of the caesium present (Rundo, 1965). Following administration to rats of a suspension of residues from a reactor fuel cooling pond, the overall behaviour of the caesium was consistent with assignment to Type F (Stradling *et al.*, 1989). In two *in vitro* studies, however, the behaviour of the caesium present in irradiated fuel fragments was consistent with assignment to Type M (Dua *et al.*, 1987; Cuddihy *et al.*, 1989).

(202) It has also been demonstrated in animal studies that when caesium is incorporated into fused aluminosilicate particles, only a small fraction is rapidly absorbed from the lungs. The rest is retained within the particles and absorbed slowly, at rates of the order of 0.001 d^{-1}; in some experiments consistent with assignment to Type M and in others to Type S (Boecker *et al.*, 1974; Snipes *et al.*, 1983; Snipes and McClellan, 1986).

Dose coefficients

(203) Studies of common chemical forms showing characteristics of absorption Types F and M have been found in the literature. A default Type F is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.20.2–4) were derived using the f_1 values given in Table 5.20.1, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.20.1. Values of f_1 for inhaled particulate compounds of caesium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F[b]	1.0	1.0
M	0.2	0.1
S	0.02	0.01

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type F is recommended for use in the absence of specific information.

Table 5.20.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-134 ($T\frac{1}{2}$ = 2.06 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	1.0E-08	6.2E-09	4.7E-09	5.3E-09	6.7E-09	7.0E-09
Bladder Wall	9.5E-09	5.8E-09	5.1E-09	4.9E-09	5.8E-09	6.8E-09
Bone Surface	9.6E-09	5.9E-09	4.4E-09	5.0E-09	6.3E-09	6.7E-09
Brain	8.7E-09	5.3E-09	4.0E-09	4.3E-09	5.0E-09	5.2E-09
Breast	7.3E-09	4.4E-09	3.2E-09	3.5E-09	4.6E-09	4.8E-09
GI-Tract						
Oesophagus	1.0E-08	6.2E-09	4.4E-09	4.9E-09	6.1E-09	6.3E-09
St Wall	9.4E-09	5.5E-09	4.3E-09	4.5E-09	5.9E-09	6.3E-09
SI Wall	1.0E-08	6.6E-09	4.9E-09	5.5E-09	6.7E-09	7.0E-09
ULI Wall	1.3E-08	8.0E-09	5.4E-09	5.3E-09	6.4E-09	6.8E-09
LLI Wall	1.8E-08	1.1E-08	7.2E-09	6.4E-09	6.6E-09	7.6E-09
Colon	1.5E-08	9.5E-09	6.2E-09	5.8E-09	6.5E-09	7.1E-09
Kidneys	9.6E-09	5.9E-09	4.5E-09	5.0E-09	6.3E-09	6.6E-09
Liver	9.8E-09	6.0E-09	4.5E-09	5.1E-09	6.3E-09	6.7E-09
Muscle	8.9E-09	5.5E-09	4.0E-09	4.5E-09	5.5E-09	5.9E-09
Ovaries	1.1E-08	6.8E-09	5.1E-09	5.6E-09	6.9E-09	7.2E-09
Pancreas	1.1E-08	6.5E-09	4.9E-09	5.6E-09	7.0E-09	7.3E-09
Red Marrow	8.4E-09	5.2E-09	4.0E-09	4.7E-09	5.9E-09	6.3E-09
Respiratory Tract						
ET Airways	5.8E-08	4.9E-08	2.7E-08	1.8E-08	1.4E-08	1.2E-08
Lungs	9.0E-09	5.5E-09	4.1E-09	4.6E-09	5.8E-09	6.0E-09
Skin	7.0E-09	4.2E-09	3.1E-09	3.3E-09	4.1E-09	4.4E-09
Spleen	9.7E-09	6.0E-09	4.5E-09	5.1E-09	6.3E-09	6.6E-09
Testes	8.5E-09	5.2E-09	3.9E-09	4.3E-09	5.5E-09	5.9E-09
Thymus	1.0E-08	6.2E-09	4.4E-09	4.9E-09	6.1E-09	6.3E-09
Thyroid	1.0E-08	6.3E-09	4.7E-09	5.1E-09	6.1E-09	6.3E-09
Uterus	1.0E-08	6.5E-09	5.0E-09	5.6E-09	7.0E-09	7.3E-09
Remainder	3.3E-08	2.7E-08	1.6E-08	1.1E-08	9.7E-09	9.1E-09
Effective Dose	1.1E-08	7.3E-09	5.2E-09	5.3E-09	6.3E-09	6.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.2(b).
Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-134 (T½ = 2.06 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.6E-08	1.3E-08	8.4E-09	5.8E-09	5.3E-09	5.0E-09
Bladder Wall	4.7E-09	3.1E-09	2.2E-09	1.9E-09	2.1E-09	2.4E-09
Bone Surface	8.8E-09	6.7E-09	4.0E-09	3.1E-09	3.3E-09	3.3E-09
Brain	3.7E-09	2.3E-09	1.7E-09	1.6E-09	1.8E-09	1.9E-09
Breast	1.3E-08	1.1E-08	8.1E-09	5.9E-09	4.5E-09	4.4E-09
GI-Tract						
Oesophagus	1.4E-08	1.1E-08	8.2E-09	6.2E-09	5.7E-09	5.3E-09
St Wall	1.0E-08	7.9E-09	5.1E-09	3.8E-09	3.9E-09	3.5E-09
SI Wall	8.9E-09	6.5E-09	3.8E-09	3.0E-09	3.0E-09	3.0E-09
ULI Wall	1.8E-08	1.3E-08	6.6E-09	4.7E-09	3.7E-09	3.6E-09
LLI Wall	3.6E-08	2.6E-08	1.2E-08	8.2E-09	5.5E-09	5.2E-09
Colon	2.6E-08	1.9E-08	9.1E-09	6.2E-09	4.5E-09	4.3E-09
Kidneys	8.5E-09	6.5E-09	3.9E-09	3.1E-09	3.2E-09	3.1E-09
Liver	1.3E-08	1.0E-08	6.5E-09	4.9E-09	4.8E-09	4.4E-09
Muscle	8.3E-09	6.4E-09	4.0E-09	3.1E-09	3.2E-09	3.1E-09
Ovaries	7.4E-09	5.2E-09	3.2E-09	2.7E-09	2.9E-09	2.9E-09
Pancreas	1.3E-08	1.0E-08	6.7E-09	4.8E-09	4.8E-09	4.3E-09
Red Marrow	6.9E-09	5.4E-09	3.7E-09	3.2E-09	3.5E-09	3.5E-09
Respiratory Tract						
ET Airways	8.2E-08	7.0E-08	3.7E-08	2.3E-08	1.4E-08	1.2E-08
Lungs	1.8E-07	1.5E-07	9.7E-08	6.8E-08	6.1E-08	5.0E-08
Skin	5.0E-09	3.7E-09	2.4E-09	1.9E-09	2.0E-09	2.0E-09
Spleen	1.2E-08	1.0E-08	6.1E-09	4.6E-09	4.4E-09	4.1E-09
Testes	3.5E-09	2.1E-09	1.4E-09	1.4E-09	1.9E-09	2.0E-09
Thymus	1.4E-08	1.1E-08	8.2E-09	6.2E-09	5.7E-09	5.3E-09
Thyroid	8.8E-09	6.8E-09	4.5E-09	3.3E-09	3.2E-09	3.1E-09
Uterus	5.9E-09	4.1E-09	2.6E-09	2.2E-09	2.6E-09	2.7E-09
Remainder	7.5E-09	5.7E-09	3.7E-09	3.0E-09	3.1E-09	3.0E-09
Effective Dose	3.2E-08	2.6E-08	1.6E-08	1.2E-08	1.1E-08	9.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-134 (T½ = 2.06 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.9E-08	3.7E-08	2.4E-08	1.5E-08	1.1E-08	1.0E-08
Bladder Wall	3.8E-09	3.2E-09	1.7E-09	9.9E-10	6.1E-10	5.1E-10
Bone Surface	1.7E-08	1.6E-08	9.3E-09	5.8E-09	4.6E-09	4.2E-09
Brain	2.9E-09	2.6E-09	1.7E-09	1.1E-09	9.0E-10	8.4E-10
Breast	3.4E-08	3.4E-08	2.5E-08	1.7E-08	1.1E-08	1.1E-08
GI-Tract						
Oesophagus	3.3E-08	3.2E-08	2.4E-08	1.7E-08	1.4E-08	1.3E-08
St Wall	2.0E-08	1.9E-08	1.2E-08	8.2E-09	6.9E-09	5.4E-09
SI Wall	1.1E-08	9.3E-09	5.2E-09	3.1E-09	1.9E-09	1.7E-09
ULI Wall	2.3E-08	1.8E-08	8.8E-09	5.4E-09	3.2E-09	2.7E-09
LLI Wall	4.3E-08	3.0E-08	1.4E-08	8.7E-09	4.9E-09	4.0E-09
Colon	3.2E-08	2.3E-08	1.1E-08	6.8E-09	3.9E-09	3.3E-09
Kidneys	1.6E-08	1.5E-08	8.8E-09	5.5E-09	4.2E-09	3.6E-09
Liver	2.9E-08	2.7E-08	1.8E-08	1.2E-08	9.9E-09	8.6E-09
Muscle	1.6E-08	1.5E-08	9.4E-09	6.1E-09	5.0E-09	4.4E-09
Ovaries	7.7E-09	6.3E-09	3.6E-09	2.1E-09	1.4E-09	1.2E-09
Pancreas	2.9E-08	2.7E-08	1.8E-08	1.1E-08	9.1E-09	7.5E-09
Red Marrow	1.3E-08	1.2E-08	8.8E-09	6.5E-09	5.7E-09	5.6E-09
Respiratory Tract						
ET Airways	1.5E-07	1.3E-07	6.8E-08	4.3E-08	2.6E-08	2.3E-08
Lungs	4.5E-07	4.1E-07	2.7E-07	1.8E-07	1.6E-07	1.4E-07
Skin	8.4E-09	7.8E-09	5.1E-09	3.2E-09	2.5E-09	2.3E-09
Spleen	2.8E-08	2.6E-08	1.6E-08	1.1E-08	8.5E-09	7.3E-09
Testes	1.9E-09	1.5E-09	7.2E-10	4.8E-10	3.1E-10	2.7E-10
Thymus	3.3E-08	3.2E-08	2.4E-08	1.7E-08	1.4E-08	1.3E-08
Thyroid	1.7E-08	1.6E-08	1.1E-08	6.4E-09	4.7E-09	4.3E-09
Uterus	5.8E-09	4.9E-09	2.6E-09	1.4E-09	9.2E-10	7.9E-10
Remainder	1.4E-08	1.3E-08	8.4E-09	5.7E-09	4.7E-09	4.2E-09
Effective Dose	7.0E-08	6.3E-08	4.1E-08	2.8E-08	2.3E-08	2.0E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.3(a).
Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-136 (T½ = 13.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	5.8E-09	3.9E-09	2.2E-09	1.6E-09	1.2E-09	1.1E-09
Bladder Wall	5.3E-09	3.5E-09	2.3E-09	1.5E-09	1.1E-09	1.1E-09
Bone Surface	5.6E-09	3.8E-09	2.1E-09	1.6E-09	1.2E-09	1.1E-09
Brain	4.9E-09	3.3E-09	1.8E-09	1.3E-09	8.9E-10	8.2E-10
Breast	4.0E-09	2.7E-09	1.4E-09	1.0E-09	8.1E-10	7.3E-10
GI-Tract						
Oesophagus	6.2E-09	4.2E-09	2.2E-09	1.6E-09	1.1E-09	1.0E-09
St Wall	5.5E-09	3.5E-09	2.1E-09	1.4E-09	1.1E-09	1.0E-09
SI Wall	6.0E-09	4.1E-09	2.3E-09	1.7E-09	1.2E-09	1.1E-09
ULI Wall	6.8E-09	4.6E-09	2.5E-09	1.7E-09	1.2E-09	1.1E-09
LLI Wall	8.8E-09	6.1E-09	3.2E-09	2.0E-09	1.2E-09	1.2E-09
Colon	7.6E-09	5.2E-09	2.8E-09	1.8E-09	1.2E-09	1.1E-09
Kidneys	5.5E-09	3.7E-09	2.1E-09	1.5E-09	1.1E-09	1.0E-09
Liver	5.6E-09	3.7E-09	2.1E-09	1.6E-09	1.1E-09	1.0E-09
Muscle	5.2E-09	3.5E-09	1.9E-09	1.4E-09	1.0E-09	9.3E-10
Ovaries	6.2E-09	4.2E-09	2.4E-09	1.8E-09	1.3E-09	1.1E-09
Pancreas	6.1E-09	4.1E-09	2.3E-09	1.7E-09	1.3E-09	1.2E-09
Red Marrow	4.7E-09	3.2E-09	1.8E-09	1.4E-09	1.1E-09	9.8E-10
Respiratory Tract						
ET Airways	6.7E-08	5.9E-08	3.2E-08	1.9E-08	1.1E-08	8.8E-09
Lungs	5.2E-09	3.5E-09	1.9E-09	1.4E-09	1.1E-09	9.6E-10
Skin	3.9E-09	2.5E-09	1.4E-09	9.7E-10	7.1E-10	6.6E-10
Spleen	5.5E-09	3.7E-09	2.1E-09	1.6E-09	1.1E-09	1.0E-09
Testes	4.7E-09	3.1E-09	1.8E-09	1.3E-09	9.7E-10	9.1E-10
Thymus	6.2E-09	4.2E-09	2.2E-09	1.6E-09	1.1E-09	1.0E-09
Thyroid	5.8E-09	3.9E-09	2.2E-09	1.6E-09	1.1E-09	1.0E-09
Uterus	6.0E-09	4.1E-09	2.3E-09	1.8E-09	1.3E-09	1.2E-09
Remainder	3.6E-08	3.1E-08	1.7E-08	1.0E-08	6.0E-09	4.8E-09
Effective Dose	7.3E-09	5.2E-09	2.9E-09	2.0E-09	1.4E-09	1.2E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-136 (T½ = 13.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.5E-09	3.2E-09	1.9E-09	1.2E-09	8.7E-10	7.3E-10
Bladder Wall	2.5E-09	1.6E-09	8.5E-10	5.7E-10	3.3E-10	3.1E-10
Bone Surface	3.0E-09	2.0E-09	1.0E-09	6.9E-10	5.0E-10	4.4E-10
Brain	1.4E-09	7.4E-10	4.3E-10	3.0E-10	2.1E-10	1.9E-10
Breast	3.5E-09	2.6E-09	1.8E-09	1.2E-09	7.6E-10	6.9E-10
GI-Tract						
Oesophagus	4.5E-09	3.2E-09	1.9E-09	1.3E-09	9.7E-10	8.4E-10
St Wall	4.1E-09	2.8E-09	1.5E-09	9.8E-10	7.4E-10	5.8E-10
SI Wall	5.5E-09	4.0E-09	2.0E-09	1.3E-09	7.7E-10	6.5E-10
ULI Wall	1.2E-08	8.9E-09	4.1E-09	2.7E-09	1.4E-09	1.2E-09
LLI Wall	2.5E-08	1.9E-08	8.4E-09	5.3E-09	2.7E-09	2.3E-09
Colon	1.8E-08	1.3E-08	6.0E-09	3.8E-09	2.0E-09	1.7E-09
Kidneys	2.9E-09	1.9E-09	1.0E-09	6.8E-10	4.7E-10	4.1E-10
Liver	3.8E-09	2.7E-09	1.5E-09	1.0E-09	7.9E-10	6.5E-10
Muscle	2.9E-09	2.0E-09	1.1E-09	7.1E-10	5.1E-10	4.4E-10
Ovaries	4.8E-09	3.5E-09	1.8E-09	1.2E-09	7.6E-10	6.1E-10
Pancreas	4.1E-09	2.8E-09	1.6E-09	1.0E-09	7.8E-10	6.1E-10
Red Marrow	2.3E-09	1.5E-09	9.7E-10	7.4E-10	5.7E-10	5.2E-10
Respiratory Tract						
ET Airways	7.1E-08	6.2E-08	3.3E-08	1.9E-08	1.1E-08	8.9E-09
Lungs	5.7E-08	4.4E-08	2.8E-08	2.1E-08	2.0E-08	1.6E-08
Skin	1.7E-09	1.1E-09	5.8E-10	3.9E-10	2.8E-10	2.5E-10
Spleen	3.7E-09	2.6E-09	1.4E-09	9.6E-10	7.1E-10	5.9E-10
Testes	1.6E-09	9.4E-10	4.9E-10	3.3E-10	2.2E-10	1.9E-10
Thymus	4.5E-09	3.2E-09	1.9E-09	1.3E-09	9.7E-10	8.4E-10
Thyroid	2.7E-09	1.8E-09	1.0E-09	6.7E-10	4.6E-10	4.0E-10
Uterus	3.2E-09	2.2E-09	1.1E-09	7.6E-10	4.6E-10	3.9E-10
Remainder	3.7E-08	3.2E-08	1.7E-08	6.9E-10	5.1E-10	4.3E-10
Effective Dose	1.3E-08	1.0E-08	6.0E-09	3.7E-09	3.1E-09	2.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-136 (T½ = 13.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.9E-09	3.1E-09	1.9E-09	1.1E-09	8.2E-10	6.7E-10
Bladder Wall	1.7E-09	1.3E-09	5.8E-10	4.1E-10	2.0E-10	1.7E-10
Bone Surface	2.2E-09	1.7E-09	8.6E-10	5.4E-10	3.8E-10	3.3E-10
Brain	4.3E-10	3.0E-10	1.8E-10	1.3E-10	8.9E-11	8.0E-11
Breast	3.2E-09	2.7E-09	1.8E-09	1.3E-09	7.6E-10	7.0E-10
GI-Tract						
Oesophagus	3.8E-09	3.1E-09	1.9E-09	1.3E-09	9.5E-10	8.3E-10
St Wall	3.6E-09	2.6E-09	1.4E-09	9.1E-10	6.8E-10	5.1E-10
SI Wall	5.4E-09	3.9E-09	1.9E-09	1.3E-09	6.9E-10	5.7E-10
ULI Wall	1.4E-08	9.6E-09	4.4E-09	2.9E-09	1.5E-09	1.2E-09
LLI Wall	3.1E-08	2.1E-08	9.3E-09	5.9E-09	3.0E-09	2.5E-09
Colon	2.1E-08	1.4E-08	6.5E-09	4.2E-09	2.1E-09	1.8E-09
Kidneys	2.1E-09	1.6E-09	8.4E-10	5.3E-10	3.6E-10	2.9E-10
Liver	3.2E-09	2.6E-09	1.5E-09	9.6E-10	7.3E-10	5.9E-10
Muscle	2.2E-09	1.7E-09	9.2E-10	5.9E-10	4.3E-10	3.5E-10
Ovaries	4.5E-09	3.3E-09	1.7E-09	1.1E-09	6.7E-10	5.1E-10
Pancreas	3.4E-09	2.6E-09	1.5E-09	9.3E-10	7.0E-10	5.2E-10
Red Marrow	1.6E-09	1.3E-09	8.2E-10	6.2E-10	4.8E-10	4.4E-10
Respiratory Tract						
ET Airways	7.1E-08	6.2E-08	3.3E-08	1.9E-08	1.1E-08	8.9E-09
Lungs	6.6E-08	5.2E-08	3.3E-08	2.5E-08	2.3E-08	1.8E-08
Skin	1.1E-09	8.3E-10	4.5E-10	3.0E-10	2.0E-10	1.8E-10
Spleen	3.1E-09	2.5E-09	1.3E-09	8.7E-10	6.4E-10	5.1E-10
Testes	8.1E-10	5.5E-10	2.6E-10	1.5E-10	7.7E-11	5.9E-11
Thymus	3.8E-09	3.1E-09	1.9E-09	1.3E-09	9.5E-10	8.3E-10
Thyroid	1.8E-09	1.4E-09	8.2E-10	5.1E-10	3.5E-10	3.0E-10
Uterus	2.5E-09	1.9E-09	9.0E-10	5.8E-10	3.1E-10	2.5E-10
Remainder	3.6E-08	3.2E-08	8.5E-10	5.7E-10	4.2E-10	3.5E-10
Effective Dose	1.5E-08	1.1E-08	5.7E-09	4.1E-09	3.5E-09	2.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-137 (T½ = 30.0 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	1.0	1.0	1.0	1.0	1.0	1.0
Adrenals	7.4E-09	4.4E-09	3.2E-09	3.6E-09	4.5E-09	4.7E-09
Bladder Wall	7.8E-09	4.7E-09	3.8E-09	3.8E-09	4.5E-09	4.9E-09
Bone Surface	7.3E-09	4.3E-09	3.1E-09	3.5E-09	4.4E-09	4.6E-09
Brain	6.9E-09	4.0E-09	2.9E-09	3.1E-09	3.8E-09	4.0E-09
Breast	6.4E-09	3.7E-09	2.6E-09	2.9E-09	3.6E-09	3.8E-09
GI-Tract						
Oesophagus	7.4E-09	4.3E-09	3.1E-09	3.4E-09	4.3E-09	4.4E-09
St Wall	7.6E-09	4.3E-09	3.1E-09	3.3E-09	4.2E-09	4.4E-09
SI Wall	7.6E-09	4.5E-09	3.3E-09	3.6E-09	4.5E-09	4.7E-09
ULI Wall	1.1E-08	7.0E-09	4.3E-09	4.1E-09	4.6E-09	4.8E-09
LLI Wall	1.9E-08	1.2E-08	6.6E-09	5.5E-09	5.2E-09	5.6E-09
Colon	1.4E-08	9.2E-09	5.3E-09	4.7E-09	4.9E-09	5.2E-09
Kidneys	7.3E-09	4.3E-09	3.1E-09	3.4E-09	4.3E-09	4.5E-09
Liver	7.3E-09	4.3E-09	3.1E-09	3.5E-09	4.3E-09	4.6E-09
Muscle	7.0E-09	4.1E-09	2.9E-09	3.2E-09	4.0E-09	4.2E-09
Ovaries	7.7E-09	4.6E-09	3.3E-09	3.7E-09	4.6E-09	4.8E-09
Pancreas	7.6E-09	4.5E-09	3.2E-09	3.7E-09	4.6E-09	4.8E-09
Red Marrow	6.8E-09	4.0E-09	2.9E-09	3.3E-09	4.2E-09	4.4E-09
Respiratory Tract						
ET Airways	3.2E-08	2.5E-08	1.4E-08	9.7E-09	7.8E-09	7.4E-09
Lungs	7.1E-09	4.2E-09	3.0E-09	3.3E-09	4.2E-09	4.3E-09
Skin	6.3E-09	3.6E-09	2.6E-09	2.8E-09	3.4E-09	3.6E-09
Spleen	7.3E-09	4.3E-09	3.1E-09	3.5E-09	4.3E-09	4.5E-09
Testes	6.9E-09	4.0E-09	2.9E-09	3.2E-09	4.0E-09	4.2E-09
Thymus	7.4E-09	4.3E-09	3.1E-09	3.4E-09	4.3E-09	4.4E-09
Thyroid	7.5E-09	4.4E-09	3.2E-09	3.5E-09	4.2E-09	4.4E-09
Uterus	7.6E-09	4.5E-09	3.3E-09	3.7E-09	4.6E-09	4.9E-09
Remainder	2.0E-08	1.5E-08	8.3E-09	6.5E-09	5.9E-09	5.8E-09
Effective Dose	8.8E-09	5.4E-09	3.6E-09	3.7E-09	4.4E-09	4.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-137 (T½ = 30.0 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	7.7E-09	6.0E-09	3.9E-09	2.9E-09	2.9E-09	2.8E-09
Bladder Wall	3.2E-09	2.0E-09	1.5E-09	1.3E-09	1.6E-09	1.8E-09
Bone Surface	4.8E-09	3.4E-09	2.1E-09	1.8E-09	2.0E-09	2.1E-09
Brain	2.6E-09	1.5E-09	1.1E-09	1.1E-09	1.4E-09	1.5E-09
Breast	6.5E-09	5.2E-09	3.8E-09	2.9E-09	2.5E-09	2.5E-09
GI-Tract						
Oesophagus	6.7E-09	5.3E-09	3.8E-09	3.0E-09	3.0E-09	2.9E-09
St Wall	6.1E-09	4.3E-09	2.7E-09	2.1E-09	2.3E-09	2.2E-09
SI Wall	6.2E-09	4.3E-09	2.4E-09	2.0E-09	2.0E-09	2.0E-09
ULI Wall	1.8E-08	1.3E-08	6.3E-09	4.3E-09	3.1E-09	2.9E-09
LLI Wall	4.5E-08	3.2E-08	1.4E-08	9.1E-09	5.6E-09	5.1E-09
Colon	3.0E-08	2.1E-08	9.8E-09	6.4E-09	4.2E-09	3.9E-09
Kidneys	4.6E-09	3.2E-09	2.0E-09	1.7E-09	2.0E-09	2.0E-09
Liver	6.3E-09	4.8E-09	3.1E-09	2.5E-09	2.6E-09	2.5E-09
Muscle	4.5E-09	3.2E-09	2.1E-09	1.7E-09	2.0E-09	2.0E-09
Ovaries	4.0E-09	2.7E-09	1.7E-09	1.6E-09	1.8E-09	1.9E-09
Pancreas	6.4E-09	4.8E-09	3.2E-09	2.5E-09	2.6E-09	2.5E-09
Red Marrow	4.0E-09	2.8E-09	2.0E-09	1.8E-09	2.1E-09	2.2E-09
Respiratory Tract						
ET Airways	6.4E-08	5.1E-08	2.5E-08	1.6E-08	1.0E-08	9.2E-09
Lungs	2.4E-07	2.0E-07	1.2E-07	8.7E-08	7.6E-08	6.3E-08
Skin	3.2E-09	2.1E-09	1.4E-09	1.2E-09	1.5E-09	1.5E-09
Spleen	6.2E-09	4.7E-09	2.9E-09	2.4E-09	2.5E-09	2.4E-09
Testes	2.6E-09	1.5E-09	1.0E-09	1.1E-09	1.4E-09	1.5E-09
Thymus	6.7E-09	5.3E-09	3.8E-09	3.0E-09	3.0E-09	2.9E-09
Thyroid	4.7E-09	3.4E-09	2.3E-09	1.8E-09	2.0E-09	2.0E-09
Uterus	3.5E-09	2.2E-09	1.5E-09	1.4E-09	1.7E-09	1.8E-09
Remainder	4.2E-09	2.9E-09	2.0E-09	1.7E-09	1.9E-09	2.0E-09
Effective Dose	3.6E-08	2.9E-08	1.8E-08	1.3E-08	1.1E-08	9.7E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.20.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cs-137 (T½ = 30.0 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.5E-08	2.4E-08	1.7E-08	1.1E-08	9.1E-09	8.7E-09
Bladder Wall	2.1E-09	1.8E-09	1.0E-09	6.3E-10	4.7E-10	4.3E-10
Bone Surface	1.1E-08	1.0E-08	6.6E-09	4.4E-09	3.8E-09	3.6E-09
Brain	1.9E-09	1.8E-09	1.2E-09	8.7E-10	7.7E-10	7.6E-10
Breast	2.3E-08	2.3E-08	1.8E-08	1.2E-08	9.1E-09	9.2E-09
GI-Tract						
Oesophagus	2.2E-08	2.2E-08	1.7E-08	1.2E-08	1.1E-08	1.1E-08
St Wall	1.4E-08	1.3E-08	8.8E-09	6.1E-09	5.3E-09	4.6E-09
SI Wall	7.9E-09	6.5E-09	3.6E-09	2.2E-09	1.5E-09	1.4E-09
ULI Wall	2.4E-08	1.7E-08	8.5E-09	5.2E-09	3.1E-09	2.8E-09
LLI Wall	5.6E-08	3.8E-08	1.8E-08	1.1E-08	5.9E-09	5.0E-09
Colon	3.7E-08	2.6E-08	1.2E-08	7.5E-09	4.3E-09	3.7E-09
Kidneys	9.7E-09	9.3E-09	6.0E-09	3.9E-09	3.3E-09	3.0E-09
Liver	1.8E-08	1.8E-08	1.3E-08	8.9E-09	7.8E-09	7.3E-09
Muscle	1.0E-08	9.7E-09	6.6E-09	4.5E-09	4.0E-09	3.8E-09
Ovaries	3.9E-09	3.3E-09	2.0E-09	1.2E-09	8.9E-10	8.1E-10
Pancreas	1.8E-08	1.8E-08	1.2E-08	8.1E-09	7.0E-09	6.4E-09
Red Marrow	8.6E-09	8.5E-09	6.4E-09	4.9E-09	4.7E-09	4.7E-09
Respiratory Tract						
ET Airways	1.9E-07	1.6E-07	8.5E-08	5.8E-08	3.7E-08	3.6E-08
Lungs	8.2E-07	7.7E-07	5.2E-07	3.6E-07	3.1E-07	3.0E-07
Skin	5.3E-09	5.1E-09	3.5E-09	2.4E-09	2.1E-09	2.0E-09
Spleen	1.8E-08	1.7E-08	1.1E-08	7.8E-09	6.7E-09	6.2E-09
Testes	1.1E-09	8.6E-10	4.7E-10	3.4E-10	2.8E-10	2.7E-10
Thymus	2.2E-08	2.2E-08	1.7E-08	1.2E-08	1.1E-08	1.1E-08
Thyroid	1.1E-08	1.1E-08	7.3E-09	4.6E-09	3.8E-09	3.6E-09
Uterus	3.1E-09	2.7E-09	1.5E-09	8.6E-10	6.7E-10	6.3E-10
Remainder	8.6E-09	8.3E-09	5.9E-09	4.2E-09	3.8E-09	3.6E-09
Effective Dose	1.1E-07	1.0E-07	7.0E-08	4.8E-08	4.2E-08	3.9E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.21. Barium

(204) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned all of the following compounds of barium (Ba) to inhalation Class W: oxides and hydroxides, sulfides, sulfates, carbonates, halides and nitrates. In contrast, all commonly occurring compounds of barium were assigned to Class D in *ICRP Publication 30*, Part 2 (ICRP, 1980).

Absorption Types

(205) No information was found on the behaviour of inhaled barium in man. A limited amount of information is available from studies of barium inhaled in several different compounds by beagle dogs. Cuddihy and Griffith (1972) observed very rapid absorption of $^{140}BaCl_2$ following inhalation of ^{140}Ba–^{140}La. By 4 days after the exposure, the lung content had decreased to about 0.3% of the initial value, consistent with assignment to Type F. In subsequent studies, Cuddihy *et al.* (1974) compared the clearance of ^{133}Ba inhaled as $BaCl_2$, $BaSO_4$, heat-treated $BaSO_4$, or in a fused aluminosilicate matrix at 16 days after the inhalation exposure. In dogs that inhaled $^{133}BaCl_2$, essentially all of the existing body content was measured in the skeleton.

(206) After inhalation of $^{133}BaSO_4$, about 10% of the initial lung content remained in the lung and for inhaled, heat-treated (900°C) $^{133}BaSO_4$, the lung contents were about 50% of the initial body contents. The results indicate either Type F or M behaviour for $BaSO_4$ with or without heat treatment. *In vitro* measurements showed heat-treated $BaSO_4$ to be consistent with assignment to Type M and untreated $BaSO_4$ with Type F. $^{133}BaSO_4$ has also been used as an effectively insoluble material to study the clearance and retention of particles deposited in the trachea in several species (Patrick and Stirling, 1977; Takahashi and Patrick, 1987; Patrick, 1989; Takahashi *et al.*, 1993). Most of these studies were of short duration, but in one, measurements were made for 6 months, and indicate Type M behaviour (Takahashi and Patrick, 1987).

(207) For ^{133}Ba embedded in fused aluminosilicate particles inhaled by dogs (Cuddihy *et al.*, 1974), the lung content at 16 d after exposure was about 70% of the initial lung content, indicating Type M or S behaviour; but the study was of insufficient duration to distinguish between the two.

Dose coefficients

(208) Studies of common chemical forms showing characteristics of absorption Types F and M have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.21.2 and 5.21.3) were derived using the f_1 values given in Table 5.21.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.21.1. Values of f_1 for inhaled particulate compounds of barium

	f_1[a]					
Absorption Type	3 mo	1 y	5 y	10 y	15 y	Adult
F	0.6	0.3	0.3	0.3	0.3	0.2
M[b]	0.2	0.1	0.1	0.1	0.1	0.1
S	0.02	0.01	0.01	0.01	0.01	0.01

[a] f_1 values for the adult are taken from Table 2. Those for children are derived according to the procedure described in Paragraph 14.
[b] Default Type M is recommended for use in the absence of specific information.

Table 5.21.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ba-133 (T½ = 10.7 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.3	0.3	0.3	0.3	0.2
Adrenals	1.1E-08	3.9E-09	2.3E-09	3.8E-09	6.9E-09	1.5E-09
Bladder Wall	4.5E-09	2.0E-09	1.2E-09	1.7E-09	2.4E-09	6.5E-10
Bone Surface	8.1E-08	2.7E-08	1.7E-08	2.6E-08	4.5E-08	8.3E-09
Brain	7.1E-09	2.7E-09	1.9E-09	3.2E-09	6.2E-09	1.1E-09
Breast	4.0E-09	1.5E-09	9.1E-10	1.3E-09	2.0E-09	4.8E-10
GI-Tract						
Oesophagus	4.9E-09	2.0E-09	1.2E-09	1.7E-09	2.9E-09	6.7E-10
St Wall	4.4E-09	1.9E-09	1.1E-09	1.5E-09	2.4E-09	6.2E-10
SI Wall	6.6E-09	3.0E-09	1.8E-09	2.5E-09	4.0E-09	1.1E-09
ULI Wall	9.8E-09	5.7E-09	3.0E-09	3.0E-09	3.8E-09	1.3E-09
LLI Wall	1.9E-08	1.2E-08	6.1E-09	5.5E-09	6.3E-09	2.4E-09
Colon	1.4E-08	8.4E-09	4.3E-09	4.1E-09	4.9E-09	1.8E-09
Kidneys	7.5E-09	2.8E-09	1.7E-09	2.5E-09	4.3E-09	1.0E-09
Liver	5.1E-09	2.0E-09	1.2E-09	1.7E-09	2.9E-09	6.9E-10
Muscle	6.6E-09	2.5E-09	1.5E-09	2.4E-09	4.1E-09	8.4E-10
Ovaries	7.5E-09	3.4E-09	2.1E-09	2.9E-09	4.7E-09	1.3E-09
Pancreas	6.1E-09	2.4E-09	1.4E-09	2.2E-09	3.9E-09	9.5E-10
Red Marrow	3.7E-08	1.2E-08	6.9E-09	1.1E-08	1.9E-08	4.8E-09
Respiratory Tract						
ET Airways	1.9E-08	1.5E-08	8.4E-09	6.1E-09	6.3E-09	2.7E-09
Lungs	7.0E-09	2.6E-09	1.5E-09	2.3E-09	4.0E-09	8.7E-10
Skin	5.1E-09	1.9E-09	1.1E-09	1.6E-09	2.8E-09	5.6E-10
Spleen	5.9E-09	2.3E-09	1.3E-09	1.9E-09	3.0E-09	7.0E-10
Testes	3.9E-09	1.6E-09	9.3E-10	1.3E-09	2.1E-09	4.6E-10
Thymus	4.9E-09	2.0E-09	1.2E-09	1.7E-09	2.9E-09	6.7E-10
Thyroid	4.3E-09	1.8E-09	1.2E-09	2.0E-09	3.8E-09	8.0E-10
Uterus	5.3E-09	2.4E-09	1.4E-09	2.0E-09	3.3E-09	8.8E-10
Remainder	6.7E-09	2.6E-09	1.6E-09	2.4E-09	4.2E-09	8.6E-10
Effective Dose	1.1E-08	4.5E-09	2.6E-09	3.7E-09	6.0E-09	1.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ba parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.21.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ba-133 (T½ = 10.7 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	8.2E-09	5.3E-09	3.3E-09	3.0E-09	3.9E-09	1.5E-09
Bladder Wall	2.1E-09	1.1E-09	6.8E-10	7.7E-10	1.0E-09	3.3E-10
Bone Surface	3.2E-08	1.3E-08	8.3E-09	1.1E-08	1.9E-08	4.2E-09
Brain	2.8E-09	1.2E-09	8.8E-10	1.4E-09	2.6E-09	5.4E-10
Breast	5.0E-09	3.9E-09	2.7E-09	2.1E-09	1.8E-09	1.1E-09
GI-Tract						
Oesophagus	5.3E-09	4.0E-09	2.8E-09	2.3E-09	2.4E-09	1.3E-09
St Wall	4.1E-09	2.8E-09	1.7E-09	1.4E-09	1.6E-09	7.3E-10
SI Wall	4.1E-09	2.4E-09	1.4E-09	1.4E-09	1.9E-09	6.6E-10
ULI Wall	7.9E-09	5.2E-09	2.6E-09	2.1E-09	2.1E-09	9.7E-10
LLI Wall	1.6E-08	1.1E-08	5.4E-09	4.0E-09	3.6E-09	1.8E-09
Colon	1.2E-08	7.8E-09	3.8E-09	2.9E-09	2.7E-09	1.3E-09
Kidneys	4.4E-09	2.4E-09	1.5E-09	1.5E-09	2.1E-09	7.0E-10
Liver	5.1E-09	3.7E-09	2.3E-09	1.9E-09	2.1E-09	1.1E-09
Muscle	4.2E-09	2.5E-09	1.6E-09	1.5E-09	2.2E-09	7.6E-10
Ovaries	4.0E-09	2.2E-09	1.3E-09	1.5E-09	2.1E-09	6.9E-10
Pancreas	5.6E-09	3.9E-09	2.4E-09	1.9E-09	2.4E-09	1.0E-09
Red Marrow	1.4E-08	5.5E-09	3.6E-09	5.1E-09	8.5E-09	2.6E-09
Respiratory Tract						
ET Airways	3.6E-08	3.0E-08	1.5E-08	9.7E-09	6.7E-09	4.8E-09
Lungs	7.2E-08	5.8E-08	3.6E-08	2.5E-08	2.3E-08	1.8E-08
Skin	2.7E-09	1.4E-09	8.8E-10	9.2E-10	1.4E-09	4.1E-10
Spleen	5.4E-09	3.8E-09	2.2E-09	1.8E-09	2.0E-09	9.1E-10
Testes	1.6E-09	7.5E-10	4.4E-10	5.5E-10	8.9E-10	2.2E-10
Thymus	5.3E-09	4.0E-09	2.8E-09	2.3E-09	2.4E-09	1.3E-09
Thyroid	3.5E-09	2.3E-09	1.5E-09	1.4E-09	2.0E-09	6.6E-10
Uterus	2.7E-09	1.5E-09	8.7E-10	9.5E-10	1.5E-09	4.5E-10
Remainder	4.0E-09	2.3E-09	1.5E-09	1.5E-09	2.2E-09	7.5E-10
Effective Dose	1.5E-08	1.0E-08	6.4E-09	5.1E-09	5.5E-09	3.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ba parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.21.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ba-133 (T½ = 10.7 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.9E-08	1.8E-08	1.2E-08	7.6E-09	6.1E-09	5.5E-09
Bladder Wall	1.3E-09	1.1E-09	5.7E-10	3.4E-10	2.2E-10	1.4E-10
Bone Surface	1.5E-08	1.3E-08	7.9E-09	5.5E-09	4.9E-09	3.6E-09
Brain	1.1E-09	9.2E-10	6.5E-10	4.9E-10	4.8E-10	3.1E-10
Breast	1.6E-08	1.6E-08	1.2E-08	7.9E-09	5.7E-09	5.7E-09
GI-Tract						
Oesophagus	1.6E-08	1.6E-08	1.2E-08	8.5E-09	7.0E-09	6.6E-09
St Wall	9.4E-09	8.9E-09	6.0E-09	4.0E-09	3.3E-09	2.7E-09
SI Wall	4.2E-09	3.5E-09	2.0E-09	1.2E-09	7.9E-10	6.0E-10
ULI Wall	8.3E-09	6.4E-09	3.3E-09	2.0E-09	1.3E-09	1.0E-09
LLI Wall	1.5E-08	1.1E-08	5.1E-09	3.2E-09	1.9E-09	1.5E-09
Colon	1.1E-08	8.3E-09	4.1E-09	2.5E-09	1.5E-09	1.2E-09
Kidneys	6.7E-09	6.1E-09	3.8E-09	2.4E-09	1.9E-09	1.6E-09
Liver	1.4E-08	1.3E-08	9.2E-09	6.3E-09	5.3E-09	4.8E-09
Muscle	7.6E-09	7.2E-09	4.8E-09	3.2E-09	2.8E-09	2.4E-09
Ovaries	2.8E-09	2.3E-09	1.3E-09	7.8E-10	5.8E-10	4.1E-10
Pancreas	1.4E-08	1.4E-08	8.9E-09	5.5E-09	4.5E-09	3.9E-09
Red Marrow	6.8E-09	6.1E-09	4.4E-09	3.5E-09	3.4E-09	2.9E-09
Respiratory Tract						
ET Airways	1.0E-07	8.9E-08	4.7E-08	3.1E-08	2.0E-08	1.9E-08
Lungs	2.1E-07	1.9E-07	1.3E-07	8.8E-08	7.5E-08	6.8E-08
Skin	3.5E-09	3.3E-09	2.2E-09	1.4E-09	1.2E-09	1.1E-09
Spleen	1.4E-08	1.3E-08	8.5E-09	5.4E-09	4.3E-09	3.9E-09
Testes	6.3E-10	4.7E-10	2.2E-10	1.6E-10	1.2E-10	5.6E-11
Thymus	1.6E-08	1.6E-08	1.2E-08	8.5E-09	7.0E-09	6.6E-09
Thyroid	8.0E-09	7.7E-09	5.0E-09	2.9E-09	2.2E-09	2.0E-09
Uterus	2.0E-09	1.7E-09	8.9E-10	5.1E-10	3.7E-10	2.5E-10
Remainder	6.4E-09	6.1E-09	4.2E-09	2.9E-09	2.6E-09	2.3E-09
Effective Dose	3.2E-08	2.9E-08	2.0E-08	1.3E-08	1.1E-08	1.0E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ba parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.21.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ba-140 (T½ = 12.7 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.3	0.3	0.3	0.3	0.2
Adrenals	4.8E-09	1.8E-09	7.7E-10	7.6E-10	7.7E-10	2.2E-10
Bladder Wall	2.6E-09	1.5E-09	7.6E-10	5.9E-10	4.0E-10	2.5E-10
Bone Surface	5.8E-08	2.0E-08	1.1E-08	9.5E-09	8.2E-09	2.0E-09
Brain	3.2E-09	1.2E-09	5.9E-10	5.8E-10	5.8E-10	1.4E-10
Breast	2.2E-09	8.4E-10	3.7E-10	3.3E-10	2.6E-10	8.9E-11
GI-Tract						
Oesophagus	2.6E-09	1.1E-09	4.7E-10	3.9E-10	3.5E-10	1.2E-10
St Wall	3.1E-09	1.5E-09	6.7E-10	5.1E-10	3.9E-10	1.8E-10
SI Wall	4.4E-09	2.9E-09	1.4E-09	1.1E-09	7.5E-10	4.6E-10
ULI Wall	2.4E-08	2.2E-08	1.0E-08	5.8E-09	2.6E-09	2.8E-09
LLI Wall	7.0E-08	6.7E-08	3.1E-08	1.7E-08	7.3E-09	8.9E-09
Colon	4.4E-08	4.2E-08	1.9E-08	1.1E-08	4.6E-09	5.4E-09
Kidneys	3.7E-09	1.4E-09	6.3E-10	5.8E-10	5.5E-10	1.9E-10
Liver	2.6E-09	1.1E-09	4.8E-10	4.1E-10	3.6E-10	1.3E-10
Muscle	3.3E-09	1.3E-09	6.2E-10	5.5E-10	4.9E-10	1.6E-10
Ovaries	4.4E-09	2.8E-09	1.4E-09	1.1E-09	8.2E-10	4.8E-10
Pancreas	3.0E-09	1.2E-09	5.4E-10	4.9E-10	4.5E-10	1.6E-10
Red Marrow	4.3E-08	1.1E-08	4.8E-09	4.7E-09	4.7E-09	1.4E-09
Respiratory Tract						
ET Airways	3.4E-08	2.8E-08	1.4E-08	8.5E-09	5.0E-09	3.9E-09
Lungs	3.3E-09	1.3E-09	5.5E-10	4.9E-10	4.7E-10	1.5E-10
Skin	2.7E-09	1.0E-09	4.4E-10	3.9E-10	3.4E-10	1.0E-10
Spleen	3.0E-09	1.2E-09	5.1E-10	4.4E-10	3.8E-10	1.3E-10
Testes	2.2E-09	9.8E-10	4.5E-10	3.5E-10	2.9E-10	1.1E-10
Thymus	2.6E-09	1.1E-09	4.7E-10	3.9E-10	3.5E-10	1.2E-10
Thyroid	2.1E-09	8.3E-10	4.2E-10	3.9E-10	4.1E-10	1.2E-10
Uterus	3.0E-09	1.7E-09	7.9E-10	6.2E-10	5.0E-10	2.5E-10
Remainder	3.3E-09	1.3E-09	6.3E-10	5.6E-10	5.0E-10	1.7E-10
Effective Dose	1.4E-08	7.8E-09	3.6E-09	2.4E-09	1.6E-09	1.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ba parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.21.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ba-140 (T½ = 12.7 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.3E-09	2.9E-09	1.7E-09	1.1E-09	8.1E-10	5.9E-10
Bladder Wall	1.4E-09	9.1E-10	4.5E-10	3.1E-10	1.8E-10	1.4E-10
Bone Surface	1.7E-08	5.4E-09	2.8E-09	2.3E-09	1.9E-09	6.8E-10
Brain	1.1E-09	4.4E-10	2.4E-10	2.1E-10	1.8E-10	8.3E-11
Breast	3.2E-09	2.4E-09	1.6E-09	1.1E-09	6.9E-10	6.1E-10
GI-Tract						
Oesophagus	3.3E-09	2.5E-09	1.6E-09	1.1E-09	8.6E-10	7.1E-10
St Wall	3.9E-09	2.5E-09	1.3E-09	8.0E-10	6.1E-10	4.5E-10
SI Wall	5.5E-09	3.9E-09	1.8E-09	1.2E-09	6.5E-10	5.0E-10
ULI Wall	2.8E-08	2.1E-08	9.0E-09	5.4E-09	2.6E-09	2.3E-09
LLI Wall	8.9E-08	6.5E-08	2.8E-08	1.7E-08	8.0E-09	7.2E-09
Colon	5.4E-08	4.0E-08	1.7E-08	1.0E-08	4.9E-09	4.4E-09
Kidneys	2.4E-09	1.5E-09	7.4E-10	4.9E-10	3.8E-10	2.6E-10
Liver	3.0E-09	2.2E-09	1.2E-09	8.3E-10	6.7E-10	5.0E-10
Muscle	2.3E-09	1.5E-09	7.8E-10	5.3E-10	4.2E-10	2.9E-10
Ovaries	3.0E-09	2.1E-09	1.0E-09	7.2E-10	4.7E-10	3.3E-10
Pancreas	3.3E-09	2.2E-09	1.3E-09	8.1E-10	6.3E-10	4.4E-10
Red Marrow	1.3E-08	3.3E-09	1.6E-09	1.4E-09	1.3E-09	6.4E-10
Respiratory Tract						
ET Airways	4.4E-08	3.5E-08	1.7E-08	1.1E-08	6.1E-09	5.1E-09
Lungs	1.4E-07	1.1E-07	6.6E-08	4.8E-08	4.3E-08	3.5E-08
Skin	1.5E-09	8.1E-10	4.4E-10	3.1E-10	2.2E-10	1.6E-10
Spleen	3.0E-09	2.1E-09	1.2E-09	7.7E-10	5.9E-10	4.4E-10
Testes	9.2E-10	4.8E-10	2.2E-10	1.5E-10	9.8E-11	5.1E-11
Thymus	3.3E-09	2.5E-09	1.6E-09	1.1E-09	8.6E-10	7.1E-10
Thyroid	2.0E-09	1.4E-09	7.9E-10	5.0E-10	3.6E-10	2.7E-10
Uterus	1.8E-09	1.2E-09	5.7E-10	3.8E-10	2.4E-10	1.6E-10
Remainder	2.2E-09	1.3E-09	7.3E-10	5.2E-10	4.1E-10	2.9E-10
Effective Dose	2.7E-08	2.0E-08	1.1E-08	7.6E-09	6.2E-09	5.1E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ba parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.21.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ba-140 (T½ = 12.7 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	3.8E-09	3.1E-09	1.8E-09	1.1E-09	8.0E-10	6.6E-10
Bladder Wall	1.0E-09	7.6E-10	3.6E-10	2.4E-10	1.3E-10	1.0E-10
Bone Surface	3.0E-09	1.7E-09	8.8E-10	5.7E-10	4.3E-10	3.2E-10
Brain	3.7E-10	2.5E-10	1.5E-10	1.1E-10	7.9E-11	6.6E-11
Breast	3.2E-09	2.7E-09	1.8E-09	1.3E-09	7.8E-10	7.2E-10
GI-Tract						
Oesophagus	3.2E-09	2.8E-09	1.8E-09	1.2E-09	9.6E-10	8.3E-10
St Wall	3.8E-09	2.6E-09	1.4E-09	8.5E-10	6.5E-10	5.0E-10
SI Wall	6.0E-09	4.1E-09	1.9E-09	1.2E-09	6.3E-10	5.1E-10
ULI Wall	3.0E-08	2.0E-08	8.7E-09	5.3E-09	2.6E-09	2.1E-09
LLI Wall	9.9E-08	6.4E-08	2.8E-08	1.7E-08	8.2E-09	6.8E-09
Colon	6.0E-08	3.9E-08	1.7E-08	1.0E-08	5.0E-09	4.2E-09
Kidneys	1.8E-09	1.4E-09	7.5E-10	4.5E-10	3.3E-10	2.6E-10
Liver	2.9E-09	2.4E-09	1.4E-09	9.0E-10	7.3E-10	5.8E-10
Muscle	1.8E-09	1.4E-09	7.9E-10	5.1E-10	3.9E-10	3.2E-10
Ovaries	2.6E-09	1.9E-09	9.6E-10	6.4E-10	3.8E-10	2.9E-10
Pancreas	3.1E-09	2.4E-09	1.4E-09	8.6E-10	6.6E-10	4.9E-10
Red Marrow	2.2E-09	1.3E-09	7.7E-10	5.8E-10	4.8E-10	4.2E-10
Respiratory Tract						
ET Airways	4.5E-08	3.7E-08	1.8E-08	1.1E-08	6.3E-09	5.3E-09
Lungs	1.7E-07	1.3E-07	7.9E-08	5.7E-08	5.1E-08	4.2E-08
Skin	9.6E-10	7.4E-10	4.2E-10	2.8E-10	1.9E-10	1.7E-10
Spleen	2.8E-09	2.3E-09	1.3E-09	8.3E-10	6.2E-10	5.0E-10
Testes	5.0E-10	3.5E-10	1.6E-10	1.0E-10	5.0E-11	3.5E-11
Thymus	3.2E-09	2.8E-09	1.8E-09	1.2E-09	9.6E-10	8.3E-10
Thyroid	1.7E-09	1.4E-09	8.5E-10	5.1E-10	3.4E-10	2.9E-10
Uterus	1.4E-09	1.1E-09	5.1E-10	3.2E-10	1.8E-10	1.4E-10
Remainder	1.7E-09	1.3E-09	7.4E-10	5.0E-10	3.8E-10	3.1E-10
Effective Dose	2.9E-08	2.2E-08	1.2E-08	8.6E-09	7.1E-09	5.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ba parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.22. Cerium

(209) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides and fluorides of cerium (Ce) to inhalation Class Y and all other compounds to Class W. This classification was endorsed in *ICRP Publication 30*, Part 1 (ICRP, 1979) which referred to further support from animal experiments. The physical, chemical and biological properties of radiocerium relevant to radiation protection guidelines were reviewed in NCRP Report 60 (NCRP, 1978).

Absorption Types

(210) There have been few reported studies of the biokinetics of cerium involving human inhalation. In one case of an accidental human exposure to a ^{144}Ce–Pr contaminated atmosphere (Glenn *et al.*, 1979), the results of lung clearance are consistent with assignment to Type M. Results of a retrospective study to evaluate lung retention of cerium particles in subjects (Pairon *et al.*, 1994), indicate Type M or S behaviour.

(211) Several animal experiments have been performed with soluble cerium as $^{144}CeCl_3$. Experiments on dogs (Cuddihy *et al.*, 1975) gave results consistent with assignment to Type M. Other experiments on Chinese hamsters (Sturbaum *et al.*, 1970) indicate Type M behaviour. Results of a study in which $CeCl_3$ was administered to rats by intratracheal instillation (Cember and Watson, 1958) were of insufficient duration (2 months) to distinguish between Types M and S. Cember and Stemmer (1964) postulated that this slow clearance of $^{144}CeCl_3$ may be due to cerium being in a bound state, and also showed that protein is capable of binding relatively large quantities of cerium. Kanapilly *et al.* (1973), however, remarked that the retention of $^{144}CeCl_3$ in the lung may be attributed to the hydrolysis of ^{144}Ce. Experiments designed to give a soluble form of $^{144}CeCl_3$, by using CsCl instead of $CeCl_3$ as the vector aerosol, gave, in this exceptional case, results consistent with assignment to Type F (Cuddihy *et al.*, 1975; Boecker and Cuddihy, 1974).

(212) Results of experiments on rats exposed by inhalation to cerium as ^{144}CeOH, are consistent with assignment to Type M (Thomas *et al.*, 1972).

(213) Studies have been conducted of the behaviour of cerium following inhalation of $^{144}CeO_2$ by mice (Lundgren *et al.*, 1974, 1980a, 1980b), Syrian hamsters (Thomas and McClellan, 1972) and rats (Lundgren *et al.*, 1992; Yan *et al.*, 1988). Some experiments gave results consistent with assignment to Type M, and others to Type S. According to Lundgren *et al.* (1992), lung clearance decreases as the initial lung deposit increases.

(214) A study of cerium associated with irradiated fuel fragments indicated that ^{144}Ce is moderately transportable from lung to blood, consistent with assignment to Type M (Stradling *et al.*, 1989). Results of a study in which irradiated UO_2 powder was administered to rats by intratracheal instillation (Lang *et al.*, 1994) are consistent with assignment of the cerium present to Type M or S but were of insufficient duration (3 months) to distinguish between the two. Studies of the *in vitro* dissolution of particles released from the Chernobyl accident (Cuddihy *et al.*, 1989) were consistent with assignment of the cerium present to Type M.

(215) It has also been demonstrated in experiments on dogs (Shyr *et al.*, 1991; McClellan *et al.* 1970) that when cerium is incorporated into fused aluminosilicate particles (Ce–FAP), the cerium is avidly retained in the lung, indicating Type S behaviour. McClellan *et al.* (1970) stated that the retention in the lung of cerium–FAP is primarily influenced by the characteristics of the FAP vector aerosol rather than that of cerium.

Dose coefficients

(216) Studies of common chemical forms showing characteristics of absorption Types M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.22.2 and 5.22.3) were derived using the f_1 values given in Table 5.22.1, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.22.1. Values of f_1 for inhaled particulate compounds of cerium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.005	5×10^{-4}
M[b]	0.005	5×10^{-4}
S	0.005	5×10^{-4}

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.22.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ce-141 (T½ = 32.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.5E-09	1.2E-09	6.2E-10	4.4E-10	2.9E-10	2.6E-10
Bladder Wall	1.2E-09	8.8E-10	4.2E-10	2.6E-10	1.5E-10	1.2E-10
Bone Surface	2.2E-07	1.4E-07	8.8E-08	3.8E-08	2.1E-08	1.7E-08
Brain	1.3E-09	8.6E-10	4.1E-10	2.4E-10	1.5E-10	1.2E-10
Breast	1.1E-09	8.5E-10	4.0E-10	2.5E-10	1.5E-10	1.2E-10
GI-Tract						
Oesophagus	1.2E-09	8.8E-10	4.2E-10	2.6E-10	1.6E-10	1.3E-10
St Wall	1.6E-09	1.2E-09	5.8E-10	3.6E-10	2.1E-10	1.8E-10
SI Wall	2.1E-09	1.6E-09	7.3E-10	4.6E-10	2.5E-10	2.1E-10
ULI Wall	6.2E-09	4.3E-09	1.8E-09	1.1E-09	5.6E-10	4.7E-10
LLI Wall	1.5E-08	9.7E-09	4.1E-09	2.5E-09	1.2E-09	9.7E-10
Colon	9.9E-09	6.6E-09	2.8E-09	1.7E-09	8.2E-10	6.9E-10
Kidneys	1.4E-09	1.1E-09	5.5E-10	3.8E-10	2.3E-10	2.1E-10
Liver	1.4E-08	3.0E-08	1.4E-08	1.2E-08	7.8E-09	7.9E-09
Muscle	1.3E-09	9.2E-10	4.4E-10	2.7E-10	1.7E-10	1.4E-10
Ovaries	1.4E-09	1.0E-09	5.0E-10	3.1E-10	1.9E-10	1.5E-10
Pancreas	1.4E-09	1.2E-09	6.2E-10	4.3E-10	2.6E-10	2.4E-10
Red Marrow	5.2E-08	2.4E-08	1.1E-08	4.6E-09	2.6E-09	1.5E-09
Respiratory Tract						
ET Airways	1.4E-08	1.0E-08	4.5E-09	2.9E-09	1.6E-09	1.5E-09
Lungs	1.4E-09	1.1E-09	5.4E-10	3.6E-10	2.4E-10	2.1E-10
Skin	1.2E-09	8.3E-10	3.8E-10	2.3E-10	1.4E-10	1.2E-10
Spleen	1.3E-09	9.4E-10	4.5E-10	2.8E-10	1.7E-10	1.4E-10
Testes	1.1E-09	8.0E-10	3.7E-10	2.2E-10	1.3E-10	1.1E-10
Thymus	1.2E-09	8.8E-10	4.2E-10	2.6E-10	1.6E-10	1.3E-10
Thyroid	1.2E-09	8.4E-10	4.0E-10	2.4E-10	1.5E-10	1.2E-10
Uterus	1.3E-09	9.4E-10	4.6E-10	2.8E-10	1.7E-10	1.4E-10
Remainder	1.3E-09	9.3E-10	4.4E-10	2.8E-10	1.7E-10	1.4E-10
Effective Dose	1.1E-08	7.3E-09	3.5E-09	2.0E-09	1.2E-09	9.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.22.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ce-141 (T½ = 32.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	4.8E-10	3.9E-10	2.2E-10	1.5E-10	1.1E-10	9.2E-11
Bladder Wall	2.6E-10	1.9E-10	9.3E-11	5.7E-11	3.4E-11	2.8E-11
Bone Surface	3.5E-08	2.2E-08	1.5E-08	6.3E-09	3.8E-09	2.9E-09
Brain	2.1E-10	1.5E-10	7.4E-11	4.3E-11	2.8E-11	2.3E-11
Breast	3.7E-10	3.0E-10	1.8E-10	1.2E-10	7.0E-11	6.6E-11
GI-Tract						
Oesophagus	4.1E-10	3.3E-10	1.9E-10	1.3E-10	9.2E-11	7.9E-11
St Wall	1.1E-09	6.9E-10	3.2E-10	1.9E-10	1.2E-10	9.8E-11
SI Wall	2.0E-09	1.4E-09	6.1E-10	3.7E-10	1.9E-10	1.6E-10
ULI Wall	1.0E-08	6.9E-09	2.9E-09	1.8E-09	8.5E-10	7.0E-10
LLI Wall	2.9E-08	1.8E-08	7.8E-09	4.7E-09	2.3E-09	1.9E-09
Colon	1.8E-08	1.2E-08	5.0E-09	3.1E-09	1.5E-09	1.2E-09
Kidneys	3.2E-10	2.6E-10	1.4E-10	9.0E-11	6.0E-11	5.1E-11
Liver	2.5E-09	4.9E-09	2.4E-09	2.1E-09	1.4E-09	1.4E-09
Muscle	3.2E-10	2.4E-10	1.3E-10	7.9E-11	5.5E-11	4.6E-11
Ovaries	4.0E-10	3.0E-10	1.5E-10	9.8E-11	5.9E-11	4.7E-11
Pancreas	4.3E-10	3.7E-10	2.0E-10	1.3E-10	9.1E-11	7.5E-11
Red Marrow	8.1E-09	3.9E-09	1.8E-09	7.8E-10	4.8E-10	2.9E-10
Respiratory Tract						
ET Airways	2.4E-08	1.7E-08	7.4E-09	4.8E-09	2.7E-09	2.5E-09
Lungs	8.7E-08	6.9E-08	4.3E-08	3.2E-08	3.1E-08	2.4E-08
Skin	2.3E-10	1.7E-10	8.5E-11	5.1E-11	3.3E-11	2.9E-11
Spleen	3.9E-10	3.1E-10	1.7E-10	1.0E-10	7.1E-11	5.7E-11
Testes	2.1E-10	1.5E-10	6.9E-11	4.1E-11	2.5E-11	2.1E-11
Thymus	4.1E-10	3.3E-10	1.9E-10	1.3E-10	9.2E-11	7.9E-11
Thyroid	3.0E-10	2.3E-10	1.2E-10	7.2E-11	4.6E-11	3.8E-11
Uterus	3.1E-10	2.3E-10	1.1E-10	7.0E-11	4.2E-11	3.4E-11
Remainder	3.4E-10	2.5E-10	1.3E-10	8.4E-11	5.8E-11	4.8E-11
Effective Dose	1.4E-08	1.1E-08	6.3E-09	4.6E-09	4.1E-09	3.2E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.22.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ce-141 (T½ = 32.5 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	3.4E-10	2.7E-10	1.6E-10	1.0E-10	7.5E-11	6.1E-11
Bladder Wall	8.9E-11	6.3E-11	3.0E-11	1.9E-11	1.0E-11	8.2E-12
Bone Surface	2.2E-09	6.6E-10	4.1E-10	2.0E-10	1.3E-10	1.0E-10
Brain	2.7E-11	1.5E-11	8.9E-12	5.8E-12	4.0E-12	3.3E-12
Breast	2.6E-10	2.2E-10	1.5E-10	1.0E-10	6.0E-11	5.9E-11
GI-Tract						
Oesophagus	2.9E-10	2.4E-10	1.6E-10	1.2E-10	8.5E-11	7.4E-11
St Wall	9.9E-10	5.9E-10	2.7E-10	1.6E-10	1.1E-10	8.2E-11
SI Wall	2.0E-09	1.3E-09	5.6E-10	3.4E-10	1.7E-10	1.4E-10
ULI Wall	1.1E-08	7.2E-09	3.0E-09	1.8E-09	8.8E-10	7.2E-10
LLI Wall	3.0E-08	2.0E-08	8.3E-09	5.0E-09	2.4E-09	2.0E-09
Colon	1.9E-08	1.3E-08	5.3E-09	3.2E-09	1.6E-09	1.3E-09
Kidneys	1.5E-10	1.2E-10	6.3E-11	3.8E-11	2.6E-11	1.9E-11
Liver	3.7E-10	3.0E-10	1.7E-10	1.2E-10	9.3E-11	8.0E-11
Muscle	1.6E-10	1.3E-10	6.9E-11	4.5E-11	3.5E-11	2.8E-11
Ovaries	2.3E-10	1.7E-10	8.4E-11	5.7E-11	3.2E-11	2.5E-11
Pancreas	2.9E-10	2.4E-10	1.3E-10	8.1E-11	6.0E-11	4.5E-11
Red Marrow	5.4E-10	1.7E-10	9.3E-11	5.8E-11	4.4E-11	3.7E-11
Respiratory Tract						
ET Airways	2.7E-08	1.9E-08	8.3E-09	5.5E-09	3.0E-09	2.9E-09
Lungs	1.1E-07	8.6E-08	5.3E-08	4.0E-08	3.8E-08	3.0E-08
Skin	7.5E-11	5.3E-11	2.9E-11	1.9E-11	1.2E-11	1.2E-11
Spleen	2.5E-10	2.1E-10	1.2E-10	7.5E-11	5.6E-11	4.4E-11
Testes	4.4E-11	2.7E-11	1.1E-11	6.8E-12	3.2E-12	2.3E-12
Thymus	2.9E-10	2.4E-10	1.6E-10	1.2E-10	8.5E-11	7.4E-11
Thyroid	1.5E-10	1.3E-10	7.4E-11	4.3E-11	2.8E-11	2.2E-11
Uterus	1.3E-10	9.6E-11	4.7E-11	2.9E-11	1.6E-11	1.2E-11
Remainder	1.8E-10	1.3E-10	7.4E-11	5.0E-11	3.7E-11	3.1E-11
Effective Dose	1.6E-08	1.2E-08	7.1E-09	5.3E-09	4.8E-09	3.8E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.22.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ce-144 (T½ = 284 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	4.4E-08	3.6E-08	1.9E-08	1.1E-08	7.1E-09	6.2E-09
Bladder Wall	4.3E-08	3.5E-08	1.8E-08	1.0E-08	6.4E-09	5.5E-09
Bone Surface	1.8E-06	1.2E-06	7.5E-07	3.3E-07	2.0E-07	1.6E-07
Brain	4.3E-08	3.5E-08	1.8E-08	1.0E-08	6.4E-09	5.5E-09
Breast	4.3E-08	3.5E-08	1.8E-08	1.0E-08	6.4E-09	5.6E-09
GI-Tract						
Oesophagus	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.5E-09	5.6E-09
St Wall	4.5E-08	3.6E-08	1.8E-08	1.1E-08	6.7E-09	5.8E-09
SI Wall	4.9E-08	3.9E-08	2.0E-08	1.2E-08	7.0E-09	6.1E-09
ULI Wall	8.3E-08	6.2E-08	2.9E-08	1.8E-08	9.7E-09	8.3E-09
LLI Wall	1.6E-07	1.1E-07	4.9E-08	2.9E-08	1.5E-08	1.3E-08
Colon	1.1E-07	8.2E-08	3.8E-08	2.3E-08	1.2E-08	1.0E-08
Kidneys	4.4E-08	3.6E-08	1.8E-08	1.1E-08	6.8E-09	6.0E-09
Liver	6.1E-07	1.5E-06	7.8E-07	6.8E-07	4.4E-07	4.6E-07
Muscle	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.5E-09	5.6E-09
Ovaries	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.6E-09	5.6E-09
Pancreas	4.4E-08	3.6E-08	1.9E-08	1.1E-08	6.9E-09	6.1E-09
Red Marrow	2.2E-06	1.2E-06	5.9E-07	2.6E-07	1.5E-07	8.8E-08
Respiratory Tract						
ET Airways	5.8E-08	4.5E-08	2.2E-08	1.3E-08	8.1E-09	7.1E-09
Lungs	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.7E-09	5.9E-09
Skin	4.3E-08	3.4E-08	1.7E-08	1.0E-08	6.4E-09	5.5E-09
Spleen	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.5E-09	5.6E-09
Testes	4.3E-08	3.4E-08	1.7E-08	1.0E-08	6.3E-09	5.5E-09
Thymus	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.5E-09	5.6E-09
Thyroid	4.3E-08	3.5E-08	1.8E-08	1.0E-08	6.4E-09	5.5E-09
Uterus	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.5E-09	5.6E-09
Remainder	4.3E-08	3.5E-08	1.8E-08	1.1E-08	6.5E-09	5.6E-09
Effective Dose	3.6E-07	2.7E-07	1.4E-07	7.8E-08	4.8E-08	4.0E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.22.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ce-144 (T½ = 284 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.1E-08	9.7E-09	5.4E-09	3.3E-09	2.3E-09	2.0E-09
Bladder Wall	1.1E-08	8.9E-09	5.0E-09	2.9E-09	2.0E-09	1.7E-09
Bone Surface	4.2E-07	3.0E-07	2.1E-07	9.1E-08	6.1E-08	4.9E-08
Brain	1.1E-08	8.9E-09	5.0E-09	2.9E-09	2.0E-09	1.7E-09
Breast	1.1E-08	9.2E-09	5.1E-09	3.0E-09	2.0E-09	1.8E-09
GI-Tract						
Oesophagus	1.1E-08	9.2E-09	5.1E-09	3.0E-09	2.1E-09	1.8E-09
St Wall	1.6E-08	1.2E-08	6.3E-09	3.7E-09	2.4E-09	2.1E-09
SI Wall	2.4E-08	1.8E-08	8.8E-09	5.2E-09	3.1E-09	2.7E-09
ULI Wall	9.2E-08	6.3E-08	2.8E-08	1.7E-08	8.7E-09	7.3E-09
LLI Wall	2.4E-07	1.6E-07	7.0E-08	4.2E-08	2.1E-08	1.8E-08
Colon	1.6E-07	1.1E-07	4.6E-08	2.8E-08	1.4E-08	1.2E-08
Kidneys	1.1E-08	9.3E-09	5.2E-09	3.1E-09	2.1E-09	1.9E-09
Liver	2.1E-07	3.9E-07	2.2E-07	1.9E-07	1.3E-07	1.4E-07
Muscle	1.1E-08	9.1E-09	5.1E-09	3.0E-09	2.0E-09	1.8E-09
Ovaries	1.1E-08	9.1E-09	5.1E-09	3.0E-09	2.0E-09	1.8E-09
Pancreas	1.1E-08	9.6E-09	5.4E-09	3.2E-09	2.2E-09	2.0E-09
Red Marrow	5.1E-07	3.2E-07	1.7E-07	7.0E-08	4.6E-08	2.8E-08
Respiratory Tract						
ET Airways	7.0E-08	5.3E-08	2.4E-08	1.6E-08	9.0E-09	8.5E-09
Lungs	7.7E-07	6.5E-07	3.9E-07	2.6E-07	2.1E-07	1.9E-07
Skin	1.1E-08	8.9E-09	5.0E-09	2.9E-09	2.0E-09	1.7E-09
Spleen	1.1E-08	9.2E-09	5.1E-09	3.0E-09	2.0E-09	1.8E-09
Testes	1.0E-08	8.8E-09	4.9E-09	2.9E-09	1.9E-09	1.7E-09
Thymus	1.1E-08	9.2E-09	5.1E-09	3.0E-09	2.1E-09	1.8E-09
Thyroid	1.1E-08	9.0E-09	5.0E-09	2.9E-09	2.0E-09	1.8E-09
Uterus	1.1E-08	9.0E-09	5.0E-09	2.9E-09	2.0E-09	1.8E-09
Remainder	1.1E-08	9.2E-09	5.1E-09	3.0E-09	2.0E-09	1.8E-09
Effective Dose	1.9E-07	1.6E-07	8.8E-08	5.5E-08	4.1E-08	3.6E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.22.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ce-144 (T½ = 284 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.5E-09	1.1E-09	6.9E-10	4.2E-10	3.1E-10	2.7E-10
Bladder Wall	6.8E-10	3.8E-10	2.2E-10	1.3E-10	8.6E-11	7.7E-11
Bone Surface	2.4E-08	1.1E-08	7.9E-09	3.5E-09	2.5E-09	2.0E-09
Brain	6.4E-10	3.5E-10	2.1E-10	1.2E-10	8.8E-11	8.0E-11
Breast	1.3E-09	1.0E-09	6.8E-10	4.5E-10	2.8E-10	2.7E-10
GI-Tract						
Oesophagus	1.3E-09	1.0E-09	6.7E-10	4.5E-10	3.4E-10	3.1E-10
St Wall	6.4E-09	3.7E-09	1.7E-09	1.0E-09	6.5E-10	5.3E-10
SI Wall	1.5E-08	9.9E-09	4.4E-09	2.6E-09	1.3E-09	1.1E-09
ULI Wall	8.9E-08	5.9E-08	2.6E-08	1.5E-08	7.6E-09	6.2E-09
LLI Wall	2.5E-07	1.7E-07	7.2E-08	4.3E-08	2.2E-08	1.8E-08
Colon	1.6E-07	1.1E-07	4.6E-08	2.7E-08	1.4E-08	1.1E-08
Kidneys	9.4E-10	6.3E-10	3.6E-10	2.2E-10	1.6E-10	1.3E-10
Liver	1.4E-08	1.4E-08	8.9E-09	7.2E-09	5.4E-09	5.8E-09
Muscle	9.5E-10	6.4E-10	3.8E-10	2.3E-10	1.8E-10	1.5E-10
Ovaries	8.0E-10	4.8E-10	2.7E-10	1.6E-10	1.1E-10	9.4E-11
Pancreas	1.3E-09	9.5E-10	5.7E-10	3.5E-10	2.6E-10	2.1E-10
Red Marrow	2.8E-08	1.1E-08	6.1E-09	2.7E-09	1.8E-09	1.2E-09
Respiratory Tract						
ET Airways	1.2E-07	9.1E-08	4.1E-08	2.7E-08	1.5E-08	1.5E-08
Lungs	1.6E-06	1.4E-06	8.7E-07	5.8E-07	4.6E-07	4.2E-07
Skin	7.6E-10	4.6E-10	2.8E-10	1.6E-10	1.2E-10	1.1E-10
Spleen	1.2E-09	9.0E-10	5.4E-10	3.3E-10	2.4E-10	2.1E-10
Testes	6.2E-10	3.4E-10	1.9E-10	1.1E-10	7.8E-11	7.0E-11
Thymus	1.3E-09	1.0E-09	6.7E-10	4.5E-10	3.4E-10	3.1E-10
Thyroid	9.8E-10	6.8E-10	4.1E-10	2.4E-10	1.6E-10	1.4E-10
Uterus	7.3E-10	4.3E-10	2.4E-10	1.4E-10	9.3E-11	8.2E-11
Remainder	1.2E-09	7.8E-10	4.5E-10	2.8E-10	2.0E-10	1.8E-10
Effective Dose	2.1E-07	1.8E-07	1.1E-07	7.3E-08	5.8E-08	5.3E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.23. Lead

(217) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned sulphides, oxides, hydroxides, halides, and nitrates of lead (Pb) to inhalation Class W. This was changed to Class D in *ICRP Publication 30*, Part 2 (ICRP, 1980), which referred to experimental evidence of rapid lung clearance for submicron-sized aerosols of lead (Hursh *et al.*, 1969; Booker *et al.*, 1969; Hursh and Mercer, 1970; Bianco *et al.*, 1974; Chamberlain *et al.*, 1978).

(218) The default absorption parameter values given below are not appropriate for the short-lived decay products of radon, ^{212}Pb and ^{214}Pb, which are outside the scope of this report; nor is the general purpose default AMAD of 1 μm for environmental exposure appropriate to assess their deposition.

Absorption Types

(219) Following instillation of ionic ^{212}Pb into the trachea and bronchi of rabbits, about 20% was absorbed with a half-time of about 4 min, the rest with a half-time of about 10 h (James *et al.*, 1977). A rapid absorption phase was also observed following intranasal instillation of ionic ^{212}Pb into rats: about 8% with a half-time of about 15 min (Greenhalgh *et al.*, 1982). All these results are consistent with assignment to Type F. The results of studies in which $^{232}UO_2(NO_3)$ with its decay products (Ballou *et al.*, 1986), or thorium (^{228}Th) nitrate with its decay products (Moody and Stradling, 1992), when administered to rats by intratracheal injection, were consistent with assignment of the ^{212}Pb present to Type F. Measurements following inhalation of PbO by rats are consistent with assignment to Type F (Rhoads and Sanders, 1985).

(220) An absorption half-time of about 6 h, i.e. an absorption rate of about 2.5 d^{-1}, was reported following human inhalation of the automobile exhaust aerosol produced by combustion of ^{203}Pb-labelled leaded gasoline (Chamberlain *et al.*, 1975, 1978; Wells *et al.*, 1977). Using ^{210}Pb as the tracer, Boudene *et al.* (1977) reported a similar absorption half-time for the bulk of a combusted-gasoline aerosol inhaled by rats, with about 15% more rapid absorption (half-time $\leqslant 1$ h). All these results are consistent with assignment of lead in gasoline exhaust aerosols to Type F.

(221) A potentially important source of environmental intake of ^{210}Pb in particulate aerosol form arises from airborne mineral dusts containing the natural long-lived parent. In this case the absorption rate will be determined by the dissolution rate of the mineral matrix in lung fluids. Measurements of the *in vitro* dissolution of radionuclides in coal fly ash (Kalkwarf *et al.*, 1984) and calcined rock dust (Kalkwarf and Jackson, 1984) indicate Type M or S behaviour for the ^{210}Pb present, but were of insufficient duration to distinguish between the two.

Dose coefficients

(222) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (in Table 5.23.2) were derived using the f_1 values given in Table 5.23.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993) and Annexe C.

Table 5.23.1 Values of f_1 for inhaled particulate compounds of lead

	f_1[a]					
Absorption Type	3 mo	1 y	5 y	10 y	15 y	Adult
F	0.6	0.4	0.4	0.4	0.4	0.2
M[b]	0.2	0.1	0.1	0.1	0.1	0.1
S	0.02	0.01	0.01	0.01	0.01	0.01

[a] f_1 values for the adult are taken from Table 2. Those for children are derived according to the procedure described in Paragraph 14.
[b] Default Type M is recommended for use in the absence of specific information.

Table 5.23.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pb-210 (T½ = 22.3 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.4	0.4	0.4	0.4	0.2
Adrenals	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Bladder Wall	1.2E-06	7.5E-07	3.7E-07	2.7E-07	1.8E-07	1.2E-07
Bone Surface	4.9E-05	3.0E-05	2.3E-05	3.1E-05	4.6E-05	2.9E-05
Brain	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Breast	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
GI-Tract						
Oesophagus	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
St Wall	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
SI Wall	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
ULI Wall	1.2E-06	7.6E-07	3.8E-07	2.8E-07	1.9E-07	1.2E-07
LLI Wall	1.3E-06	8.0E-07	4.0E-07	2.9E-07	1.9E-07	1.2E-07
Colon	1.2E-06	7.8E-07	3.9E-07	2.8E-07	1.9E-07	1.2E-07
Kidneys	3.6E-05	2.3E-05	1.2E-05	1.1E-05	7.9E-06	4.9E-06
Liver	2.1E-05	1.3E-05	6.9E-06	5.9E-06	4.1E-06	2.5E-06
Muscle	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Ovaries	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Pancreas	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Red Marrow	1.8E-05	1.1E-05	5.5E-06	4.6E-06	4.0E-06	3.2E-06
Respiratory Tract						
ET Airways	1.2E-06	7.5E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Lungs	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Skin	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Spleen	3.9E-05	2.4E-05	1.3E-05	1.0E-05	6.8E-06	3.7E-06
Testes	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Thymus	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Thyroid	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Uterus	1.2E-06	7.4E-07	3.7E-07	2.7E-07	1.8E-07	1.1E-07
Remainder	1.8E-06	1.1E-06	5.8E-07	4.4E-07	3.0E-07	1.8E-07
Effective Dose	4.7E-06	2.9E-06	1.5E-06	1.4E-06	1.3E-06	9.0E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pb parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.23.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pb-210 (T½ = 22.3 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Bladder Wall	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.6E-08	6.5E-08
Bone Surface	1.8E-05	1.1E-05	8.6E-06	1.1E-05	1.8E-05	1.3E-05
Brain	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Breast	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
GI-Tract						
Oesophagus	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
St Wall	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
SI Wall	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
ULI Wall	5.1E-07	3.3E-07	1.8E-07	1.2E-07	8.8E-08	6.7E-08
LLI Wall	5.5E-07	3.5E-07	1.9E-07	1.3E-07	9.4E-08	7.1E-08
Colon	5.3E-07	3.4E-07	1.8E-07	1.3E-07	9.0E-08	6.9E-08
Kidneys	1.5E-05	9.7E-06	5.8E-06	4.6E-06	3.8E-06	2.8E-06
Liver	9.0E-06	5.8E-06	3.2E-06	2.6E-06	1.9E-06	1.4E-06
Muscle	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Ovaries	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Pancreas	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Red Marrow	7.5E-06	4.4E-06	2.5E-06	1.9E-06	1.7E-06	1.6E-06
Respiratory Tract						
ET Airways	2.1E-05	1.7E-05	7.6E-06	5.1E-06	2.9E-06	2.8E-06
Lungs	2.6E-05	2.2E-05	1.3E-05	8.3E-06	6.6E-06	5.5E-06
Skin	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Spleen	1.7E-05	1.1E-05	6.1E-06	4.5E-06	3.3E-06	2.2E-06
Testes	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Thymus	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Thyroid	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Uterus	5.0E-07	3.1E-07	1.7E-07	1.2E-07	8.5E-08	6.5E-08
Remainder	7.8E-07	4.9E-07	2.8E-07	2.0E-07	1.4E-07	1.1E-07
Effective Dose	5.0E-06	3.7E-06	2.2E-06	1.5E-06	1.3E-06	1.1E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pb parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.23.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pb-210 (T½ = 22.3 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Bladder Wall	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Bone Surface	1.8E-06	1.3E-06	1.2E-06	1.5E-06	2.0E-06	1.5E-06
Brain	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Breast	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
GI-Tract						
Oesophagus	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
St Wall	5.0E-08	3.5E-08	2.2E-08	1.5E-08	1.2E-08	1.0E-08
SI Wall	5.1E-08	3.6E-08	2.2E-08	1.5E-08	1.2E-08	1.1E-08
ULI Wall	6.4E-08	4.7E-08	2.8E-08	1.8E-08	1.4E-08	1.3E-08
LLI Wall	1.0E-07	7.4E-08	4.3E-08	2.7E-08	2.0E-08	1.8E-08
Colon	8.0E-08	5.9E-08	3.5E-08	2.2E-08	1.7E-08	1.5E-08
Kidneys	1.6E-06	1.1E-06	7.7E-07	5.9E-07	5.1E-07	4.5E-07
Liver	9.1E-07	6.5E-07	4.3E-07	3.2E-07	2.6E-07	2.3E-07
Muscle	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Ovaries	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Pancreas	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Red Marrow	7.2E-07	4.8E-07	3.1E-07	2.3E-07	2.1E-07	2.1E-07
Respiratory Tract						
ET Airways	1.5E-04	1.3E-04	6.8E-05	4.7E-05	2.9E-05	2.9E-05
Lungs	1.5E-04	1.5E-04	9.5E-05	5.9E-05	4.8E-05	4.6E-05
Skin	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Spleen	1.7E-06	1.2E-06	8.1E-07	5.7E-07	4.4E-07	3.6E-07
Testes	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Thymus	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Thyroid	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Uterus	4.9E-08	3.4E-08	2.1E-08	1.4E-08	1.2E-08	1.0E-08
Remainder	1.6E-07	1.1E-07	6.5E-08	4.6E-08	3.3E-08	3.1E-08
Effective Dose	1.8E-05	1.8E-05	1.1E-05	7.2E-06	5.9E-06	5.6E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pb parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.24. Polonium

(223) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned oxides, hydroxides and nitrates of polonium (Po) to inhalation Class W, and all other compounds of the element to Class D. These classifications were adopted by ICRP in *ICRP Publication 30*, Part 1 (ICRP, 1979).

(224) The default absorption parameter values given below are not appropriate for the short-lived decay products of polonium: ^{214}Po, ^{216}Po and ^{218}Po, which are outside the scope of this report; nor is the general purpose default AMAD of 1 μm for environmental exposure appropriate to assess their deposition.

Absorption Types

(225) Scott and West (1975) measured excretion of ^{210}Po in urine and faeces following the accidental inhalation by a worker of material from an unencapsulated ^{210}Po source (probably in the form of small particles of ^{210}Po oxide). Only about 3% of the estimated activity deposited in the respiratory tract was excreted in the urine: the bulk of the ^{210}Po activity being excreted in the faeces, indicative of Type M behaviour.

(226) Cohen *et al.* (1979a, 1979b) showed that the ^{210}Po that condenses with cigarette smoke tar is not readily soluble, and that it is retained in the alveolar interstitial tissue of cigarette smokers, indicative of Type M behaviour.

(227) Fractional lung retention of ^{210}Po was approximately 30% at 30 d after inhalation by rats of a NaCl aerosol carrying ^{210}Po as the chloride (Berke and DiPasqua, 1964; Casarett, 1964), and after intratracheal instillation into rats of ^{210}Po chloride in acid solution (Thomas and Stannard, 1964), consistent with assignment to Type M.

(228) Fractional lung retention of ^{210}Po was approximately 30% at 30 d after intratracheal instillation into rabbits of a ^{210}Po hydroxide colloid (Morrow and Della Rosa, 1964), consistent with assignment to Type M.

(229) A potentially important source of environmental intake of ^{210}Po in particulate aerosol form arises from airborne mineral dusts containing the natural long-lived parent. In this case the absorption rate will be determined by the dissolution rate of the mineral matrix in lung fluids. Measurements of the *in vitro* dissolution of radionuclides in coal fly ash (Kalkwarf *et al.*, 1984) and calcined rock dust (Kalkwarf and Jackson, 1984) indicate Type M or S behaviour for the ^{210}Po present, but were of insufficient duration to distinguish between the two.

Dose coefficients

(230) Dose coefficients (in Table 5.24.2) were derived using the f_1 values given in Table 5.24.1, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.24.1. Values of f_1 for inhaled particulate compounds of polonium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.2	0.1
M[b]	0.2	0.1
S	0.02	0.01

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type M is recommended for use in the absence of specific information.

Table 5.24.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Po-210 (T½ = 138 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Bladder Wall	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Bone Surface	2.3E-05	1.3E-05	4.5E-06	2.4E-06	1.4E-06	8.0E-07
Brain	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Breast	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
GI-Tract						
Oesophagus	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
St Wall	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
SI Wall	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
ULI Wall	1.7E-06	1.1E-06	5.0E-07	3.0E-07	1.7E-07	1.4E-07
LLI Wall	1.8E-06	1.2E-06	5.3E-07	3.2E-07	1.8E-07	1.5E-07
Colon	1.7E-06	1.1E-06	5.2E-07	3.1E-07	1.7E-07	1.5E-07
Kidneys	5.1E-05	3.4E-05	1.7E-05	1.1E-05	7.7E-06	6.4E-06
Liver	3.1E-05	2.2E-05	1.0E-05	6.6E-06	4.1E-06	3.3E-06
Muscle	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Ovaries	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Pancreas	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Red Marrow	2.3E-05	1.4E-05	6.1E-06	3.2E-06	1.8E-06	1.3E-06
Respiratory Tract						
ET Airways	1.6E-06	1.1E-06	5.0E-07	3.0E-07	1.7E-07	1.4E-07
Lungs	1.7E-06	1.1E-06	5.2E-07	3.1E-07	1.9E-07	1.6E-07
Skin	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Spleen	6.3E-05	4.2E-05	2.0E-05	1.3E-05	7.8E-06	5.5E-06
Testes	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Thymus	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Thyroid	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Uterus	1.6E-06	1.1E-06	4.9E-07	2.9E-07	1.7E-07	1.4E-07
Remainder	3.3E-05	2.2E-05	1.0E-05	6.5E-06	4.0E-06	3.3E-06
Effective Dose	7.4E-06	4.8E-06	2.2E-06	1.3E-06	7.7E-07	6.1E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.24.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Po-210 (T½ = 138 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Bladder Wall	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Bone Surface	8.9E-06	4.1E-06	1.5E-06	7.9E-07	4.6E-07	2.8E-07
Brain	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Breast	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
GI-Tract						
Oesophagus	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
St Wall	6.5E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
SI Wall	6.5E-07	3.5E-07	1.7E-07	9.8E-08	5.8E-08	5.0E-08
ULI Wall	7.1E-07	3.9E-07	1.8E-07	1.1E-07	6.3E-08	5.4E-08
LLI Wall	8.2E-07	4.7E-07	2.2E-07	1.3E-07	7.3E-08	6.2E-08
Colon	7.6E-07	4.3E-07	2.0E-07	1.2E-07	6.7E-08	5.7E-08
Kidneys	2.0E-05	1.1E-05	5.7E-06	3.8E-06	2.7E-06	2.2E-06
Liver	1.2E-05	7.1E-06	3.4E-06	2.2E-06	1.4E-06	1.2E-06
Muscle	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Ovaries	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Pancreas	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Red Marrow	9.1E-06	4.6E-06	2.1E-06	1.1E-06	6.3E-07	4.6E-07
Respiratory Tract						
ET Airways	3.2E-05	2.4E-05	9.9E-06	6.6E-06	3.6E-06	3.5E-06
Lungs	1.1E-04	8.1E-05	5.1E-05	3.5E-05	3.1E-05	2.6E-05
Skin	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Spleen	2.5E-05	1.4E-05	6.8E-06	4.2E-06	2.7E-06	1.9E-06
Testes	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Thymus	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Thyroid	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Uterus	6.4E-07	3.5E-07	1.6E-07	9.7E-08	5.7E-08	4.9E-08
Remainder	1.0E-06	5.6E-07	2.7E-07	1.6E-07	1.0E-07	8.4E-08
Effective Dose	1.5E-05	1.1E-05	6.7E-06	4.6E-06	4.0E-06	3.3E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

Table 5.24.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Po-210 (T½ = 138 d).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Bladder Wall	4.4E-08	1.9E-08	8.5E-09	5.1E-09	2.9E-09	2.4E-09
Bone Surface	6.1E-07	2.2E-07	7.7E-08	4.1E-08	2.3E-08	1.4E-08
Brain	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Breast	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
GI-Tract						
Oesophagus	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
St Wall	4.9E-08	2.1E-08	9.6E-09	5.7E-09	3.2E-09	2.7E-09
SI Wall	5.5E-08	2.6E-08	1.2E-08	7.0E-09	3.8E-09	3.2E-09
ULI Wall	1.1E-07	6.5E-08	2.8E-08	1.7E-08	8.6E-09	7.2E-09
LLI Wall	2.4E-07	1.5E-07	6.4E-08	3.9E-08	2.0E-08	1.6E-08
Colon	1.7E-07	1.0E-07	4.4E-08	2.6E-08	1.3E-08	1.1E-08
Kidneys	1.4E-06	5.9E-07	2.9E-07	2.0E-07	1.3E-07	1.1E-07
Liver	8.4E-07	3.8E-07	1.7E-07	1.2E-07	7.0E-08	5.7E-08
Muscle	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Ovaries	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Pancreas	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Red Marrow	6.2E-07	2.4E-07	1.1E-07	5.6E-08	3.1E-08	2.3E-08
Respiratory Tract						
ET Airways	5.7E-05	4.4E-05	1.9E-05	1.3E-05	7.1E-06	6.9E-06
Lungs	1.5E-04	1.1E-04	7.2E-05	4.9E-05	4.3E-05	3.5E-05
Skin	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Spleen	1.7E-06	7.2E-07	3.5E-07	2.2E-07	1.3E-07	9.6E-08
Testes	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Thymus	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Thyroid	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Uterus	4.4E-08	1.9E-08	8.5E-09	5.0E-09	2.8E-09	2.4E-09
Remainder	1.0E-07	4.8E-08	2.2E-08	1.4E-08	8.3E-09	7.5E-09
Effective Dose	1.8E-05	1.4E-05	8.6E-06	5.9E-06	5.1E-06	4.3E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

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5.25. Radium

(231) The ICRP Task Group on Lung Dynamics interpreted the data of Marinelli *et al.* (1953) as indicating a half-life of 180 d in the lungs for inhaled radium sulphate (TGLD, 1966). However, because this analysis did not take account of extrapulmonary deposits, and because re-analysis of the data indicated a somewhat more rapid clearance from the lungs, all commonly occurring compounds of radium (Ra) were assigned to inhalation Class W in *ICRP Publication 30*, Part 1 (ICRP, 1979).

Absorption Types

(232) The results of a study in which $^{232}UO_2(NO_3)$ with its decay products was administered to rats by intratracheal injection (Ballou *et al.*, 1986) were consistent with assignment of the ^{224}Ra present to Type F. The results of a study in which radium nitrate (alone or with thorium nitrate) was administered to rats by intratracheal injection, were consistent with assignment to Type F (Moody and Stradling, 1992).

(233) Looney and Archer (1956) reported a lung clearance half-time of 90 d following the inhalation of a mixture of radium and barium sulphate. In another case of human inhalation of radium, Toohey *et al.* (1984) reported a half-life of 120 d for lung clearance; however, the radium compound was unknown, and most likely highly insoluble, since the amount recovered in faecal excretion corresponded closely to the amount clearing from the lungs.

(234) Measurements of the *in vitro* dissolution of radionuclides in coal fly ash (Kalkwarf *et al.*, 1984) indicate Type M or S behaviour for the ^{226}Ra present, but were of insufficient duration to distinguish between the two.

Dose coefficients

(235) Dose coefficients (given in Tables 5.25.2–4) were derived using the f_1 values given in Table 5.25.1, and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993) and Annexe C. In addition, the escape from the body of radon formed as a decay product within the respiratory tract is included (Paragraph 75). For calculational purposes a rate of 100 d^{-1} is assumed for this process, in addition to the other routes of removal. This extends the approach adopted for ^{222}Rn following intakes of ^{226}Ra in *ICRP Publication 30*, Part 1.

Table 5.25.1. Values of f_1 for inhaled particulate compounds of radium

	f_1[a]					
Absorption Type	3 mo	1 y	5 y	10 y	15 y	Adult
F	0.6	0.3	0.3	0.3	0.3	0.2
M[b]	0.2	0.1	0.1	0.1	0.1	0.1
S	0.02	0.01	0.01	0.01	0.01	0.01

[a] f_1 values for the adult are taken from Table 2. Those for children are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.25.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-224 (T½ = 3.66 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.3	0.3	0.3	0.3	0.2
Adrenals	1.5E-07	9.7E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Bladder Wall	1.5E-07	9.7E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Bone Surface	5.9E-05	2.3E-05	1.3E-05	1.0E-05	7.9E-06	2.3E-06
Brain	1.4E-07	9.6E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Breast	1.4E-07	9.6E-08	4.4E-08	2.5E-08	1.2E-08	1.2E-08
GI-Tract						
Oesophagus	1.5E-07	9.6E-08	4.4E-08	2.5E-08	1.2E-08	1.2E-08
St Wall	1.5E-07	1.0E-07	4.5E-08	2.6E-08	1.3E-08	1.3E-08
SI Wall	1.5E-07	1.0E-07	4.7E-08	2.6E-08	1.3E-08	1.3E-08
ULI Wall	2.8E-07	2.5E-07	1.1E-07	6.0E-08	2.6E-08	3.2E-08
LLI Wall	5.2E-07	5.2E-07	2.4E-07	1.2E-07	5.1E-08	7.0E-08
Colon	3.8E-07	3.7E-07	1.7E-07	8.7E-08	3.6E-08	4.8E-08
Kidneys	7.2E-07	3.5E-07	1.6E-07	1.2E-07	8.3E-08	4.0E-08
Liver	5.2E-07	4.4E-07	2.1E-07	1.2E-07	5.6E-08	6.8E-08
Muscle	1.5E-07	9.6E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Ovaries	1.4E-07	9.6E-08	4.3E-08	2.4E-08	1.2E-08	1.2E-08
Pancreas	1.5E-07	9.6E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Red Marrow	6.1E-06	1.7E-06	7.2E-07	6.2E-07	5.3E-07	2.2E-07
Respiratory Tract						
ET Airways	1.7E-05	1.1E-05	4.7E-06	3.1E-06	1.7E-06	1.7E-06
Lungs	3.9E-07	2.8E-07	1.6E-07	1.1E-07	1.0E-07	8.1E-08
Skin	1.4E-07	9.6E-08	4.4E-08	2.5E-08	1.2E-08	1.2E-08
Spleen	1.5E-07	9.6E-08	4.4E-08	2.4E-08	1.2E-08	1.2E-08
Testes	1.5E-07	9.5E-08	4.3E-08	2.4E-08	1.2E-08	1.2E-08
Thymus	1.5E-07	9.6E-08	4.4E-08	2.5E-08	1.2E-08	1.2E-08
Thyroid	1.4E-07	9.6E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Uterus	1.5E-07	9.7E-08	4.4E-08	2.5E-08	1.3E-08	1.2E-08
Remainder	1.6E-07	1.0E-07	4.7E-08	2.7E-08	1.4E-08	1.3E-08
Effective Dose	1.5E-06	6.0E-07	2.9E-07	2.2E-07	1.7E-07	7.5E-08

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-224 (T½ = 3.66 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	4.1E-08	2.2E-08	9.6E-09	5.4E-09	2.7E-09	2.7E-09
Bladder Wall	4.1E-08	2.2E-08	9.5E-09	5.5E-09	2.7E-09	2.7E-09
Bone Surface	1.5E-05	4.3E-06	2.3E-06	1.9E-06	1.4E-06	4.1E-07
Brain	4.0E-08	2.1E-08	9.3E-09	5.3E-09	2.6E-09	2.6E-09
Breast	4.1E-08	2.1E-08	9.5E-09	5.5E-09	2.7E-09	2.7E-09
GI-Tract						
Oesophagus	4.1E-08	2.2E-08	9.6E-09	5.5E-09	2.7E-09	2.7E-09
St Wall	5.6E-08	3.0E-08	1.3E-08	7.4E-09	3.8E-09	3.5E-09
SI Wall	6.4E-08	3.9E-08	1.7E-08	9.8E-09	4.7E-09	4.3E-09
ULI Wall	2.6E-07	1.9E-07	7.8E-08	4.6E-08	2.1E-08	1.9E-08
LLI Wall	6.6E-07	4.7E-07	2.0E-07	1.2E-07	5.4E-08	5.0E-08
Colon	4.3E-07	3.1E-07	1.3E-07	7.7E-08	3.5E-08	3.2E-08
Kidneys	2.1E-07	8.6E-08	3.9E-08	2.8E-08	1.8E-08	1.1E-08
Liver	1.4E-07	9.0E-08	4.1E-08	2.4E-08	1.1E-08	1.4E-08
Muscle	4.1E-08	2.1E-08	9.4E-09	5.4E-09	2.6E-09	2.6E-09
Ovaries	4.1E-08	2.2E-08	9.6E-09	5.5E-09	2.7E-09	2.7E-09
Pancreas	4.1E-08	2.2E-08	9.5E-09	5.4E-09	2.7E-09	2.6E-09
Red Marrow	1.5E-06	3.3E-07	1.3E-07	1.1E-07	9.3E-08	4.0E-08
Respiratory Tract						
ET Airways	2.6E-05	1.7E-05	7.2E-06	4.8E-06	2.6E-06	2.5E-06
Lungs	9.0E-05	6.7E-05	4.3E-05	3.2E-05	3.1E-05	2.5E-05
Skin	4.0E-08	2.1E-08	9.3E-09	5.3E-09	2.6E-09	2.6E-09
Spleen	4.1E-08	2.1E-08	9.5E-09	5.4E-09	2.7E-09	2.6E-09
Testes	4.1E-08	2.1E-08	9.1E-09	5.2E-09	2.5E-09	2.5E-09
Thymus	4.1E-08	2.2E-08	9.6E-09	5.5E-09	2.7E-09	2.7E-09
Thyroid	4.1E-08	2.1E-08	9.4E-09	5.3E-09	2.6E-09	2.6E-09
Uterus	4.1E-08	2.2E-08	9.5E-09	5.4E-09	2.6E-09	2.6E-09
Remainder	5.7E-08	3.0E-08	1.3E-08	7.9E-09	4.1E-09	4.0E-09
Effective Dose	1.1E-05	8.2E-06	5.3E-06	3.9E-06	3.7E-06	3.0E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-224 (T½ = 3.66 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	8.8E-09	5.2E-09	2.3E-09	1.3E-09	6.8E-10	6.1E-10
Bladder Wall	8.7E-09	5.1E-09	2.1E-09	1.3E-09	6.1E-10	5.6E-10
Bone Surface	1.1E-06	2.7E-07	1.4E-07	1.1E-07	7.7E-08	2.4E-08
Brain	8.2E-09	4.7E-09	2.0E-09	1.2E-09	5.5E-10	5.1E-10
Breast	8.7E-09	5.1E-09	2.3E-09	1.4E-09	6.6E-10	6.1E-10
GI-Tract						
Oesophagus	8.9E-09	5.3E-09	2.3E-09	1.4E-09	7.0E-10	6.4E-10
St Wall	2.5E-08	1.4E-08	5.8E-09	3.4E-09	1.8E-09	1.5E-09
SI Wall	3.9E-08	2.5E-08	1.1E-08	6.4E-09	3.0E-09	2.5E-09
ULI Wall	2.7E-07	1.8E-07	7.3E-08	4.4E-08	2.0E-08	1.7E-08
LLI Wall	7.3E-07	4.7E-07	2.0E-07	1.2E-07	5.6E-08	4.7E-08
Colon	4.7E-07	3.1E-07	1.3E-07	7.7E-08	3.6E-08	3.0E-08
Kidneys	3.7E-08	2.1E-08	9.3E-09	5.9E-09	3.2E-09	3.0E-09
Liver	2.1E-08	1.3E-08	5.7E-09	3.4E-09	1.6E-09	1.7E-09
Muscle	8.6E-09	5.0E-09	2.1E-09	1.3E-09	6.2E-10	5.6E-10
Ovaries	9.6E-09	5.8E-09	2.5E-09	1.5E-09	7.6E-10	6.7E-10
Pancreas	8.8E-09	5.2E-09	2.2E-09	1.3E-09	6.6E-10	5.9E-10
Red Marrow	1.2E-07	2.4E-08	9.5E-09	7.8E-09	5.6E-09	2.7E-09
Respiratory Tract						
ET Airways	2.7E-05	1.8E-05	7.5E-06	5.0E-06	2.7E-06	2.7E-06
Lungs	1.0E-04	7.6E-05	4.9E-05	3.7E-05	3.5E-05	2.8E-05
Skin	8.3E-09	4.8E-09	2.0E-09	1.2E-09	5.7E-10	5.3E-10
Spleen	8.7E-09	5.1E-09	2.2E-09	1.3E-09	6.5E-10	5.9E-10
Testes	8.4E-09	4.8E-09	2.0E-09	1.2E-09	5.5E-10	5.1E-10
Thymus	8.9E-09	5.3E-09	2.3E-09	1.4E-09	7.0E-10	6.4E-10
Thyroid	8.4E-09	4.9E-09	2.1E-09	1.2E-09	6.0E-10	5.5E-10
Uterus	8.9E-09	5.3E-09	2.2E-09	1.3E-09	6.3E-10	5.7E-10
Remainder	2.4E-08	1.3E-08	5.7E-09	3.7E-09	2.0E-09	1.9E-09
Effective Dose	1.2E-05	9.2E-06	5.9E-06	4.4E-06	4.2E-06	3.4E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-226 (T½ = 1.60E+03 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.3	0.3	0.3	0.3	0.2
Adrenals	3.0E-07	2.1E-07	1.2E-07	8.2E-08	7.1E-08	5.3E-08
Bladder Wall	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.4E-08	5.2E-08
Bone Surface	9.1E-05	2.9E-05	2.1E-05	3.5E-05	8.2E-05	1.6E-05
Brain	2.9E-07	2.1E-07	1.2E-07	8.2E-08	7.0E-08	5.3E-08
Breast	2.9E-07	2.1E-07	1.2E-07	7.9E-08	6.3E-08	5.2E-08
GI-Tract						
Oesophagus	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.5E-08	5.2E-08
St Wall	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.4E-08	5.2E-08
SI Wall	3.0E-07	2.2E-07	1.2E-07	8.1E-08	6.6E-08	5.3E-08
ULI Wall	3.9E-07	2.8E-07	1.5E-07	9.8E-08	7.4E-08	6.0E-08
LLI Wall	7.0E-07	5.1E-07	2.5E-07	1.6E-07	1.1E-07	8.7E-08
Colon	5.3E-07	3.8E-07	1.9E-07	1.2E-07	8.9E-08	7.2E-08
Kidneys	3.9E-07	2.5E-07	1.5E-07	1.4E-07	2.1E-07	7.7E-08
Liver	2.1E-06	1.5E-06	7.1E-07	4.8E-07	3.4E-07	2.3E-07
Muscle	2.9E-07	2.1E-07	1.2E-07	8.1E-08	6.7E-08	5.2E-08
Ovaries	3.0E-07	2.2E-07	1.3E-07	9.0E-08	6.6E-08	5.3E-08
Pancreas	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.6E-08	5.2E-08
Red Marrow	1.1E-05	3.0E-06	1.6E-06	2.2E-06	3.6E-06	1.1E-06
Respiratory Tract						
ET Airways	3.3E-07	2.4E-07	1.3E-07	8.6E-08	7.0E-08	5.6E-08
Lungs	3.5E-07	2.6E-07	1.5E-07	1.0E-07	8.4E-08	6.7E-08
Skin	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.5E-08	5.2E-08
Spleen	3.7E-07	2.4E-07	1.4E-07	1.3E-07	1.7E-07	6.9E-08
Testes	3.1E-07	2.2E-07	1.4E-07	1.2E-07	6.6E-08	5.2E-08
Thymus	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.5E-08	5.2E-08
Thyroid	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.7E-08	5.2E-08
Uterus	2.9E-07	2.1E-07	1.2E-07	8.0E-08	6.5E-08	5.2E-08
Remainder	3.0E-07	2.1E-07	1.2E-07	8.2E-08	6.9E-08	5.3E-08
Effective Dose	2.6E-06	9.4E-07	5.5E-07	7.2E-07	1.3E-06	3.6E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-226 (T½ = 1.60E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.2E-07	8.0E-08	4.8E-08	3.3E-08	3.0E-08	2.4E-08
Bladder Wall	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.7E-08	2.4E-08
Bone Surface	3.3E-05	1.1E-05	8.5E-06	1.5E-05	3.5E-05	7.4E-06
Brain	1.2E-07	8.0E-08	4.8E-08	3.2E-08	3.0E-08	2.4E-08
Breast	1.2E-07	8.0E-08	4.8E-08	3.1E-08	2.7E-08	2.4E-08
GI-Tract						
Oesophagus	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.8E-08	2.4E-08
St Wall	1.2E-07	8.2E-08	4.9E-08	3.2E-08	2.8E-08	2.4E-08
SI Wall	1.3E-07	8.6E-08	5.0E-08	3.3E-08	2.9E-08	2.4E-08
ULI Wall	2.2E-07	1.5E-07	7.9E-08	5.0E-08	3.7E-08	3.2E-08
LLI Wall	5.5E-07	3.8E-07	1.8E-07	1.1E-07	7.0E-08	5.9E-08
Colon	3.6E-07	2.5E-07	1.2E-07	7.7E-08	5.2E-08	4.4E-08
Kidneys	1.5E-07	9.2E-08	5.9E-08	5.8E-08	8.9E-08	3.5E-08
Liver	8.4E-07	5.6E-07	2.8E-07	1.9E-07	1.5E-07	1.1E-07
Muscle	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.9E-08	2.4E-08
Ovaries	1.2E-07	8.3E-08	5.1E-08	3.6E-08	2.8E-08	2.4E-08
Pancreas	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.8E-08	2.4E-08
Red Marrow	3.9E-06	1.1E-06	6.7E-07	9.1E-07	1.5E-06	5.2E-07
Respiratory Tract						
ET Airways	4.9E-05	3.8E-05	1.6E-05	1.1E-05	6.1E-06	6.0E-06
Lungs	1.2E-04	9.1E-05	5.7E-05	3.8E-05	3.3E-05	2.8E-05
Skin	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.8E-08	2.4E-08
Spleen	1.5E-07	9.1E-08	5.8E-08	5.2E-08	7.1E-08	3.2E-08
Testes	1.2E-07	8.4E-08	5.5E-08	4.8E-08	2.8E-08	2.4E-08
Thymus	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.8E-08	2.4E-08
Thyroid	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.8E-08	2.4E-08
Uterus	1.2E-07	8.0E-08	4.8E-08	3.2E-08	2.8E-08	2.4E-08
Remainder	1.4E-07	9.6E-08	5.5E-08	3.8E-08	3.2E-08	2.7E-08
Effective Dose	1.5E-05	1.1E-05	7.0E-06	4.9E-06	4.5E-06	3.5E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-226 (T½ = 1.60E+03 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	1.2E-08	8.1E-09	5.4E-09	4.0E-09	3.8E-09	3.4E-09
Bladder Wall	1.1E-08	7.8E-09	5.1E-09	3.7E-09	3.4E-09	3.2E-09
Bone Surface	3.0E-06	1.5E-06	1.6E-06	2.2E-06	3.2E-06	9.5E-07
Brain	1.1E-08	7.6E-09	5.1E-09	3.8E-09	3.6E-09	3.2E-09
Breast	1.1E-08	8.0E-09	5.3E-09	3.8E-09	3.5E-09	3.3E-09
GI-Tract						
Oesophagus	1.1E-08	8.0E-09	5.4E-09	3.9E-09	3.6E-09	3.4E-09
St Wall	1.6E-08	1.1E-08	6.4E-09	4.5E-09	3.9E-09	3.6E-09
SI Wall	2.3E-08	1.6E-08	8.6E-09	5.8E-09	4.6E-09	4.1E-09
ULI Wall	1.1E-07	7.6E-08	3.6E-08	2.2E-08	1.3E-08	1.1E-08
LLI Wall	4.4E-07	3.0E-07	1.4E-07	8.1E-08	4.5E-08	3.9E-08
Colon	2.5E-07	1.7E-07	7.9E-08	4.8E-08	2.7E-08	2.3E-08
Kidneys	1.5E-08	1.0E-08	7.8E-09	7.8E-09	8.9E-09	4.8E-09
Liver	7.5E-08	5.0E-08	3.0E-08	2.1E-08	1.7E-08	1.4E-08
Muscle	1.1E-08	7.8E-09	5.2E-09	3.8E-09	3.6E-09	3.3E-09
Ovaries	1.2E-08	8.5E-09	5.6E-09	4.2E-09	3.6E-09	3.3E-09
Pancreas	1.1E-08	8.0E-09	5.3E-09	3.8E-09	3.6E-09	3.3E-09
Red Marrow	3.2E-07	1.2E-07	1.0E-07	1.2E-07	1.4E-07	7.0E-08
Respiratory Tract						
ET Airways	2.1E-04	1.7E-04	8.6E-05	5.9E-05	3.6E-05	3.6E-05
Lungs	2.8E-04	2.4E-04	1.6E-04	1.0E-04	8.7E-05	7.9E-05
Skin	1.1E-08	7.7E-09	5.1E-09	3.7E-09	3.4E-09	3.2E-09
Spleen	1.4E-08	9.8E-09	7.3E-09	6.8E-09	7.4E-09	4.4E-09
Testes	1.2E-08	8.3E-09	6.1E-09	4.9E-09	3.4E-09	3.2E-09
Thymus	1.1E-08	8.0E-09	5.4E-09	3.9E-09	3.6E-09	3.4E-09
Thyroid	1.1E-08	7.8E-09	5.2E-09	3.8E-09	3.5E-09	3.2E-09
Uterus	1.1E-08	7.8E-09	5.1E-09	3.7E-09	3.4E-09	3.2E-09
Remainder	1.2E-07	8.1E-08	4.4E-08	3.1E-08	2.1E-08	2.1E-08
Effective Dose	3.4E-05	2.9E-05	1.9E-05	1.2E-05	1.0E-05	9.5E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-228 (T½ = 5.75 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.6	0.3	0.3	0.3	0.3	0.2
Adrenals	2.1E-06	1.0E-06	5.3E-07	4.2E-07	4.4E-07	2.0E-07
Bladder Wall	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Bone Surface	4.8E-04	1.6E-04	1.0E-04	1.3E-04	2.0E-04	2.9E-05
Brain	2.1E-06	9.9E-07	5.3E-07	4.2E-07	4.3E-07	2.0E-07
Breast	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.2E-07	2.0E-07
GI-Tract						
Oesophagus	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
St Wall	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
SI Wall	2.1E-06	1.0E-06	5.3E-07	4.2E-07	4.3E-07	2.0E-07
ULI Wall	2.6E-06	1.2E-06	6.1E-07	4.8E-07	5.3E-07	2.2E-07
LLI Wall	3.6E-06	1.5E-06	7.6E-07	6.1E-07	7.3E-07	2.6E-07
Colon	3.0E-06	1.3E-06	6.8E-07	5.3E-07	6.2E-07	2.4E-07
Kidneys	1.2E-05	4.2E-06	2.2E-06	2.3E-06	3.0E-06	5.6E-07
Liver	2.4E-05	9.7E-06	4.9E-06	4.2E-06	4.7E-06	1.4E-06
Muscle	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Ovaries	4.0E-06	1.7E-06	1.0E-06	1.0E-06	1.1E-06	2.7E-07
Pancreas	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Red Marrow	7.1E-05	2.2E-05	1.1E-05	1.2E-05	1.5E-05	3.0E-06
Respiratory Tract						
ET Airways	2.1E-06	1.0E-06	5.4E-07	4.2E-07	4.3E-07	2.0E-07
Lungs	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Skin	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Spleen	2.0E-06	9.7E-07	5.2E-07	4.1E-07	4.2E-07	1.9E-07
Testes	4.4E-06	1.8E-06	1.2E-06	1.5E-06	1.2E-06	2.7E-07
Thymus	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Thyroid	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Uterus	2.1E-06	9.9E-07	5.3E-07	4.1E-07	4.3E-07	2.0E-07
Remainder	2.2E-06	1.0E-06	5.5E-07	4.4E-07	4.6E-07	2.0E-07
Effective Dose	1.7E-05	5.7E-06	3.1E-06	3.6E-06	4.6E-06	9.0E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-228 (T½ = 5.75 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.2	0.1	0.1	0.1	0.1	0.1
Adrenals	1.2E-06	7.6E-07	4.4E-07	2.9E-07	2.8E-07	2.1E-07
Bladder Wall	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
Bone Surface	2.7E-04	1.6E-04	1.2E-04	1.1E-04	1.3E-04	5.6E-05
Brain	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
Breast	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
GI-Tract						
Oesophagus	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
St Wall	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
SI Wall	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
ULI Wall	1.5E-06	9.5E-07	5.4E-07	3.5E-07	3.4E-07	2.6E-07
LLI Wall	2.1E-06	1.3E-06	7.5E-07	4.6E-07	4.8E-07	3.8E-07
Colon	1.8E-06	1.1E-06	6.3E-07	4.0E-07	4.0E-07	3.1E-07
Kidneys	8.0E-06	4.9E-06	3.0E-06	2.2E-06	2.3E-06	1.4E-06
Liver	1.5E-05	9.2E-06	5.3E-06	3.6E-06	3.4E-06	2.4E-06
Muscle	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
Ovaries	2.4E-06	1.6E-06	1.2E-06	9.3E-07	8.5E-07	5.0E-07
Pancreas	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
Red Marrow	4.2E-05	2.4E-05	1.4E-05	1.0E-05	1.0E-05	4.7E-06
Respiratory Tract						
ET Airways	3.1E-05	2.5E-05	1.2E-05	7.9E-06	4.6E-06	4.4E-06
Lungs	4.2E-05	3.6E-05	2.2E-05	1.4E-05	1.2E-05	9.7E-06
Skin	1.2E-06	7.5E-07	4.4E-07	2.8E-07	2.7E-07	2.0E-07
Spleen	1.2E-06	7.4E-07	4.3E-07	2.8E-07	2.7E-07	2.0E-07
Testes	2.7E-06	1.8E-06	1.3E-06	1.4E-06	9.7E-07	5.0E-07
Thymus	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
Thyroid	1.2E-06	7.5E-07	4.4E-07	2.9E-07	2.7E-07	2.0E-07
Uterus	1.2E-06	7.5E-07	4.4E-07	2.8E-07	2.7E-07	2.0E-07
Remainder	1.3E-06	8.1E-07	4.7E-07	3.1E-07	3.0E-07	2.2E-07
Effective Dose	1.5E-05	1.0E-05	6.3E-06	4.6E-06	4.4E-06	2.6E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.25.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Ra-228 (T½ = 5.75 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.01	0.01	0.01	0.01	0.01
Adrenals	2.3E-07	1.9E-07	1.3E-07	8.3E-08	7.8E-08	8.0E-08
Bladder Wall	1.8E-07	1.5E-07	9.5E-08	6.3E-08	6.2E-08	6.4E-08
Bone Surface	5.0E-05	4.4E-05	3.4E-05	2.7E-05	2.7E-05	2.2E-05
Brain	1.8E-07	1.5E-07	9.5E-08	6.3E-08	6.2E-08	6.4E-08
Breast	2.2E-07	1.9E-07	1.3E-07	8.4E-08	7.8E-08	8.0E-08
GI-Tract						
Oesophagus	2.2E-07	1.9E-07	1.3E-07	8.5E-08	8.1E-08	8.3E-08
St Wall	2.0E-07	1.7E-07	1.1E-07	7.3E-08	7.1E-08	7.2E-08
SI Wall	1.9E-07	1.6E-07	1.0E-07	6.6E-08	6.4E-08	6.6E-08
ULI Wall	2.8E-07	2.3E-07	1.4E-07	9.0E-08	8.8E-08	9.4E-08
LLI Wall	4.6E-07	3.7E-07	2.2E-07	1.4E-07	1.4E-07	1.5E-07
Colon	3.6E-07	2.9E-07	1.7E-07	1.1E-07	1.1E-07	1.2E-07
Kidneys	1.4E-06	1.2E-06	8.4E-07	6.1E-07	6.0E-07	6.0E-07
Liver	2.4E-06	2.0E-06	1.3E-06	9.0E-07	8.8E-07	9.2E-07
Muscle	2.0E-07	1.6E-07	1.1E-07	7.0E-08	6.8E-08	7.0E-08
Ovaries	4.7E-07	4.3E-07	3.4E-07	2.3E-07	2.1E-07	1.9E-07
Pancreas	2.1E-07	1.8E-07	1.2E-07	7.7E-08	7.4E-08	7.5E-08
Red Marrow	6.8E-06	5.6E-06	3.7E-06	2.5E-06	2.1E-06	1.7E-06
Respiratory Tract						
ET Airways	3.4E-04	3.0E-04	1.6E-04	1.1E-04	7.0E-05	7.0E-05
Lungs	3.9E-04	3.9E-04	2.6E-04	1.6E-04	1.3E-04	1.3E-04
Skin	1.9E-07	1.6E-07	1.0E-07	6.6E-08	6.4E-08	6.7E-08
Spleen	2.1E-07	1.8E-07	1.1E-07	7.6E-08	7.3E-08	7.4E-08
Testes	5.2E-07	4.8E-07	4.0E-07	3.4E-07	2.2E-07	1.9E-07
Thymus	2.2E-07	1.9E-07	1.3E-07	8.5E-08	8.1E-08	8.3E-08
Thyroid	2.0E-07	1.7E-07	1.1E-07	7.0E-08	6.8E-08	7.0E-08
Uterus	1.8E-07	1.5E-07	9.6E-08	6.3E-08	6.2E-08	6.4E-08
Remainder	3.9E-07	3.0E-07	1.8E-07	1.3E-07	1.1E-07	1.1E-07
Effective Dose	4.9E-05	4.8E-05	3.2E-05	2.0E-05	1.6E-05	1.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Ra parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.26. Thorium

(236) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides, oxides and hydroxides of thorium (Th) to inhalation Class Y, and nitrates to Class W. By default, other unspecified compounds were assigned to Class D (see Paragraph 54). *ICRP Publication 30*, Part 1 (ICRP, 1979) endorsed the assignment of oxides and hydroxides to Class Y, citing experiments in which beagles inhaled ThO_2 (Ballou and Hursh, 1972), in support. All other compounds of thorium were assigned to Class W, on the basis of experiments on the inhalation of $ThCl_4$ by rats (Boecker *et al.*, 1963). Industrial hygiene aspects of thorium were reviewed by Albert (1966).

Absorption Types

(237) Measurements of thorium following intratracheal instillation into rats as the citrate (Thomas *et al.*, 1963) indicate Type F behaviour at tracer level and Type M when administered with carrier. The results of experiments in which rats inhaled thorium citrate or chloride (Boecker, 1963; Boecker *et al.*, 1963) indicate Type M behaviour. For the chloride, no effect of mass on lung clearance was observed.

(238) Measurements following intratracheal instillation into rats of thorium sulphate (Scott *et al.*, 1952) indicate Type M behaviour.

(239) Following intratracheal instillation into rats of thorium fluoride, hydroxide and nitrate, substantial fractions were retained in the lungs for periods of months, with retention times increasing with the mass deposited in the lung, (Stradling *et al.*, 1991, 1993; Moody *et al.*, 1994). Results for the nitrate and hydroxide indicate Type M behaviour. Results for the fluoride indicate Type M behaviour at low mass levels and Type S at higher levels.

(240) Following accidental inhalation of ^{228}Th oxide by one person (Newton *et al.*, 1981) monitoring data indicate either Type M or S behaviour. The results of experiments in which dogs inhaled ThO_2 (Ballou and Hursh, 1972) indicate Type M or S behaviour, but were of insufficient duration to distinguish between the two.

(241) Measurements of thorium decay products in the chest and exhaled air of former thorium refinery workers, made 3 or more years after the end of exposure to a range of compounds from monazite ore to thorium nitrate, indicate Type S behaviour for at least some of the material (Rundo *et al.*, 1981). Analysis of tissues from one worker at autopsy 30 years post exposure showed an excess concentration of thorium in lung and lymph nodes, also indicating Type S behaviour (Mausner, 1982). Excess concentrations of thorium in the lungs and lymph nodes were also found in autopsy tissues from retired uranium miners and millers by Singh *et al.*, (1987). There is also experimental evidence that thorium present in uranium ore dust is retained in the lungs longer than other constituents of the particle matrix (Stuart and Jackson, 1974, 1975; Singh *et al.*, 1986).

(242) Measurements of environmental levels of thorium in autopsy tissues from members of the public showed that the fraction of thorium in the lungs ($\sim$25% of the estimated total body content) was considerably greater than that of plutonium ($\sim$5%), and suggested a long term lung retention half-time for thorium of between 1 and 8 years (Wrenn *et al.*, 1981; Singh and Wrenn, 1983). These results indicate that environmental thorium is inhaled mainly in insoluble forms.

Dose coefficients

(243) Studies of common chemical forms showing characteristics of absorption Types M and S have been found in the literature. A default Type S is recommended for use in the

absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.26.2–5) were derived for the f_1 values given in Table 5.26.1, and the biokinetic data given in *ICRP Publication 69* (ICRP, 1995) and Annexe C. In addition, the escape from the body of radon formed as a decay product within the respiratory tract is included (Paragraph 75). For calculational purposes a rate of 100 d^{-1} is assumed for this process, in addition to the other routes of removal. This extends the approach adopted for ^{222}Rn following intakes of ^{226}Ra in *ICRP Publication 30*, Part 1.

Table 5.26.1. Values of f_1 for inhaled particulate compounds of thorium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.005	5×10^{-4}
M	0.005	5×10^{-4}
S[b]	0.005	5×10^{-4}

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[b] Default Type S is recommended for use in the absence of specific information.

Table 5.26.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-228 (T½ = 1.91 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Bladder Wall	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Bone Surface	4.3E-03	3.9E-03	2.7E-03	1.8E-03	1.4E-03	1.2E-03
Brain	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Breast	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
GI-Tract						
Oesophagus	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
St Wall	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
SI Wall	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
ULI Wall	2.4E-05	2.0E-05	1.0E-05	5.5E-06	3.5E-06	4.5E-06
LLI Wall	3.3E-05	2.9E-05	1.5E-05	7.6E-06	4.7E-06	7.0E-06
Colon	2.8E-05	2.4E-05	1.2E-05	6.4E-06	4.0E-06	5.6E-06
Kidneys	1.6E-04	1.3E-04	6.8E-05	4.3E-05	3.0E-05	3.1E-05
Liver	2.9E-04	2.3E-04	1.2E-04	6.8E-05	4.3E-05	4.9E-05
Muscle	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Ovaries	3.6E-05	3.3E-05	2.5E-05	1.7E-05	1.1E-05	9.7E-06
Pancreas	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Red Marrow	8.4E-04	6.5E-04	3.3E-04	1.9E-04	1.2E-04	9.1E-05
Respiratory Tract						
ET Airways	2.2E-05	1.8E-05	8.7E-06	5.0E-06	3.1E-06	3.5E-06
Lungs	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Skin	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Spleen	1.9E-05	1.6E-05	7.8E-06	4.3E-06	2.8E-06	3.2E-06
Testes	4.0E-05	3.9E-05	2.6E-05	2.1E-05	1.5E-05	9.8E-06
Thymus	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Thyroid	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Uterus	1.9E-05	1.6E-05	7.9E-06	4.4E-06	2.8E-06	3.2E-06
Remainder	2.1E-05	1.7E-05	8.6E-06	4.8E-06	3.1E-06	3.5E-06
Effective Dose	1.8E-04	1.5E-04	8.3E-05	5.2E-05	3.6E-05	2.9E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-228 (T½ = 1.91 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	5.2E-06	4.5E-06	2.5E-06	1.4E-06	9.7E-07	1.1E-06
Bladder Wall	5.2E-06	4.5E-06	2.5E-06	1.4E-06	9.7E-07	1.1E-06
Bone Surface	1.2E-03	1.1E-03	8.7E-04	5.7E-04	4.7E-04	4.2E-04
Brain	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
Breast	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
GI-Tract						
Oesophagus	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
St Wall	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
SI Wall	5.2E-06	4.5E-06	2.5E-06	1.4E-06	9.6E-07	1.1E-06
ULI Wall	6.7E-06	5.9E-06	3.3E-06	1.7E-06	1.2E-06	1.6E-06
LLI Wall	9.6E-06	8.6E-06	4.8E-06	2.4E-06	1.7E-06	2.5E-06
Colon	7.9E-06	7.1E-06	3.9E-06	2.0E-06	1.4E-06	2.0E-06
Kidneys	4.3E-05	3.6E-05	2.1E-05	1.3E-05	1.0E-05	1.1E-05
Liver	7.7E-05	6.5E-05	3.6E-05	2.1E-05	1.5E-05	1.7E-05
Muscle	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
Ovaries	9.8E-06	9.6E-06	8.0E-06	5.4E-06	3.8E-06	3.4E-06
Pancreas	5.2E-06	4.5E-06	2.5E-06	1.4E-06	9.6E-07	1.1E-06
Red Marrow	2.2E-04	1.9E-04	1.0E-04	5.9E-05	4.2E-05	3.2E-05
Respiratory Tract						
ET Airways	2.3E-04	1.8E-04	7.7E-05	5.2E-05	2.9E-05	2.8E-05
Lungs	7.1E-04	5.6E-04	3.5E-04	2.5E-04	2.2E-04	1.8E-04
Skin	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
Spleen	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.7E-07	1.1E-06
Testes	1.1E-05	1.1E-05	8.3E-06	7.1E-06	5.0E-06	3.5E-06
Thymus	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
Thyroid	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
Uterus	5.2E-06	4.5E-06	2.5E-06	1.3E-06	9.6E-07	1.1E-06
Remainder	5.8E-06	5.0E-06	2.7E-06	1.5E-06	1.1E-06	1.2E-06
Effective Dose	1.3E-04	1.1E-04	6.8E-05	4.6E-05	3.9E-05	3.2E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-228 (T½ = 1.91 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	3.7E-07	2.4E-07	1.4E-07	7.9E-08	6.3E-08	7.3E-08
Bladder Wall	3.4E-07	2.1E-07	1.3E-07	6.9E-08	5.5E-08	6.6E-08
Bone Surface	8.1E-05	5.8E-05	4.5E-05	3.0E-05	2.6E-05	2.4E-05
Brain	3.4E-07	2.1E-07	1.3E-07	6.9E-08	5.5E-08	6.6E-08
Breast	3.6E-07	2.4E-07	1.4E-07	8.1E-08	6.3E-08	7.3E-08
GI-Tract						
Oesophagus	3.6E-07	2.4E-07	1.4E-07	8.0E-08	6.4E-08	7.4E-08
St Wall	3.6E-07	2.3E-07	1.4E-07	7.6E-08	6.0E-08	7.0E-08
SI Wall	3.7E-07	2.3E-07	1.3E-07	7.4E-08	5.8E-08	6.8E-08
ULI Wall	6.1E-07	4.0E-07	2.2E-07	1.2E-07	8.9E-08	1.1E-07
LLI Wall	1.2E-06	8.3E-07	4.4E-07	2.4E-07	1.6E-07	2.0E-07
Colon	8.8E-07	5.9E-07	3.1E-07	1.7E-07	1.2E-07	1.5E-07
Kidneys	2.8E-06	1.7E-06	1.1E-06	6.9E-07	5.7E-07	6.3E-07
Liver	5.0E-06	3.1E-06	1.8E-06	1.1E-06	8.4E-07	1.0E-06
Muscle	3.5E-07	2.2E-07	1.3E-07	7.3E-08	5.8E-08	6.8E-08
Ovaries	6.9E-07	5.1E-07	4.2E-07	2.7E-07	2.1E-07	2.0E-07
Pancreas	3.6E-07	2.3E-07	1.4E-07	7.7E-08	6.1E-08	7.1E-08
Red Marrow	1.4E-05	8.7E-06	5.2E-06	3.0E-06	2.2E-06	1.8E-06
Respiratory Tract						
ET Airways	6.9E-04	5.6E-04	2.6E-04	1.8E-04	1.0E-04	1.0E-04
Lungs	1.3E-03	1.1E-03	6.7E-04	4.5E-04	3.9E-04	3.3E-04
Skin	3.4E-07	2.2E-07	1.3E-07	7.1E-08	5.6E-08	6.7E-08
Spleen	3.6E-07	2.3E-07	1.4E-07	7.6E-08	6.1E-08	7.0E-08
Testes	7.8E-07	5.8E-07	4.5E-07	4.1E-07	2.6E-07	2.0E-07
Thymus	3.6E-07	2.4E-07	1.4E-07	8.0E-08	6.4E-08	7.4E-08
Thyroid	3.5E-07	2.2E-07	1.3E-07	7.3E-08	5.8E-08	6.8E-08
Uterus	3.4E-07	2.1E-07	1.3E-07	6.9E-08	5.5E-08	6.6E-08
Remainder	7.5E-07	4.8E-07	2.6E-07	1.6E-07	1.1E-07	1.2E-07
Effective Dose	1.6E-04	1.3E-04	8.2E-05	5.5E-05	4.7E-05	4.0E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-230 (T½ = 7.70E+04 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Bladder Wall	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Bone Surface	6.3E-03	6.5E-03	5.7E-03	5.3E-03	5.2E-03	5.9E-03
Brain	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Breast	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
GI-Tract						
Oesophagus	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
St Wall	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
SI Wall	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
ULI Wall	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
LLI Wall	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Colon	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Kidneys	2.8E-04	2.5E-04	1.6E-04	1.2E-04	9.4E-05	9.0E-05
Liver	2.4E-04	2.2E-04	1.4E-04	1.0E-04	8.1E-05	7.7E-05
Muscle	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Ovaries	1.0E-04	1.0E-04	8.9E-05	7.3E-05	6.2E-05	4.8E-05
Pancreas	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Red Marrow	7.9E-04	7.1E-04	4.2E-04	2.8E-04	2.2E-04	2.0E-04
Respiratory Tract						
ET Airways	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Lungs	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.2E-06	6.6E-06
Skin	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Spleen	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.2E-06	6.6E-06
Testes	1.1E-04	1.1E-04	8.3E-05	6.7E-05	6.2E-05	4.9E-05
Thymus	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Thyroid	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Uterus	2.4E-05	2.1E-05	1.3E-05	9.4E-06	7.1E-06	6.6E-06
Remainder	2.7E-05	2.4E-05	1.5E-05	1.1E-05	8.1E-06	7.4E-06
Effective Dose	2.1E-04	2.0E-04	1.4E-04	1.1E-04	9.9E-05	1.0E-04

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-230 (T½ = 7.70E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Bladder Wall	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Bone Surface	2.0E-03	2.1E-03	2.0E-03	1.8E-03	2.0E-03	2.3E-03
Brain	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Breast	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
GI-Tract						
Oesophagus	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
St Wall	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
SI Wall	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
ULI Wall	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
LLI Wall	7.3E-06	6.9E-06	4.7E-06	3.2E-06	2.7E-06	2.6E-06
Colon	7.2E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Kidneys	8.3E-05	8.0E-05	5.6E-05	4.0E-05	3.6E-05	3.5E-05
Liver	7.4E-05	7.1E-05	4.9E-05	3.5E-05	3.1E-05	3.0E-05
Muscle	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Ovaries	3.2E-05	3.4E-05	3.1E-05	2.5E-05	2.3E-05	1.9E-05
Pancreas	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Red Marrow	2.4E-04	2.2E-04	1.5E-04	9.7E-05	8.3E-05	8.0E-05
Respiratory Tract						
ET Airways	5.5E-05	4.4E-05	2.1E-05	1.4E-05	8.7E-06	8.4E-06
Lungs	1.2E-04	9.4E-05	5.9E-05	4.0E-05	3.4E-05	2.9E-05
Skin	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Spleen	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Testes	3.5E-05	3.7E-05	2.9E-05	2.4E-05	2.3E-05	1.9E-05
Thymus	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Thyroid	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Uterus	7.1E-06	6.8E-06	4.6E-06	3.2E-06	2.7E-06	2.6E-06
Remainder	8.1E-06	7.7E-06	5.3E-06	3.6E-06	3.0E-06	2.9E-06
Effective Dose	7.7E-05	7.4E-05	5.5E-05	4.3E-05	4.2E-05	4.3E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-230 ($T½$ = 7.70E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Bladder Wall	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Bone Surface	2.7E-04	2.6E-04	2.5E-04	2.4E-04	2.6E-04	2.8E-04
Brain	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Breast	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
GI-Tract						
Oesophagus	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
St Wall	7.4E-07	6.2E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
SI Wall	7.4E-07	6.2E-07	4.7E-07	3.4E-07	3.2E-07	3.0E-07
ULI Wall	8.0E-07	6.6E-07	4.8E-07	3.5E-07	3.2E-07	3.1E-07
LLI Wall	9.3E-07	7.5E-07	5.2E-07	3.7E-07	3.3E-07	3.2E-07
Colon	8.5E-07	7.0E-07	5.0E-07	3.6E-07	3.3E-07	3.1E-07
Kidneys	8.8E-06	7.5E-06	5.9E-06	4.5E-06	4.4E-06	4.4E-06
Liver	7.7E-06	6.6E-06	5.1E-06	3.9E-06	3.7E-06	3.7E-06
Muscle	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Ovaries	4.0E-06	3.8E-06	3.4E-06	2.8E-06	2.6E-06	2.3E-06
Pancreas	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Red Marrow	2.4E-05	2.0E-05	1.4E-05	1.1E-05	1.0E-05	1.0E-05
Respiratory Tract						
ET Airways	2.0E-04	1.7E-04	8.5E-05	5.8E-05	3.6E-05	3.5E-05
Lungs	2.7E-04	2.4E-04	1.5E-04	1.0E-04	8.4E-05	7.7E-05
Skin	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Spleen	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.2E-07	3.0E-07
Testes	4.2E-06	3.8E-06	3.2E-06	2.7E-06	2.6E-06	2.3E-06
Thymus	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Thyroid	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Uterus	7.3E-07	6.1E-07	4.6E-07	3.4E-07	3.1E-07	3.0E-07
Remainder	9.4E-07	7.7E-07	5.7E-07	4.2E-07	3.7E-07	3.6E-07
Effective Dose	4.0E-05	3.5E-05	2.4E-05	1.6E-05	1.5E-05	1.4E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-232 (T½ = 1.40E+10 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	5.2E-05	4.9E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Bladder Wall	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Bone Surface	6.6E-03	6.9E-03	6.1E-03	5.7E-03	5.5E-03	5.7E-03
Brain	5.2E-05	4.9E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Breast	5.1E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
GI-Tract						
Oesophagus	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
St Wall	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
SI Wall	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
ULI Wall	5.2E-05	4.9E-05	3.4E-05	2.5E-05	2.0E-05	1.8E-05
LLI Wall	5.4E-05	5.1E-05	3.5E-05	2.7E-05	2.1E-05	1.8E-05
Colon	5.3E-05	5.0E-05	3.4E-05	2.6E-05	2.0E-05	1.8E-05
Kidneys	2.6E-04	2.4E-04	1.6E-04	1.2E-04	9.7E-05	8.9E-05
Liver	2.6E-04	2.4E-04	1.6E-04	1.2E-04	9.9E-05	8.9E-05
Muscle	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Ovaries	1.2E-04	1.2E-04	9.8E-05	7.9E-05	6.6E-05	5.2E-05
Pancreas	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Red Marrow	7.8E-04	7.2E-04	4.5E-04	3.2E-04	2.6E-04	2.3E-04
Respiratory Tract						
ET Airways	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Lungs	5.2E-05	4.9E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Skin	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Spleen	5.2E-05	4.9E-05	3.4E-05	2.5E-05	1.9E-05	1.7E-05
Testes	1.3E-04	1.3E-04	9.4E-05	7.4E-05	6.6E-05	5.3E-05
Thymus	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Thyroid	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Uterus	5.2E-05	4.8E-05	3.3E-05	2.5E-05	1.9E-05	1.7E-05
Remainder	5.5E-05	5.1E-05	3.5E-05	2.6E-05	2.0E-05	1.8E-05
Effective Dose	2.3E-04	2.2E-04	1.6E-04	1.3E-04	1.2E-04	1.1E-04

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-232 (T½ = 1.40E+10 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Bladder Wall	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Bone Surface	2.1E-03	2.3E-03	2.1E-03	2.0E-03	2.1E-03	2.2E-03
Brain	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Breast	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.2E-06	6.7E-06
GI-Tract						
Oesophagus	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
St Wall	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.2E-06	6.7E-06
SI Wall	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
ULI Wall	1.6E-05	1.6E-05	1.2E-05	8.7E-06	7.5E-06	6.8E-06
LLI Wall	1.7E-05	1.6E-05	1.2E-05	9.1E-06	7.8E-06	7.1E-06
Colon	1.6E-05	1.6E-05	1.2E-05	8.9E-06	7.6E-06	6.9E-06
Kidneys	8.0E-05	7.8E-05	5.6E-05	4.1E-05	3.7E-05	3.5E-05
Liver	8.0E-05	7.8E-05	5.7E-05	4.2E-05	3.8E-05	3.5E-05
Muscle	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Ovaries	3.7E-05	3.9E-05	3.4E-05	2.7E-05	2.5E-05	2.0E-05
Pancreas	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Red Marrow	2.4E-04	2.3E-04	1.6E-04	1.1E-04	9.7E-05	8.8E-05
Respiratory Tract						
ET Airways	5.6E-05	4.7E-05	2.5E-05	1.8E-05	1.2E-05	1.2E-05
Lungs	1.1E-04	8.5E-05	5.5E-05	3.7E-05	3.1E-05	2.7E-05
Skin	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.2E-06	6.7E-06
Spleen	1.6E-05	1.6E-05	1.2E-05	8.6E-06	7.3E-06	6.8E-06
Testes	4.0E-05	4.1E-05	3.3E-05	2.6E-05	2.5E-05	2.1E-05
Thymus	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Thyroid	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Uterus	1.6E-05	1.6E-05	1.2E-05	8.5E-06	7.3E-06	6.7E-06
Remainder	1.7E-05	1.6E-05	1.2E-05	8.8E-06	7.6E-06	7.0E-06
Effective Dose	8.3E-05	8.1E-05	6.3E-05	5.0E-05	4.7E-05	4.5E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-232 (T½ = 1.40E+10 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.8E-06	1.6E-06	1.3E-06	9.6E-07	8.9E-07	8.3E-07
Bladder Wall	1.8E-06	1.6E-06	1.2E-06	9.4E-07	8.7E-07	8.2E-07
Bone Surface	3.1E-04	3.0E-04	2.9E-04	2.6E-04	2.8E-04	2.9E-04
Brain	1.8E-06	1.6E-06	1.2E-06	9.4E-07	8.7E-07	8.2E-07
Breast	1.8E-06	1.6E-06	1.3E-06	9.5E-07	8.8E-07	8.3E-07
GI-Tract						
Oesophagus	1.8E-06	1.6E-06	1.3E-06	9.6E-07	8.9E-07	8.3E-07
St Wall	1.8E-06	1.6E-06	1.2E-06	9.5E-07	8.8E-07	8.2E-07
SI Wall	1.8E-06	1.6E-06	1.2E-06	9.5E-07	8.7E-07	8.2E-07
ULI Wall	1.9E-06	1.6E-06	1.3E-06	9.9E-07	9.2E-07	8.6E-07
LLI Wall	2.1E-06	1.8E-06	1.4E-06	1.1E-06	1.0E-06	9.4E-07
Colon	2.0E-06	1.7E-06	1.4E-06	1.0E-06	9.6E-07	9.0E-07
Kidneys	9.2E-06	8.0E-06	6.4E-06	5.0E-06	4.9E-06	4.8E-06
Liver	9.6E-06	8.5E-06	6.8E-06	5.4E-06	5.2E-06	5.1E-06
Muscle	1.8E-06	1.6E-06	1.2E-06	9.5E-07	8.8E-07	8.2E-07
Ovaries	4.7E-06	4.4E-06	3.9E-06	3.1E-06	2.9E-06	2.6E-06
Pancreas	1.8E-06	1.6E-06	1.3E-06	9.5E-07	8.8E-07	8.3E-07
Red Marrow	2.7E-05	2.3E-05	1.8E-05	1.4E-05	1.3E-05	1.2E-05
Respiratory Tract						
ET Airways	2.4E-04	2.1E-04	1.1E-04	7.7E-05	5.0E-05	5.1E-05
Lungs	3.7E-04	3.5E-04	2.5E-04	1.7E-04	1.6E-04	1.6E-04
Skin	1.8E-06	1.6E-06	1.2E-06	9.4E-07	8.7E-07	8.2E-07
Spleen	1.8E-06	1.6E-06	1.3E-06	9.6E-07	8.9E-07	8.4E-07
Testes	4.9E-06	4.5E-06	3.8E-06	3.1E-06	2.9E-06	2.6E-06
Thymus	1.8E-06	1.6E-06	1.3E-06	9.6E-07	8.9E-07	8.3E-07
Thyroid	1.8E-06	1.6E-06	1.2E-06	9.5E-07	8.8E-07	8.2E-07
Uterus	1.8E-06	1.6E-06	1.2E-06	9.4E-07	8.7E-07	8.2E-07
Remainder	1.9E-06	1.6E-06	1.3E-06	9.9E-07	9.2E-07	8.6E-07
Effective Dose	5.4E-05	5.0E-05	3.7E-05	2.6E-05	2.5E-05	2.5E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.5(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-234 (T½ = 24.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.6E-09	1.8E-09	8.1E-10	4.9E-10	2.9E-10	3.2E-10
Bladder Wall	2.7E-09	1.8E-09	8.7E-10	5.4E-10	3.4E-10	3.8E-10
Bone Surface	1.8E-07	1.3E-07	7.6E-08	4.1E-08	2.3E-08	2.1E-08
Brain	2.6E-09	1.7E-09	7.9E-10	4.7E-10	2.8E-10	3.1E-10
Breast	2.6E-09	1.7E-09	7.7E-10	4.6E-10	2.7E-10	3.1E-10
GI-Tract						
Oesophagus	2.6E-09	1.7E-09	7.8E-10	4.7E-10	2.7E-10	3.1E-10
St Wall	4.3E-09	2.7E-09	1.2E-09	6.9E-10	3.9E-10	4.0E-10
SI Wall	6.6E-09	4.3E-09	1.9E-09	1.1E-09	5.7E-10	5.6E-10
ULI Wall	2.7E-08	1.8E-08	7.2E-09	4.4E-09	2.0E-09	1.8E-09
LLI Wall	7.0E-08	4.5E-08	1.9E-08	1.1E-08	5.2E-09	4.5E-09
Colon	4.6E-08	3.0E-08	1.2E-08	7.4E-09	3.4E-09	2.9E-09
Kidneys	4.1E-08	2.7E-08	1.3E-08	8.9E-09	6.1E-09	7.5E-09
Liver	1.7E-08	1.2E-08	5.5E-09	3.6E-09	2.3E-09	2.7E-09
Muscle	2.6E-09	1.7E-09	7.9E-10	4.7E-10	2.8E-10	3.1E-10
Ovaries	2.7E-09	2.6E-09	2.3E-09	2.1E-09	1.1E-09	1.0E-09
Pancreas	2.6E-09	1.7E-09	7.9E-10	4.8E-10	2.8E-10	3.2E-10
Red Marrow	2.5E-07	1.5E-07	6.2E-08	3.3E-08	1.9E-08	1.2E-08
Respiratory Tract						
ET Airways	1.6E-08	1.1E-08	4.9E-09	3.1E-09	1.7E-09	1.7E-09
Lungs	2.7E-09	1.8E-09	8.5E-10	5.2E-10	3.2E-10	3.5E-10
Skin	2.6E-09	1.7E-09	7.8E-10	4.6E-10	2.7E-10	3.1E-10
Spleen	2.6E-09	1.7E-09	7.9E-10	4.7E-10	2.7E-10	3.1E-10
Testes	2.3E-09	2.8E-09	2.1E-09	2.1E-09	2.0E-09	1.0E-09
Thymus	2.6E-09	1.7E-09	7.8E-10	4.7E-10	2.7E-10	3.1E-10
Thyroid	2.6E-09	1.7E-09	7.8E-10	4.7E-10	2.7E-10	3.1E-10
Uterus	2.6E-09	1.7E-09	7.9E-10	4.7E-10	2.8E-10	3.1E-10
Remainder	3.1E-09	2.1E-09	9.7E-10	5.8E-10	3.4E-10	3.9E-10
Effective Dose	4.0E-08	2.5E-08	1.1E-08	6.1E-09	3.5E-09	2.5E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.5(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-234 (T½ = 24.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	4.6E-10	3.2E-10	1.6E-10	9.3E-11	6.0E-11	6.3E-11
Bladder Wall	4.1E-10	2.8E-10	1.4E-10	8.7E-11	5.6E-11	6.4E-11
Bone Surface	2.7E-08	1.9E-08	1.2E-08	6.3E-09	3.7E-09	3.4E-09
Brain	3.8E-10	2.6E-10	1.2E-10	7.3E-11	4.5E-11	5.1E-11
Breast	4.3E-10	3.0E-10	1.5E-10	9.1E-11	5.5E-11	6.1E-11
GI-Tract						
Oesophagus	4.4E-10	3.0E-10	1.5E-10	9.2E-11	6.0E-11	6.4E-11
St Wall	4.1E-09	2.3E-09	9.5E-10	5.5E-10	3.2E-10	2.7E-10
SI Wall	8.9E-09	5.8E-09	2.4E-09	1.5E-09	7.0E-10	6.0E-10
ULI Wall	5.1E-08	3.4E-08	1.4E-08	8.5E-09	4.0E-09	3.3E-09
LLI Wall	1.4E-07	9.2E-08	3.9E-08	2.3E-08	1.1E-08	9.3E-09
Colon	9.1E-08	5.9E-08	2.5E-08	1.5E-08	7.1E-09	5.9E-09
Kidneys	6.0E-09	4.0E-09	2.0E-09	1.3E-09	9.7E-10	1.2E-09
Liver	2.5E-09	1.8E-09	8.7E-10	5.7E-10	3.7E-10	4.5E-10
Muscle	4.2E-10	2.8E-10	1.4E-10	8.1E-11	5.1E-11	5.6E-11
Ovaries	4.7E-10	4.2E-10	3.8E-10	3.4E-10	1.8E-10	1.7E-10
Pancreas	4.4E-10	3.0E-10	1.5E-10	8.7E-11	5.6E-11	5.9E-11
Red Marrow	3.6E-08	2.2E-08	9.6E-09	4.9E-09	3.0E-09	1.9E-09
Respiratory Tract						
ET Airways	2.7E-08	1.9E-08	7.9E-09	5.2E-09	2.9E-09	2.7E-09
Lungs	1.9E-07	1.5E-07	9.1E-08	6.4E-08	5.5E-08	4.6E-08
Skin	3.9E-10	2.6E-10	1.3E-10	7.4E-11	4.6E-11	5.2E-11
Spleen	4.3E-10	3.0E-10	1.4E-10	8.6E-11	5.4E-11	5.8E-11
Testes	3.5E-10	4.3E-10	3.3E-10	3.2E-10	3.2E-10	1.6E-10
Thymus	4.4E-10	3.0E-10	1.5E-10	9.2E-11	6.0E-11	6.4E-11
Thyroid	4.0E-10	2.8E-10	1.3E-10	7.9E-11	4.9E-11	5.4E-11
Uterus	4.1E-10	2.8E-10	1.3E-10	7.9E-11	4.8E-11	5.3E-11
Remainder	6.5E-10	4.3E-10	2.0E-10	1.2E-10	7.6E-11	8.0E-11
Effective Dose	3.9E-08	2.9E-08	1.5E-08	1.0E-08	7.9E-09	6.6E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.26.5(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Th-234 (T½ = 24.1 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.1E-10	7.4E-11	4.3E-11	2.6E-11	1.9E-11	1.5E-11
Bladder Wall	4.6E-11	2.3E-11	1.1E-11	7.1E-12	3.9E-12	3.4E-12
Bone Surface	1.6E-09	4.1E-10	2.5E-10	1.3E-10	8.1E-11	7.3E-11
Brain	2.6E-11	9.1E-12	4.9E-12	3.1E-12	2.0E-12	2.0E-12
Breast	8.7E-11	6.1E-11	4.1E-11	2.8E-11	1.7E-11	1.6E-11
GI-Tract						
Oesophagus	9.4E-11	6.7E-11	4.2E-11	2.8E-11	2.2E-11	1.9E-11
St Wall	4.0E-09	2.2E-09	9.0E-10	5.2E-10	3.0E-10	2.4E-10
SI Wall	9.1E-09	5.9E-09	2.5E-09	1.5E-09	7.1E-10	5.9E-10
ULI Wall	5.4E-08	3.5E-08	1.5E-08	9.0E-09	4.2E-09	3.5E-09
LLI Wall	1.5E-07	9.7E-08	4.1E-08	2.5E-08	1.2E-08	9.9E-09
Colon	9.6E-08	6.2E-08	2.6E-08	1.6E-08	7.6E-09	6.2E-09
Kidneys	3.6E-10	1.0E-10	5.4E-11	3.5E-11	2.5E-11	2.8E-11
Liver	2.0E-10	9.0E-11	4.8E-11	3.1E-11	2.3E-11	2.1E-11
Muscle	6.6E-11	4.0E-11	2.1E-11	1.3E-11	9.8E-12	8.2E-12
Ovaries	9.8E-11	6.2E-11	3.3E-11	2.3E-11	1.3E-11	1.1E-11
Pancreas	8.9E-11	6.0E-11	3.4E-11	2.1E-11	1.5E-11	1.2E-11
Red Marrow	2.0E-09	4.3E-10	1.9E-10	1.0E-10	6.4E-11	4.3E-11
Respiratory Tract						
ET Airways	3.0E-08	2.1E-08	8.8E-09	5.8E-09	3.2E-09	3.0E-09
Lungs	2.4E-07	1.9E-07	1.1E-07	7.9E-08	6.8E-08	5.7E-08
Skin	3.9E-11	1.9E-11	1.0E-11	6.5E-12	4.3E-12	4.1E-12
Spleen	8.6E-11	5.8E-11	3.1E-11	2.0E-11	1.4E-11	1.2E-11
Testes	2.9E-11	1.5E-11	9.4E-12	8.0E-12	6.9E-12	3.7E-12
Thymus	9.4E-11	6.7E-11	4.2E-11	2.8E-11	2.2E-11	1.9E-11
Thyroid	5.6E-11	3.5E-11	2.0E-11	1.2E-11	7.8E-12	6.7E-12
Uterus	5.7E-11	3.2E-11	1.5E-11	9.5E-12	5.2E-12	4.3E-12
Remainder	2.4E-10	1.4E-10	6.9E-11	4.4E-11	2.6E-11	2.2E-11
Effective Dose	4.1E-08	3.1E-08	1.7E-08	1.1E-08	9.1E-09	7.7E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Th parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.27. Uranium

(244) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides, oxides and hydroxides of uranium (U) to inhalation Class Y, and nitrates to Class W. By default, other unspecified compounds were assigned to Class D (see Paragraph 54). *ICRP Publication 30*, Part 1 (ICRP, 1979), assigned uranium hexafluoride (UF_6), uranyl difluoride (UO_2F_2) and uranyl nitrate ($UO_2(NO_3)_2$) to Class D on the basis of studies of Chalabreysse (1970). The trioxide (UO_3), tetrafluoride (UF_4) and chloride (UCl_4) were found to be less soluble in studies reported by Hursh and Spoor (1973), and Morrow *et al.* (1972), and were assigned to Class W. Uranium dioxide (UO_2) and uranium octoxide (U_3O_8) were assigned to Class Y on the basis of inhalation studies in dogs (Morrow *et al.*, 1966).

(245) A comprehensive review of studies of the lung clearance of inhaled uranium compounds was carried out by Eidson (1994). Other, more recent publications have also been included here.

Absorption Types

(246) UF_6 exists in vapour form, but in the presence of water in the atmosphere and in the respiratory tract, it is rapidly converted to UO_2F_2. Since UF_6 and UO_2F_2 are generally inhaled at the same time, the mixture is treated here as an aerosol rather than a vapour. Following accidental exposures in humans, the rapid urinary excretion observed, (Beau and Chalabreysse, 1989; Fisher *et al.*, 1990) is consistent with assignment to Type F. Experiments in beagle dogs (Morrow *et al.*, 1982) have also shown that most of the initial lung burden is rapidly translocated to blood.

(247) In rats exposed to aerosols of $UO_2(NO_3)_2$ in aqueous solution (Ballou *et al.*, 1986), 15–45% of the deposited material is retained in the lung at 30 d, according to particle size, supporting assignment to Type M. Measurements following intratracheal instillation into rats are consistent with assignment to Type F (Ellender, 1987; Stradling *et al.*, 1991).

(248) The reported behaviour of uranium tetrafluoride is complex. Measurement of urinary excretion following inhalation by humans (Chalabreysse *et al.*, 1989) and experiments in rats and baboons (Stradling *et al.*, 1985a; André *et al.*, 1989; Ansoborlo *et al.*, 1990) show that a large fraction of the lung deposit is rapidly absorbed. However, considerable variation in behaviour was observed, with some experiments indicating Type F behaviour and others Type M.

(249) Uranium trioxide, ammonium diuranate (ADU) and uranium octoxide are found in various hydration states alone or more often mixed in various proportions in industrial processes. The human data from accidental intakes (West *et al.*, 1979; Eidson, 1990), and from monitoring data in workers from processing facilities (Barber and Forrest, 1995), the many animal studies in rats, dogs and monkeys (Morrow *et al.*, 1972; Eidson and Damon, 1985a,b; Stradling *et al.*, 1985b; Métivier *et al.*, 1992), and extensive *in vitro* studies (Mansur, 1988; Hengé-Napoli *et al.*, 1989) show that the behaviour depends on particular processes but, in most cases, is consistent with assignment to Type M, although pure UO_3 would be assigned to Type F. Considerable variation in the behaviour of U_3O_8 was observed, with some studies indicating Type M behaviour and others Type S.

(250) Following an accidental release from a nuclear reactor, fission and activation products may be present in fragments of irradiated fuel, of which the matrix is predominantly uranium oxide (Devell, 1988; Begichev *et al.*, 1989; Toivonen *et al.*, 1992). In studies of the *in vitro* dissolution of particles released from the Chernobyl accident, seven out of ten of which

consisted mainly of uranium (Cuddihy *et al.*, 1989), were consistent with assignment of all the γ-emitting radionuclides present to Type M.

(251) Human studies have shown that UO_2 can be very insoluble (Pomroy and Noel, 1981; Price, 1989). Experiments in rats, dogs, monkeys and baboons (Leach *et al.*, 1973; Stradling *et al.*, 1989; Métivier *et al.*, 1992) also support the assignment of UO_2 to Type S.

Dose coefficients

(252) Studies of common chemical forms showing characteristics of absorption Types F, M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.27.2–7) were derived for the f_1 values given in Table 5.27.1, and the biokinetic data given in *ICRP Publication 69* (ICRP, 1995) and Annexe C. In addition, the escape from the body of radon formed as a decay product within the respiratory tract is included (Paragraph 75). For calculational purposes a rate of 100 d^{-1} is assumed for this process, in addition to the other routes of removal. This extends the approach adopted for ^{222}Rn following intakes of ^{226}Ra in *ICRP Publication 30*, Part 1.

Table 5.27.1. Values of f_1 for inhaled particulate compounds of uranium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.04	0.02
M[b]	0.04	0.02
S	0.02	0.002

[a]f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b]Default Type M is recommended for use in the absence of specific information.

Table 5.27.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-232 (T½ = 72.0 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Bladder Wall	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Bone Surface	3.7E-04	2.1E-04	1.5E-04	1.9E-04	2.7E-04	8.8E-05
Brain	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Breast	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
GI-Tract						
Oesophagus	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
St Wall	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
SI Wall	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
ULI Wall	5.2E-06	4.4E-06	3.1E-06	2.5E-06	2.3E-06	2.0E-06
LLI Wall	5.9E-06	4.8E-06	3.3E-06	2.7E-06	2.6E-06	2.1E-06
Colon	5.5E-06	4.6E-06	3.2E-06	2.6E-06	2.4E-06	2.1E-06
Kidneys	3.6E-05	2.7E-05	1.6E-05	1.2E-05	1.1E-05	8.3E-06
Liver	3.0E-05	2.3E-05	1.5E-05	1.2E-05	1.2E-05	8.7E-06
Muscle	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Ovaries	6.1E-06	5.0E-06	3.6E-06	3.1E-06	2.9E-06	2.1E-06
Pancreas	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Red Marrow	5.4E-05	2.8E-05	1.6E-05	1.7E-05	1.8E-05	8.5E-06
Respiratory Tract						
ET Airways	4.9E-06	4.3E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Lungs	4.9E-06	4.3E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Skin	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Spleen	4.8E-06	4.2E-06	2.9E-06	2.4E-06	2.2E-06	1.9E-06
Testes	6.6E-06	5.4E-06	4.0E-06	3.7E-06	2.9E-06	2.1E-06
Thymus	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Thyroid	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Uterus	4.8E-06	4.2E-06	3.0E-06	2.5E-06	2.2E-06	2.0E-06
Remainder	5.2E-06	4.5E-06	3.1E-06	2.6E-06	2.3E-06	2.0E-06
Effective Dose	1.6E-05	1.0E-05	6.9E-06	6.8E-06	7.5E-06	4.0E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-232 (T½ = 72.0 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.8E-07	9.2E-07
Bladder Wall	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.8E-07	9.2E-07
Bone Surface	2.2E-04	1.8E-04	1.4E-04	1.3E-04	1.6E-04	8.1E-05
Brain	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.8E-07	9.2E-07
Breast	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
GI-Tract						
Oesophagus	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
St Wall	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
SI Wall	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
ULI Wall	2.3E-06	2.1E-06	1.5E-06	1.1E-06	1.1E-06	9.9E-07
LLI Wall	2.9E-06	2.5E-06	1.7E-06	1.2E-06	1.2E-06	1.1E-06
Colon	2.6E-06	2.2E-06	1.6E-06	1.2E-06	1.1E-06	1.1E-06
Kidneys	1.5E-05	1.2E-05	8.0E-06	5.8E-06	5.3E-06	4.6E-06
Liver	1.6E-05	1.4E-05	9.0E-06	6.4E-06	6.1E-06	5.4E-06
Muscle	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
Ovaries	3.0E-06	2.8E-06	2.2E-06	1.7E-06	1.6E-06	1.3E-06
Pancreas	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
Red Marrow	3.4E-05	2.6E-05	1.6E-05	1.2E-05	1.2E-05	7.0E-06
Respiratory Tract						
ET Airways	8.6E-05	6.8E-05	3.1E-05	2.1E-05	1.2E-05	1.2E-05
Lungs	1.8E-04	1.4E-04	8.9E-05	6.0E-05	5.1E-05	4.3E-05
Skin	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
Spleen	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.6E-07	9.1E-07
Testes	3.3E-06	3.0E-06	2.4E-06	2.2E-06	1.7E-06	1.3E-06
Thymus	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
Thyroid	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
Uterus	2.0E-06	1.8E-06	1.3E-06	1.0E-06	9.7E-07	9.2E-07
Remainder	2.2E-06	2.0E-06	1.4E-06	1.1E-06	1.0E-06	9.6E-07
Effective Dose	3.0E-05	2.4E-05	1.6E-05	1.1E-05	1.0E-05	7.8E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-232 (T½ = 72.0 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	4.4E-07	3.3E-07	2.5E-07	1.9E-07	2.0E-07	2.0E-07
Bladder Wall	4.1E-07	3.1E-07	2.4E-07	1.8E-07	1.9E-07	1.9E-07
Bone Surface	7.2E-05	6.7E-05	5.5E-05	4.5E-05	4.6E-05	4.1E-05
Brain	4.1E-07	3.1E-07	2.4E-07	1.8E-07	1.9E-07	1.9E-07
Breast	4.4E-07	3.3E-07	2.5E-07	1.9E-07	2.0E-07	2.0E-07
GI-Tract						
Oesophagus	4.4E-07	3.3E-07	2.5E-07	2.0E-07	2.0E-07	2.1E-07
St Wall	4.3E-07	3.3E-07	2.5E-07	1.9E-07	1.9E-07	2.0E-07
SI Wall	4.3E-07	3.2E-07	2.4E-07	1.9E-07	1.9E-07	1.9E-07
ULI Wall	5.7E-07	4.4E-07	3.1E-07	2.3E-07	2.3E-07	2.4E-07
LLI Wall	8.6E-07	6.7E-07	4.4E-07	3.2E-07	3.2E-07	3.5E-07
Colon	7.0E-07	5.4E-07	3.7E-07	2.7E-07	2.7E-07	2.9E-07
Kidneys	3.1E-06	2.3E-06	1.7E-06	1.3E-06	1.3E-06	1.4E-06
Liver	3.9E-06	3.3E-06	2.4E-06	1.8E-06	1.8E-06	2.0E-06
Muscle	4.2E-07	3.2E-07	2.4E-07	1.9E-07	1.9E-07	2.0E-07
Ovaries	8.4E-07	7.4E-07	6.0E-07	4.5E-07	4.3E-07	4.2E-07
Pancreas	4.3E-07	3.3E-07	2.5E-07	1.9E-07	1.9E-07	2.0E-07
Red Marrow	9.1E-06	7.9E-06	5.5E-06	3.9E-06	3.6E-06	3.3E-06
Respiratory Tract						
ET Airways	6.2E-04	5.4E-04	2.9E-04	2.0E-04	1.3E-04	1.3E-04
Lungs	8.3E-04	7.9E-04	5.4E-04	3.5E-04	3.1E-04	3.0E-04
Skin	4.2E-07	3.1E-07	2.4E-07	1.8E-07	1.9E-07	1.9E-07
Spleen	4.2E-07	3.2E-07	2.4E-07	1.9E-07	1.9E-07	2.0E-07
Testes	9.3E-07	8.2E-07	7.0E-07	5.8E-07	4.5E-07	4.2E-07
Thymus	4.4E-07	3.3E-07	2.5E-07	2.0E-07	2.0E-07	2.1E-07
Thyroid	4.2E-07	3.2E-07	2.4E-07	1.9E-07	1.9E-07	2.0E-07
Uterus	4.1E-07	3.1E-07	2.3E-07	1.8E-07	1.8E-07	1.9E-07
Remainder	7.9E-07	5.7E-07	3.9E-07	2.9E-07	2.6E-07	2.7E-07
Effective Dose	1.0E-04	9.7E-05	6.6E-05	4.3E-05	3.8E-05	3.7E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-233 ($T½$ = 1.58E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Bladder Wall	8.8E-07	8.0E-07	5.6E-07	4.4E-07	3.6E-07	3.5E-07
Bone Surface	5.1E-05	2.5E-05	1.6E-05	1.9E-05	2.9E-05	1.0E-05
Brain	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Breast	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
GI-Tract						
Oesophagus	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
St Wall	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
SI Wall	8.8E-07	8.1E-07	5.5E-07	4.4E-07	3.6E-07	3.5E-07
ULI Wall	9.0E-07	8.2E-07	5.6E-07	4.4E-07	3.6E-07	3.5E-07
LLI Wall	9.5E-07	8.5E-07	5.7E-07	4.5E-07	3.7E-07	3.5E-07
Colon	9.2E-07	8.3E-07	5.7E-07	4.4E-07	3.7E-07	3.5E-07
Kidneys	1.8E-05	1.4E-05	7.7E-06	5.3E-06	3.9E-06	3.5E-06
Liver	3.8E-06	3.5E-06	2.3E-06	1.7E-06	1.4E-06	1.3E-06
Muscle	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Ovaries	9.0E-07	8.3E-07	5.7E-07	4.6E-07	3.7E-07	3.5E-07
Pancreas	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Red Marrow	6.1E-06	2.8E-06	1.6E-06	1.6E-06	1.7E-06	1.0E-06
Respiratory Tract						
ET Airways	8.8E-07	8.1E-07	5.5E-07	4.4E-07	3.6E-07	3.5E-07
Lungs	9.4E-07	8.5E-07	5.8E-07	4.6E-07	3.8E-07	3.6E-07
Skin	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Spleen	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.5E-07
Testes	9.4E-07	8.7E-07	6.1E-07	5.1E-07	3.7E-07	3.5E-07
Thymus	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Thyroid	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Uterus	8.8E-07	8.0E-07	5.5E-07	4.4E-07	3.6E-07	3.4E-07
Remainder	1.1E-06	9.7E-07	6.4E-07	4.9E-07	4.0E-07	3.8E-07
Effective Dose	2.2E-06	1.4E-06	9.4E-07	8.4E-07	8.6E-07	5.8E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-233 (T½ = 1.58E+05 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Bladder Wall	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Bone Surface	1.5E-05	8.5E-06	6.3E-06	7.3E-06	1.2E-05	4.3E-06
Brain	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Breast	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
GI-Tract						
Oesophagus	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
St Wall	3.0E-07	2.8E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
SI Wall	3.1E-07	2.8E-07	2.1E-07	1.6E-07	1.4E-07	1.4E-07
ULI Wall	3.6E-07	3.1E-07	2.2E-07	1.7E-07	1.5E-07	1.4E-07
LLI Wall	4.7E-07	3.9E-07	2.5E-07	1.9E-07	1.6E-07	1.5E-07
Colon	4.0E-07	3.4E-07	2.3E-07	1.8E-07	1.5E-07	1.5E-07
Kidneys	5.9E-06	4.6E-06	2.8E-06	1.9E-06	1.5E-06	1.4E-06
Liver	1.3E-06	1.2E-06	8.4E-07	6.2E-07	5.6E-07	5.6E-07
Muscle	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Ovaries	3.1E-07	2.8E-07	2.1E-07	1.7E-07	1.5E-07	1.4E-07
Pancreas	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Red Marrow	1.8E-06	9.4E-07	6.0E-07	5.8E-07	6.7E-07	4.2E-07
Respiratory Tract						
ET Airways	4.9E-05	3.8E-05	1.7E-05	1.1E-05	6.3E-06	6.1E-06
Lungs	1.2E-04	9.1E-05	5.7E-05	3.9E-05	3.3E-05	2.8E-05
Skin	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Spleen	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Testes	3.2E-07	3.0E-07	2.3E-07	1.9E-07	1.5E-07	1.4E-07
Thymus	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Thyroid	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Uterus	3.0E-07	2.7E-07	2.0E-07	1.6E-07	1.4E-07	1.4E-07
Remainder	4.0E-07	3.4E-07	2.4E-07	1.8E-07	1.6E-07	1.6E-07
Effective Dose	1.5E-05	1.1E-05	7.2E-06	4.9E-06	4.3E-06	3.6E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-233 (T½ = 1.58E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Bladder Wall	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.8E-08
Bone Surface	2.5E-06	1.3E-06	1.2E-06	1.2E-06	1.4E-06	8.0E-07
Brain	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Breast	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
GI-Tract						
Oesophagus	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
St Wall	5.2E-08	3.1E-08	2.4E-08	1.9E-08	1.8E-08	1.8E-08
SI Wall	5.8E-08	3.6E-08	2.6E-08	2.1E-08	1.9E-08	1.8E-08
ULI Wall	1.2E-07	7.5E-08	4.4E-08	3.1E-08	2.4E-08	2.3E-08
LLI Wall	2.4E-07	1.6E-07	8.3E-08	5.4E-08	3.7E-08	3.4E-08
Colon	1.7E-07	1.1E-07	6.1E-08	4.1E-08	3.0E-08	2.8E-08
Kidneys	8.4E-07	4.1E-07	2.9E-07	2.1E-07	2.0E-07	2.0E-07
Liver	2.2E-07	1.3E-07	1.1E-07	8.4E-08	8.4E-08	8.4E-08
Muscle	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Ovaries	5.1E-08	3.2E-08	2.6E-08	2.1E-08	2.0E-08	1.9E-08
Pancreas	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Red Marrow	2.6E-07	1.1E-07	9.2E-08	8.5E-08	8.5E-08	6.8E-08
Respiratory Tract						
ET Airways	2.1E-04	1.7E-04	8.7E-05	6.0E-05	3.6E-05	3.6E-05
Lungs	2.8E-04	2.5E-04	1.6E-04	1.0E-04	8.7E-05	8.0E-05
Skin	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Spleen	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Testes	5.3E-08	3.3E-08	2.8E-08	2.3E-08	2.0E-08	1.9E-08
Thymus	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Thyroid	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Uterus	4.7E-08	2.8E-08	2.3E-08	1.9E-08	1.8E-08	1.7E-08
Remainder	1.7E-07	1.1E-07	6.5E-08	4.8E-08	3.7E-08	3.7E-08
Effective Dose	3.4E-05	3.0E-05	1.9E-05	1.2E-05	1.1E-05	9.6E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-234 (T½ = 2.44E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Bladder Wall	8.6E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Bone Surface	5.0E-05	2.4E-05	1.6E-05	1.8E-05	2.7E-05	9.5E-06
Brain	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Breast	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
GI-Tract						
Oesophagus	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
St Wall	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
SI Wall	8.6E-07	7.9E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
ULI Wall	8.8E-07	8.0E-07	5.4E-07	4.3E-07	3.5E-07	3.4E-07
LLI Wall	9.3E-07	8.3E-07	5.6E-07	4.4E-07	3.5E-07	3.4E-07
Colon	9.0E-07	8.1E-07	5.5E-07	4.3E-07	3.5E-07	3.4E-07
Kidneys	1.8E-05	1.4E-05	7.6E-06	5.2E-06	3.8E-06	3.5E-06
Liver	3.8E-06	3.4E-06	2.2E-06	1.6E-06	1.3E-06	1.3E-06
Muscle	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Ovaries	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Pancreas	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Red Marrow	5.9E-06	2.7E-06	1.5E-06	1.5E-06	1.6E-06	9.9E-07
Respiratory Tract						
ET Airways	8.6E-07	7.9E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Lungs	9.1E-07	8.2E-07	5.7E-07	4.4E-07	3.7E-07	3.5E-07
Skin	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Spleen	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Testes	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Thymus	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Thyroid	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Uterus	8.5E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.4E-07
Remainder	1.1E-06	9.5E-07	6.3E-07	4.8E-07	3.9E-07	3.7E-07
Effective Dose	2.1E-06	1.4E-06	9.0E-07	8.0E-07	8.2E-07	5.6E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-234 (T½ = 2.44E+05 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Bladder Wall	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Bone Surface	1.5E-05	8.0E-06	5.9E-06	6.8E-06	1.1E-05	3.9E-06
Brain	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Breast	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
GI-Tract						
Oesophagus	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
St Wall	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
SI Wall	3.0E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
ULI Wall	3.5E-07	3.0E-07	2.1E-07	1.6E-07	1.4E-07	1.4E-07
LLI Wall	4.6E-07	3.8E-07	2.5E-07	1.8E-07	1.5E-07	1.5E-07
Colon	3.9E-07	3.4E-07	2.3E-07	1.7E-07	1.5E-07	1.4E-07
Kidneys	5.8E-06	4.6E-06	2.8E-06	1.9E-06	1.5E-06	1.4E-06
Liver	1.3E-06	1.2E-06	8.1E-07	5.9E-07	5.2E-07	5.3E-07
Muscle	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Ovaries	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Pancreas	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Red Marrow	1.7E-06	9.0E-07	5.7E-07	5.5E-07	6.3E-07	4.0E-07
Respiratory Tract						
ET Airways	4.9E-05	3.8E-05	1.6E-05	1.1E-05	6.2E-06	6.0E-06
Lungs	1.2E-04	9.0E-05	5.6E-05	3.8E-05	3.2E-05	2.7E-05
Skin	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Spleen	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Testes	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Thymus	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Thyroid	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Uterus	2.9E-07	2.7E-07	2.0E-07	1.5E-07	1.4E-07	1.4E-07
Remainder	3.9E-07	3.4E-07	2.4E-07	1.8E-07	1.6E-07	1.5E-07
Effective Dose	1.5E-05	1.1E-05	7.0E-06	4.8E-06	4.2E-06	3.5E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-234 (T½ = 2.44E+05 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	4.5E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Bladder Wall	4.5E-08	2.6E-08	2.1E-08	1.7E-08	1.7E-08	1.6E-08
Bone Surface	2.1E-06	8.9E-07	8.3E-07	9.1E-07	1.1E-06	5.0E-07
Brain	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Breast	4.5E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
GI-Tract						
Oesophagus	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
St Wall	4.9E-08	2.9E-08	2.2E-08	1.8E-08	1.7E-08	1.7E-08
SI Wall	5.6E-08	3.4E-08	2.5E-08	1.9E-08	1.8E-08	1.7E-08
ULI Wall	1.1E-07	7.3E-08	4.2E-08	3.0E-08	2.3E-08	2.2E-08
LLI Wall	2.4E-07	1.6E-07	8.1E-08	5.3E-08	3.5E-08	3.2E-08
Colon	1.7E-07	1.1E-07	5.9E-08	4.0E-08	2.8E-08	2.6E-08
Kidneys	8.2E-07	4.0E-07	2.8E-07	2.1E-07	1.9E-07	1.9E-07
Liver	1.9E-07	1.1E-07	8.6E-08	6.8E-08	6.7E-08	6.9E-08
Muscle	4.5E-08	2.6E-08	2.1E-08	1.7E-08	1.7E-08	1.6E-08
Ovaries	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Pancreas	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Red Marrow	2.4E-07	8.6E-08	7.0E-08	6.6E-08	6.7E-08	5.2E-08
Respiratory Tract						
ET Airways	2.0E-04	1.7E-04	8.6E-05	5.9E-05	3.6E-05	3.6E-05
Lungs	2.8E-04	2.4E-04	1.6E-04	1.0E-04	8.5E-05	7.8E-05
Skin	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Spleen	4.5E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Testes	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Thymus	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Thyroid	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Uterus	4.4E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Remainder	1.6E-07	1.0E-07	6.3E-08	4.6E-08	3.5E-08	3.5E-08
Effective Dose	3.3E-05	2.9E-05	1.9E-05	1.2E-05	1.0E-05	9.4E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.5(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-235 (T½ = 7.04E+08 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Bladder Wall	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Bone Surface	4.7E-05	2.2E-05	1.5E-05	1.7E-05	2.5E-05	9.0E-06
Brain	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Breast	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
GI-Tract						
Oesophagus	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
St Wall	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
SI Wall	8.0E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
ULI Wall	8.2E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.1E-07
LLI Wall	8.7E-07	7.8E-07	5.2E-07	4.1E-07	3.3E-07	3.2E-07
Colon	8.4E-07	7.6E-07	5.1E-07	4.0E-07	3.3E-07	3.1E-07
Kidneys	1.7E-05	1.3E-05	7.1E-06	4.9E-06	3.5E-06	3.2E-06
Liver	3.5E-06	3.2E-06	2.0E-06	1.5E-06	1.2E-06	1.2E-06
Muscle	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Ovaries	8.1E-07	7.5E-07	5.1E-07	4.1E-07	3.3E-07	3.1E-07
Pancreas	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Red Marrow	5.5E-06	2.5E-06	1.4E-06	1.4E-06	1.5E-06	9.2E-07
Respiratory Tract						
ET Airways	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.1E-07
Lungs	8.4E-07	7.6E-07	5.2E-07	4.1E-07	3.4E-07	3.2E-07
Skin	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
Spleen	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
Testes	8.5E-07	7.8E-07	5.5E-07	4.5E-07	3.3E-07	3.1E-07
Thymus	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
Thyroid	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Uterus	7.9E-07	7.3E-07	5.0E-07	3.9E-07	3.2E-07	3.1E-07
Remainder	9.9E-07	8.8E-07	5.8E-07	4.5E-07	3.6E-07	3.4E-07
Effective Dose	2.0E-06	1.3E-06	8.5E-07	7.5E-07	7.7E-07	5.2E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.5(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-235 (T½ = 7.04E+08 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Bladder Wall	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Bone Surface	1.4E-05	7.6E-06	5.5E-06	6.3E-06	1.0E-05	3.7E-06
Brain	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Breast	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
GI-Tract						
Oesophagus	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
St Wall	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
SI Wall	2.8E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
ULI Wall	3.3E-07	2.9E-07	2.0E-07	1.5E-07	1.3E-07	1.3E-07
LLI Wall	4.5E-07	3.7E-07	2.4E-07	1.7E-07	1.4E-07	1.4E-07
Colon	3.8E-07	3.2E-07	2.2E-07	1.6E-07	1.4E-07	1.3E-07
Kidneys	5.4E-06	4.2E-06	2.6E-06	1.7E-06	1.4E-06	1.3E-06
Liver	1.2E-06	1.1E-06	7.5E-07	5.5E-07	4.9E-07	4.9E-07
Muscle	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Ovaries	2.8E-07	2.5E-07	1.9E-07	1.5E-07	1.3E-07	1.3E-07
Pancreas	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Red Marrow	1.6E-06	8.4E-07	5.3E-07	5.1E-07	5.9E-07	3.8E-07
Respiratory Tract						
ET Airways	4.5E-05	3.5E-05	1.5E-05	1.0E-05	5.7E-06	5.6E-06
Lungs	1.0E-04	8.1E-05	5.0E-05	3.4E-05	2.9E-05	2.4E-05
Skin	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Spleen	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Testes	2.9E-07	2.7E-07	2.0E-07	1.6E-07	1.3E-07	1.3E-07
Thymus	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Thyroid	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Uterus	2.7E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Remainder	3.6E-07	3.1E-07	2.2E-07	1.7E-07	1.5E-07	1.4E-07
Effective Dose	1.3E-05	1.0E-05	6.3E-06	4.3E-06	3.7E-06	3.1E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.5(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-235 (T½ = 7.04E+08 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	5.1E-08	3.3E-08	2.6E-08	2.0E-08	1.9E-08	1.8E-08
Bladder Wall	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Bone Surface	2.0E-06	8.4E-07	7.8E-07	8.5E-07	1.0E-06	4.7E-07
Brain	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Breast	4.9E-08	3.2E-08	2.6E-08	2.0E-08	1.8E-08	1.8E-08
GI-Tract						
Oesophagus	4.9E-08	3.2E-08	2.6E-08	2.1E-08	1.9E-08	1.9E-08
St Wall	5.1E-08	3.2E-08	2.4E-08	1.9E-08	1.8E-08	1.7E-08
SI Wall	5.4E-08	3.3E-08	2.4E-08	1.8E-08	1.7E-08	1.6E-08
ULI Wall	1.1E-07	7.5E-08	4.3E-08	3.0E-08	2.3E-08	2.1E-08
LLI Wall	2.5E-07	1.7E-07	8.5E-08	5.5E-08	3.6E-08	3.3E-08
Colon	1.8E-07	1.2E-07	6.1E-08	4.1E-08	2.8E-08	2.6E-08
Kidneys	7.6E-07	3.7E-07	2.6E-07	1.9E-07	1.8E-07	1.8E-07
Liver	1.9E-07	1.1E-07	8.5E-08	6.6E-08	6.5E-08	6.7E-08
Muscle	4.5E-08	2.8E-08	2.2E-08	1.8E-08	1.7E-08	1.7E-08
Ovaries	4.3E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.5E-08
Pancreas	4.8E-08	3.1E-08	2.4E-08	1.9E-08	1.8E-08	1.7E-08
Red Marrow	2.2E-07	8.3E-08	6.8E-08	6.4E-08	6.4E-08	5.0E-08
Respiratory Tract						
ET Airways	1.9E-04	1.6E-04	7.9E-05	5.4E-05	3.3E-05	3.3E-05
Lungs	2.5E-04	2.2E-04	1.4E-04	9.2E-05	7.7E-05	7.0E-05
Skin	4.3E-08	2.6E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
Spleen	4.8E-08	3.1E-08	2.4E-08	1.9E-08	1.8E-08	1.7E-08
Testes	4.5E-08	2.6E-08	2.2E-08	1.8E-08	1.6E-08	1.5E-08
Thymus	4.9E-08	3.2E-08	2.6E-08	2.1E-08	1.9E-08	1.9E-08
Thyroid	4.5E-08	2.8E-08	2.2E-08	1.7E-08	1.7E-08	1.6E-08
Uterus	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Remainder	1.6E-07	9.9E-08	6.0E-08	4.5E-08	3.4E-08	3.4E-08
Effective Dose	3.0E-05	2.6E-05	1.7E-05	1.1E-05	9.2E-06	8.5E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.6(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-236 (T½ = 2.34E+07 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Bladder Wall	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Bone Surface	4.7E-05	2.2E-05	1.5E-05	1.7E-05	2.6E-05	9.0E-06
Brain	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Breast	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
GI-Tract						
Oesophagus	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
St Wall	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
SI Wall	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
ULI Wall	8.3E-07	7.6E-07	5.2E-07	4.0E-07	3.3E-07	3.2E-07
LLI Wall	8.8E-07	7.9E-07	5.3E-07	4.1E-07	3.4E-07	3.2E-07
Colon	8.5E-07	7.7E-07	5.2E-07	4.1E-07	3.3E-07	3.2E-07
Kidneys	1.7E-05	1.3E-05	7.2E-06	5.0E-06	3.6E-06	3.3E-06
Liver	3.6E-06	3.3E-06	2.1E-06	1.5E-06	1.3E-06	1.2E-06
Muscle	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Ovaries	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Pancreas	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Red Marrow	5.6E-06	2.6E-06	1.4E-06	1.4E-06	1.5E-06	9.3E-07
Respiratory Tract						
ET Airways	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Lungs	8.6E-07	7.8E-07	5.4E-07	4.2E-07	3.5E-07	3.3E-07
Skin	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Spleen	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Testes	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Thymus	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Thyroid	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Uterus	8.1E-07	7.4E-07	5.1E-07	4.0E-07	3.3E-07	3.2E-07
Remainder	1.0E-06	9.0E-07	5.9E-07	4.5E-07	3.7E-07	3.5E-07
Effective Dose	2.0E-06	1.3E-06	8.5E-07	7.5E-07	7.8E-07	5.3E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.6(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-236 ($T\frac{1}{2}$ = 2.34E+07 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Bladder Wall	2.7E-07	2.5E-07	1.9E-07	1.5E-07	1.3E-07	1.3E-07
Bone Surface	1.4E-05	7.6E-06	5.5E-06	6.4E-06	1.0E-05	3.7E-06
Brain	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Breast	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
GI-Tract						
Oesophagus	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
St Wall	2.8E-07	2.5E-07	1.9E-07	1.5E-07	1.3E-07	1.3E-07
SI Wall	2.8E-07	2.6E-07	1.9E-07	1.5E-07	1.3E-07	1.3E-07
ULI Wall	3.3E-07	2.9E-07	2.0E-07	1.5E-07	1.4E-07	1.3E-07
LLI Wall	4.3E-07	3.6E-07	2.3E-07	1.7E-07	1.4E-07	1.4E-07
Colon	3.7E-07	3.2E-07	2.2E-07	1.6E-07	1.4E-07	1.4E-07
Kidneys	5.5E-06	4.3E-06	2.6E-06	1.8E-06	1.4E-06	1.3E-06
Liver	1.2E-06	1.1E-06	7.7E-07	5.6E-07	5.0E-07	5.1E-07
Muscle	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Ovaries	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Pancreas	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Red Marrow	1.6E-06	8.5E-07	5.4E-07	5.2E-07	6.0E-07	3.8E-07
Respiratory Tract						
ET Airways	4.6E-05	3.6E-05	1.6E-05	1.1E-05	5.9E-06	5.7E-06
Lungs	1.1E-04	8.3E-05	5.2E-05	3.5E-05	3.0E-05	2.5E-05
Skin	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Spleen	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Testes	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Thymus	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Thyroid	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Uterus	2.7E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
Remainder	3.7E-07	3.2E-07	2.2E-07	1.7E-07	1.5E-07	1.4E-07
Effective Dose	1.4E-05	1.0E-05	6.5E-06	4.5E-06	3.9E-06	3.2E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.6(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-236 (T½ = 2.34E+07 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Bladder Wall	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Bone Surface	2.0E-06	8.4E-07	7.9E-07	8.6E-07	1.0E-06	4.8E-07
Brain	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Breast	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
GI-Tract						
Oesophagus	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
St Wall	4.7E-08	2.7E-08	2.1E-08	1.7E-08	1.6E-08	1.6E-08
SI Wall	5.3E-08	3.2E-08	2.3E-08	1.8E-08	1.7E-08	1.6E-08
ULI Wall	1.1E-07	6.9E-08	4.0E-08	2.8E-08	2.2E-08	2.0E-08
LLI Wall	2.3E-07	1.5E-07	7.6E-08	5.0E-08	3.3E-08	3.0E-08
Colon	1.6E-07	1.0E-07	5.6E-08	3.7E-08	2.7E-08	2.5E-08
Kidneys	7.8E-07	3.8E-07	2.7E-07	1.9E-07	1.8E-07	1.8E-07
Liver	1.8E-07	1.0E-07	8.2E-08	6.4E-08	6.3E-08	6.6E-08
Muscle	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Ovaries	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Pancreas	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Red Marrow	2.2E-07	8.1E-08	6.7E-08	6.3E-08	6.3E-08	4.9E-08
Respiratory Tract						
ET Airways	1.9E-04	1.6E-04	8.1E-05	5.6E-05	3.4E-05	3.4E-05
Lungs	2.6E-04	2.3E-04	1.5E-04	9.4E-05	7.9E-05	7.2E-05
Skin	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Spleen	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Testes	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Thymus	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Thyroid	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Uterus	4.2E-08	2.5E-08	2.0E-08	1.6E-08	1.6E-08	1.5E-08
Remainder	1.6E-07	9.8E-08	5.9E-08	4.4E-08	3.3E-08	3.4E-08
Effective Dose	3.1E-05	2.7E-05	1.8E-05	1.1E-05	9.5E-06	8.7E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.7(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-238 ($T½$ = 4.47E+09 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Bladder Wall	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Bone Surface	4.5E-05	2.1E-05	1.4E-05	1.6E-05	2.4E-05	8.7E-06
Brain	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Breast	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
GI-Tract						
Oesophagus	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
St Wall	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
SI Wall	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
ULI Wall	7.8E-07	7.1E-07	4.9E-07	3.8E-07	3.1E-07	3.0E-07
LLI Wall	8.3E-07	7.4E-07	5.0E-07	3.9E-07	3.2E-07	3.0E-07
Colon	8.0E-07	7.3E-07	4.9E-07	3.8E-07	3.1E-07	3.0E-07
Kidneys	1.6E-05	1.2E-05	6.8E-06	4.6E-06	3.4E-06	3.1E-06
Liver	3.3E-06	3.1E-06	2.0E-06	1.5E-06	1.2E-06	1.2E-06
Muscle	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Ovaries	7.8E-07	7.2E-07	4.9E-07	3.9E-07	3.1E-07	3.0E-07
Pancreas	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Red Marrow	5.4E-06	2.5E-06	1.4E-06	1.4E-06	1.5E-06	9.1E-07
Respiratory Tract						
ET Airways	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Lungs	8.1E-07	7.3E-07	5.0E-07	3.9E-07	3.3E-07	3.1E-07
Skin	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Spleen	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Testes	8.2E-07	7.5E-07	5.3E-07	4.3E-07	3.2E-07	3.0E-07
Thymus	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Thyroid	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Uterus	7.6E-07	7.0E-07	4.8E-07	3.8E-07	3.1E-07	3.0E-07
Remainder	9.5E-07	8.4E-07	5.6E-07	4.3E-07	3.4E-07	3.3E-07
Effective Dose	1.9E-06	1.3E-06	8.2E-07	7.3E-07	7.4E-07	5.0E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.7(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-238 (T½ = 4.47E+09 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.04	0.02	0.02	0.02	0.02	0.02
Adrenals	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Bladder Wall	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Bone Surface	1.3E-05	7.3E-06	5.3E-06	6.1E-06	9.7E-06	3.5E-06
Brain	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Breast	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
GI-Tract						
Oesophagus	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
St Wall	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
SI Wall	2.7E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
ULI Wall	3.1E-07	2.7E-07	1.9E-07	1.5E-07	1.3E-07	1.3E-07
LLI Wall	4.2E-07	3.5E-07	2.2E-07	1.6E-07	1.4E-07	1.3E-07
Colon	3.6E-07	3.1E-07	2.1E-07	1.5E-07	1.3E-07	1.3E-07
Kidneys	5.1E-06	4.1E-06	2.5E-06	1.7E-06	1.3E-06	1.3E-06
Liver	1.1E-06	1.0E-06	7.2E-07	5.2E-07	4.7E-07	4.8E-07
Muscle	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Ovaries	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Pancreas	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Red Marrow	1.6E-06	8.5E-07	5.3E-07	5.1E-07	5.9E-07	3.7E-07
Respiratory Tract						
ET Airways	4.2E-05	3.3E-05	1.4E-05	9.6E-06	5.4E-06	5.2E-06
Lungs	9.8E-05	7.5E-05	4.7E-05	3.1E-05	2.6E-05	2.2E-05
Skin	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Spleen	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Testes	2.8E-07	2.6E-07	2.0E-07	1.6E-07	1.3E-07	1.2E-07
Thymus	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Thyroid	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Uterus	2.6E-07	2.4E-07	1.8E-07	1.4E-07	1.2E-07	1.2E-07
Remainder	3.4E-07	3.0E-07	2.1E-07	1.6E-07	1.4E-07	1.4E-07
Effective Dose	1.2E-05	9.4E-06	5.9E-06	4.0E-06	3.4E-06	2.9E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.27.7(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for U-238 (T½ = 4.47E+09 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.02	0.002	0.002	0.002	0.002	0.002
Adrenals	4.1E-08	2.5E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Bladder Wall	4.0E-08	2.3E-08	1.9E-08	1.5E-08	1.5E-08	1.5E-08
Bone Surface	1.9E-06	8.1E-07	7.5E-07	8.2E-07	9.6E-07	4.6E-07
Brain	4.0E-08	2.3E-08	1.9E-08	1.5E-08	1.5E-08	1.4E-08
Breast	4.1E-08	2.4E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
GI-Tract						
Oesophagus	4.1E-08	2.4E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
St Wall	4.5E-08	2.7E-08	2.1E-08	1.6E-08	1.5E-08	1.5E-08
SI Wall	5.1E-08	3.1E-08	2.3E-08	1.7E-08	1.6E-08	1.6E-08
ULI Wall	1.1E-07	7.3E-08	4.2E-08	2.9E-08	2.2E-08	2.1E-08
LLI Wall	2.4E-07	1.7E-07	8.5E-08	5.4E-08	3.7E-08	3.3E-08
Colon	1.7E-07	1.1E-07	6.0E-08	4.0E-08	2.8E-08	2.6E-08
Kidneys	7.3E-07	3.5E-07	2.5E-07	1.8E-07	1.7E-07	1.7E-07
Liver	1.7E-07	9.9E-08	7.8E-08	6.1E-08	6.0E-08	6.2E-08
Muscle	4.0E-08	2.4E-08	1.9E-08	1.5E-08	1.5E-08	1.5E-08
Ovaries	4.1E-08	2.4E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Pancreas	4.1E-08	2.4E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Red Marrow	2.2E-07	8.2E-08	6.7E-08	6.2E-08	6.3E-08	4.9E-08
Respiratory Tract						
ET Airways	1.8E-04	1.5E-04	7.4E-05	5.1E-05	3.1E-05	3.1E-05
Lungs	2.4E-04	2.1E-04	1.3E-04	8.7E-05	7.3E-05	6.7E-05
Skin	4.0E-08	2.3E-08	1.9E-08	1.5E-08	1.5E-08	1.5E-08
Spleen	4.1E-08	2.4E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Testes	4.3E-08	2.5E-08	2.1E-08	1.7E-08	1.5E-08	1.5E-08
Thymus	4.1E-08	2.4E-08	2.0E-08	1.6E-08	1.5E-08	1.5E-08
Thyroid	4.0E-08	2.4E-08	1.9E-08	1.5E-08	1.5E-08	1.5E-08
Uterus	4.0E-08	2.3E-08	1.9E-08	1.5E-08	1.5E-08	1.4E-08
Remainder	1.4E-07	9.0E-08	5.5E-08	4.1E-08	3.1E-08	3.1E-08
Effective Dose	2.9E-05	2.5E-05	1.6E-05	1.0E-05	8.7E-06	8.0E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for U parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.28. Neptunium

(253) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides, oxides, and hydroxides of neptunium (Np) to inhalation Class Y, nitrates to Class W, and by default, all other compounds of the element to Class D (see Paragraph 54). In *ICRP Publication 30*, Part 2 (ICRP, 1980), all compounds of neptunium were assigned to Class W.

Absorption Types

(254) Qualitative data on global fallout suggest that ^{237}Np in the human lung is lost preferentially to ^{239}Pu (Efurd *et al.*, 1986), which indicates Type M behaviour. Animal data on inhaled neptunium are limited to the rat.

(255) The rat studies reported by Lyubchanskii and Levdik (1972) and reviewed by Moskalev *et al.* (1975, 1979) included inhalation of $^{237}Np(V,VI)$ nitrate, and $^{237}Np(IV)$ oxalate aerosols. The nitrate was eliminated from the lungs more rapidly than the oxalate. A simple two-compartment retention model showed 26% of the nitrate being lost with a half-time of 15.4 d and 8.1% with a half-time of 168 d. For the oxalate, 43.8% was lost with a half-time of 22.3 d and 22.6% with a half-time of 151 d. Retention of neptunium was similar to that in parallel experiments with several soluble forms of plutonium, whereas clearance of americium compounds was more rapid. In other studies in rats exposed to aerosols of $^{237}Np(V)$ nitrate, lung clearance followed a three-compartment model with half-times of 1, 35, and 10 000 d (Sullivan *et al.*, 1986). The percentage of initial lung deposit retained at 4, 28 and 90 d was 23, 12.6 and 2.5, respectively, and was not greatly different from the results of Lyubchanskii and Levdik (1972). In contrast to the earlier work of Ballou *et al.* (1962) and Bair *et al.* (1963), which employed larger masses of inhaled ^{237}Np-contaminated "industrial dust", average lung retention values in the Sullivan *et al.* (1986) experiments were higher; 12% at 4 d and 8.5% at 4 weeks. These results are consistent with the assignment of nitrate and oxalate to Type M.

Dose coefficients

(256) Dose coefficients (given in Tables 5.28.2 and 5.28.3) were derived using the f_1 values given in Table 5.28.1, and the biokinetic data in *ICRP Publication 67* (ICRP, 1993).

Table 5.28.1. Values of f_1 for inhaled particulate compounds of neptunium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.005	5×10^{-4}
M[b]	0.005	5×10^{-4}
S	0.005	5×10^{-4}

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.28.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Np-237 (T½ = 2.14E+06 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Bladder Wall	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
Bone Surface	2.5E-03	2.6E-03	1.9E-03	1.9E-03	2.2E-03	2.6E-03
Brain	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Breast	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
GI-Tract						
Oesophagus	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
St Wall	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
SI Wall	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
ULI Wall	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
LLI Wall	1.5E-05	1.3E-05	8.1E-06	6.0E-06	4.5E-06	3.5E-06
Colon	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Kidneys	6.0E-05	5.0E-05	2.6E-05	1.7E-05	1.2E-05	9.4E-06
Liver	1.1E-04	9.7E-05	6.6E-05	4.6E-05	3.6E-05	4.2E-05
Muscle	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Ovaries	5.8E-05	6.1E-05	5.3E-05	4.9E-05	4.5E-05	3.5E-05
Pancreas	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Red Marrow	3.7E-04	3.3E-04	1.8E-04	1.2E-04	9.8E-05	1.0E-04
Respiratory Tract						
ET Airways	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Lungs	1.5E-05	1.3E-05	8.1E-06	6.0E-06	4.5E-06	3.5E-06
Skin	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
Spleen	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
Testes	6.9E-05	7.2E-05	4.7E-05	4.0E-05	4.5E-05	3.6E-05
Thymus	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.4E-06
Thyroid	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Uterus	1.5E-05	1.3E-05	8.0E-06	5.9E-06	4.5E-06	3.5E-06
Remainder	1.5E-05	1.4E-05	8.2E-06	6.1E-06	4.6E-06	3.5E-06
Effective Dose	9.8E-05	9.3E-05	6.0E-05	5.0E-05	4.7E-05	5.0E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Np parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.28.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Np-237 (T½ = 2.14E+06 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Bladder Wall	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Bone Surface	7.9E-04	8.3E-04	6.8E-04	6.7E-04	8.5E-04	1.0E-03
Brain	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Breast	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
GI-Tract						
Oesophagus	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
St Wall	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
SI Wall	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
ULI Wall	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
LLI Wall	4.7E-06	4.4E-06	2.8E-06	2.1E-06	1.7E-06	1.4E-06
Colon	4.6E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.4E-06
Kidneys	1.7E-05	1.6E-05	8.9E-06	5.7E-06	4.5E-06	3.7E-06
Liver	3.2E-05	3.1E-05	2.3E-05	1.6E-05	1.4E-05	1.6E-05
Muscle	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Ovaries	1.8E-05	2.0E-05	1.9E-05	1.7E-05	1.7E-05	1.4E-05
Pancreas	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Red Marrow	1.1E-04	1.0E-04	6.3E-05	4.2E-05	3.7E-05	3.9E-05
Respiratory Tract						
ET Airways	5.3E-05	4.2E-05	1.9E-05	1.3E-05	7.8E-06	7.2E-06
Lungs	1.2E-04	9.4E-05	5.9E-05	4.0E-05	3.4E-05	2.9E-05
Skin	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Spleen	4.5E-06	4.3E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Testes	2.2E-05	2.3E-05	1.7E-05	1.5E-05	1.7E-05	1.4E-05
Thymus	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Thyroid	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Uterus	4.5E-06	4.2E-06	2.8E-06	2.0E-06	1.7E-06	1.3E-06
Remainder	4.7E-06	4.4E-06	2.9E-06	2.1E-06	1.7E-06	1.4E-06
Effective Dose	4.4E-05	4.0E-05	2.8E-05	2.2E-05	2.2E-05	2.3E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Np parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.28.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Np-237 (T½ = 2.14E+06 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	4.7E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
Bladder Wall	4.5E-07	3.8E-07	2.8E-07	2.1E-07	1.8E-07	1.6E-07
Bone Surface	1.1E-04	1.0E-04	9.6E-05	9.8E-05	1.2E-04	1.3E-04
Brain	4.5E-07	3.8E-07	2.8E-07	2.1E-07	1.8E-07	1.6E-07
Breast	4.6E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
GI-Tract						
Oesophagus	4.6E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
St Wall	4.6E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
SI Wall	4.7E-07	3.9E-07	2.9E-07	2.1E-07	1.8E-07	1.6E-07
ULI Wall	5.3E-07	4.3E-07	3.1E-07	2.2E-07	1.9E-07	1.6E-07
LLI Wall	6.7E-07	5.3E-07	3.5E-07	2.5E-07	2.0E-07	1.8E-07
Colon	5.9E-07	4.7E-07	3.2E-07	2.3E-07	2.0E-07	1.7E-07
Kidneys	1.6E-06	1.3E-06	8.6E-07	5.9E-07	5.3E-07	4.8E-07
Liver	3.5E-06	3.0E-06	2.4E-06	1.9E-06	1.9E-06	2.2E-06
Muscle	4.6E-07	3.8E-07	2.8E-07	2.1E-07	1.9E-07	1.6E-07
Ovaries	2.5E-06	2.4E-06	2.2E-06	1.9E-06	1.9E-06	1.7E-06
Pancreas	4.6E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
Red Marrow	1.1E-05	9.0E-06	6.5E-06	4.9E-06	4.8E-06	5.1E-06
Respiratory Tract						
ET Airways	2.0E-04	1.7E-04	8.6E-05	5.9E-05	3.6E-05	3.6E-05
Lungs	2.8E-04	2.4E-04	1.6E-04	1.0E-04	8.6E-05	7.9E-05
Skin	4.5E-07	3.8E-07	2.8E-07	2.1E-07	1.8E-07	1.6E-07
Spleen	4.6E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
Testes	2.6E-06	2.4E-06	2.0E-06	1.9E-06	1.9E-06	1.8E-06
Thymus	4.6E-07	3.9E-07	2.9E-07	2.1E-07	1.9E-07	1.6E-07
Thyroid	4.6E-07	3.8E-07	2.8E-07	2.1E-07	1.8E-07	1.6E-07
Uterus	4.5E-07	3.8E-07	2.8E-07	2.1E-07	1.8E-07	1.6E-07
Remainder	5.8E-07	4.6E-07	3.3E-07	2.4E-07	2.1E-07	1.8E-07
Effective Dose	3.7E-05	3.2E-05	2.1E-05	1.4E-05	1.3E-05	1.2E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Np parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.28.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Np-239 (T½ = 2.36 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.6E-10	1.8E-10	8.5E-11	5.4E-11	3.5E-11	3.0E-11
Bladder Wall	3.2E-10	2.4E-10	1.8E-10	1.3E-10	1.0E-10	1.0E-10
Bone Surface	1.8E-08	1.5E-08	8.3E-09	4.6E-09	3.1E-09	2.7E-09
Brain	2.2E-10	1.5E-10	7.1E-11	4.4E-11	2.8E-11	2.3E-11
Breast	2.1E-10	1.4E-10	6.4E-11	3.9E-11	2.4E-11	2.0E-11
GI-Tract						
Oesophagus	2.8E-10	1.9E-10	8.2E-11	4.8E-11	2.9E-11	2.3E-11
St Wall	7.7E-10	4.5E-10	1.9E-10	1.2E-10	6.6E-11	5.5E-11
SI Wall	1.5E-09	9.7E-10	4.1E-10	2.6E-10	1.3E-10	1.1E-10
ULI Wall	6.4E-09	4.2E-09	1.7E-09	1.1E-09	4.8E-10	4.0E-10
LLI Wall	1.4E-08	8.9E-09	3.7E-09	2.2E-09	1.0E-09	8.6E-10
Colon	9.5E-09	6.2E-09	2.6E-09	1.6E-09	7.1E-10	6.0E-10
Kidneys	1.3E-09	8.4E-10	4.2E-10	2.8E-10	1.9E-10	1.6E-10
Liver	5.2E-10	3.8E-10	2.7E-10	1.7E-10	1.2E-10	1.7E-10
Muscle	2.5E-10	1.7E-10	7.9E-11	4.9E-11	3.0E-11	2.5E-11
Ovaries	3.2E-10	2.5E-10	1.5E-10	1.2E-10	7.4E-11	6.2E-11
Pancreas	2.5E-10	1.7E-10	8.2E-11	5.2E-11	3.3E-11	2.8E-11
Red Marrow	3.7E-09	2.2E-09	1.1E-09	5.7E-10	3.5E-10	2.4E-10
Respiratory Tract						
ET Airways	2.0E-08	1.5E-08	7.0E-09	4.3E-09	2.4E-09	2.1E-09
Lungs	3.7E-10	2.6E-10	1.4E-10	9.7E-11	8.1E-11	6.4E-11
Skin	2.1E-10	1.4E-10	6.4E-11	3.9E-11	2.4E-11	2.0E-11
Spleen	2.4E-10	1.6E-10	7.6E-11	4.7E-11	2.9E-11	2.4E-11
Testes	1.6E-10	1.4E-10	8.9E-11	7.6E-11	7.4E-11	4.5E-11
Thymus	2.8E-10	1.9E-10	8.2E-11	4.8E-11	2.9E-11	2.3E-11
Thyroid	2.2E-10	1.5E-10	7.0E-11	4.3E-11	2.8E-11	2.3E-11
Uterus	2.8E-10	2.0E-10	9.5E-11	6.1E-11	3.7E-11	3.1E-11
Remainder	1.0E-08	2.0E-10	9.2E-11	5.7E-11	3.5E-11	2.9E-11
Effective Dose	2.6E-09	1.4E-09	6.3E-10	3.8E-10	2.1E-10	1.7E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Np parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.28.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Np-239 ($T½$ = 2.36 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.1E-10	8.3E-11	4.4E-11	2.7E-11	1.9E-11	1.5E-11
Bladder Wall	1.2E-10	8.5E-11	4.8E-11	3.4E-11	2.1E-11	2.0E-11
Bone Surface	2.0E-09	1.6E-09	9.3E-10	5.1E-10	3.6E-10	5.1E-10
Brain	3.3E-11	2.2E-11	1.2E-11	7.8E-12	5.1E-12	4.8E-12
Breast	8.1E-11	6.1E-11	3.7E-11	2.4E-11	1.4E-11	1.3E-11
GI-Tract						
Oesophagus	1.4E-10	1.0E-10	5.0E-11	3.2E-11	2.1E-11	1.7E-11
St Wall	1.2E-09	6.6E-10	2.8E-10	1.6E-10	9.4E-11	7.5E-11
SI Wall	2.5E-09	1.7E-09	7.0E-10	4.3E-10	2.0E-10	1.7E-10
ULI Wall	1.2E-08	8.0E-09	3.3E-09	2.0E-09	9.4E-10	7.7E-10
LLI Wall	2.7E-08	1.7E-08	7.2E-09	4.4E-09	2.1E-09	1.7E-09
Colon	1.9E-08	1.2E-08	5.0E-09	3.0E-09	1.4E-09	1.2E-09
Kidneys	2.0E-10	1.3E-10	6.7E-11	4.4E-11	3.0E-11	2.5E-11
Liver	1.4E-10	1.0E-10	6.2E-11	4.0E-11	2.8E-11	3.3E-11
Muscle	9.9E-11	7.1E-11	3.5E-11	2.2E-11	1.4E-11	1.2E-11
Ovaries	3.1E-10	2.3E-10	1.1E-10	7.9E-11	4.4E-11	3.7E-11
Pancreas	1.2E-10	8.6E-11	4.4E-11	2.8E-11	1.8E-11	1.5E-11
Red Marrow	4.5E-10	2.7E-10	1.4E-10	7.8E-11	5.3E-11	4.5E-11
Respiratory Tract						
ET Airways	2.4E-08	1.8E-08	8.1E-09	5.0E-09	2.8E-09	2.5E-09
Lungs	2.3E-08	1.7E-08	1.1E-08	8.4E-09	8.1E-09	6.3E-09
Skin	4.9E-11	3.3E-11	1.6E-11	1.0E-11	6.2E-12	5.7E-12
Spleen	1.0E-10	7.4E-11	3.8E-11	2.4E-11	1.6E-11	1.3E-11
Testes	5.2E-11	3.9E-11	1.9E-11	1.5E-11	1.1E-11	1.0E-11
Thymus	1.4E-10	1.0E-10	5.0E-11	3.2E-11	2.1E-11	1.7E-11
Thyroid	5.6E-11	4.2E-11	2.3E-11	1.4E-11	9.3E-12	8.2E-12
Uterus	1.6E-10	1.2E-10	5.8E-11	3.9E-11	2.1E-11	1.7E-11
Remainder	1.2E-08	9.1E-09	4.8E-11	3.2E-11	1.9E-11	1.6E-11
Effective Dose	5.9E-09	4.2E-09	2.0E-09	1.4E-09	1.2E-09	9.3E-10

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Np parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.28.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Np-239 (T½ = 2.36 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	9.5E-11	7.2E-11	3.9E-11	2.4E-11	1.7E-11	1.3E-11
Bladder Wall	9.1E-11	6.7E-11	3.3E-11	2.2E-11	1.2E-11	9.9E-12
Bone Surface	2.2E-10	1.0E-10	5.0E-11	3.1E-11	2.5E-11	5.4E-11
Brain	1.1E-11	7.2E-12	4.5E-12	3.5E-12	2.4E-12	2.3E-12
Breast	6.7E-11	5.3E-11	3.4E-11	2.3E-11	1.3E-11	1.2E-11
GI-Tract						
Oesophagus	1.2E-10	9.3E-11	4.7E-11	3.0E-11	2.0E-11	1.6E-11
St Wall	1.2E-09	6.8E-10	2.8E-10	1.7E-10	9.7E-11	7.7E-11
SI Wall	2.6E-09	1.7E-09	7.3E-10	4.5E-10	2.1E-10	1.8E-10
ULI Wall	1.3E-08	8.4E-09	3.5E-09	2.1E-09	9.9E-10	8.1E-10
LLI Wall	2.8E-08	1.8E-08	7.6E-09	4.6E-09	2.2E-09	1.8E-09
Colon	1.9E-08	1.3E-08	5.3E-09	3.2E-09	1.5E-09	1.2E-09
Kidneys	6.9E-11	4.7E-11	2.5E-11	1.6E-11	1.0E-11	7.9E-12
Liver	9.6E-11	7.1E-11	3.8E-11	2.4E-11	1.6E-11	1.4E-11
Muscle	8.1E-11	6.0E-11	3.0E-11	1.9E-11	1.2E-11	1.0E-11
Ovaries	3.1E-10	2.2E-10	1.1E-10	7.4E-11	4.0E-11	3.2E-11
Pancreas	1.0E-10	7.6E-11	3.9E-11	2.5E-11	1.7E-11	1.3E-11
Red Marrow	7.1E-11	4.2E-11	2.6E-11	2.0E-11	1.4E-11	1.4E-11
Respiratory Tract						
ET Airways	2.5E-08	1.8E-08	8.2E-09	5.1E-09	2.9E-09	2.5E-09
Lungs	2.5E-08	1.9E-08	1.2E-08	9.4E-09	9.1E-09	7.1E-09
Skin	3.0E-11	2.1E-11	1.0E-11	6.7E-12	4.2E-12	3.7E-12
Spleen	8.3E-11	6.4E-11	3.4E-11	2.1E-11	1.4E-11	1.1E-11
Testes	3.9E-11	2.7E-11	1.1E-11	7.5E-12	3.4E-12	3.0E-12
Thymus	1.2E-10	9.3E-11	4.7E-11	3.0E-11	2.0E-11	1.6E-11
Thyroid	3.8E-11	3.0E-11	1.7E-11	1.1E-11	7.2E-12	6.2E-12
Uterus	1.5E-10	1.1E-10	5.4E-11	3.6E-11	1.9E-11	1.5E-11
Remainder	1.3E-10	8.7E-11	4.3E-11	2.9E-11	1.7E-11	1.4E-11
Effective Dose	5.6E-09	4.0E-09	2.2E-09	1.6E-09	1.3E-09	1.0E-09

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Np parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.29. Plutonium

(257) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides, oxides and hydroxides of plutonium (Pu), to inhalation Class Y, and nitrates to Class W. By default other unspecified compounds were assigned to Class D (see Paragraph 54).

(258) *ICRP Publication 19* (ICRP, 1972) provided a comprehensive review of the literature up to 1971 relating to the biokinetics of plutonium, with entry by inhalation considered in detail. For PuO_2 there was a substantial amount of data from dogs, as well as from rodents. Data were also available for a variety of other compounds, including nitrate, citrate, chloride and ammonium plutonium pentacarbonate, mainly for rats. It was recommended that in view of the ready hydrolysis of most soluble compounds at physiological pH, none should be considered Class D, except those stable enough to remain soluble under physiological conditions, e.g. the DTPA chelate.

(259) *ICRP Publication 30*, Part 1 (ICRP, 1979), taking *ICRP Publication 19* and later reviews into account, assigned PuO_2 to Class Y, and all other commonly occurring compounds of plutonium to Class W. Chelated forms of plutonium were specifically excluded from the report, because their behaviour after uptake to blood is different from that described in the biokinetic model that applies to intakes from all other forms.

(260) *ICRP Publication 48* (ICRP, 1986) provided a further review of the literature relating to the biokinetics of plutonium (and related elements). This complemented *ICRP Publication 19* by placing emphasis on the more recent data available, especially that derived from human tissues taken at autopsy. Generally the assignment of the oxide to Class Y and other commonly occurring compounds to Class W was supported, and this was retained in *ICRP Publication 30*, Part 4 (ICRP, 1988). The desirability of using material-specific information was, however, strongly re-emphasized.

Absorption Types

(a) *Simple compounds*

(261) Of the variety of more soluble compounds, the nitrate and tributyl–phosphate (Pu–TBP) complexes are of particular importance in industrial processes. Results of biokinetic studies of plutonium nitrate following intratracheal instillation into rats, and inhalation by rats, dogs or monkeys are consistent with assignment to Type M (Stather and Howden, 1975; Brooks *et al.*, 1981; Dagle *et al.*, 1983; Stradling *et al.*, 1987; Moody *et al.*, 1994). Measurements following inhalation of Pu–TBP by rats and baboons are also consistent with assignment to Type M (Stradling *et al.*, 1985; Métivier *et al.*, 1989). The importance of the mass of plutonium deposited in the lung has been recognized for both materials, as absorption can be inhibited by relatively high mass loadings, possibly because of colloid formation (Nolibé *et al.*, 1989). Such mass effects are not considered to be of concern for exposures to environmental levels of plutonium.

(262) The various oxide forms of plutonium have been the most thoroughly studied of actinide aerosols. Generally, two distinct phases of absorption to blood from the respiratory tract are exhibited. A small fraction, typically less than 1%, is absorbed within about a day, with the remainder being cleared from the lung with half-times of the order of years (absorption rate of the order of 10^{-4} d^{-1}) (ICRP, 1972, 1986). Both the fraction rapidly absorbed and the long-term retention half-time can be influenced by the method of formation of the material and its history. Plutonium-239* dioxide, formed by complete oxidation of the

*Where reference is made to ^{239}Pu, this may well include ^{240}Pu.

metal or a salt at about 1 000°C (high-fired), for example, has repeatedly demonstrated the very low absorption generally associated with PuO_2 (Type S) (Bair *et al.*, 1980; Morgan *et al.*, 1988a). Material formed at lower temperatures was more readily absorbed (Type M), reflecting incomplete oxidation of the plutonium (Mewhinney *et al.*, 1976).

(263) Studies in several animal species have demonstrated Type S behaviour of $^{239}PuO_2$. Measurements following inhalation of high fired polydisperse $^{239}PuO_2$ by baboons, rhesus monkeys and dogs indicate Type S behaviour (Bair *et al.*, 1980; LaBauve *et al.*, 1980), as do data from dogs that inhaled monodisperse particles (0.72, 1.4, and 2.8 μm AMAD) (Guilmette *et al.*, 1984, 1987). These data are in general agreement with observed lung retention patterns of $^{239}PuO_2$ in exposed workers (Ramsden, 1976, 1984; Ramsden *et al.*, 1978; Spitz and Robinson, 1981; Carbaugh *et al.*, 1991; Foster, 1991).

(264) Bioassay data from accidentally exposed workers as well as data from experimental studies have shown a much greater rate of absorption of plutonium to blood following inhalation of $^{238}PuO_2$ compared with that of $^{239}PuO_2$. This has been attributed to radiolytic fragmentation of the particles due to the high specific activity of ^{238}Pu (Fleisher and Raabe 1977; Diel and Mewhinney, 1981). Thus, the lung retention and absorption to blood of ^{238}Pu in dogs inhaling the dioxide form (Mewhinney and Diel, 1983; Park *et al.*, 1986a,b) were consistent with Type M. Similarly, workers inhaling purported oxide or "ceramic" forms of ^{238}Pu showed urinary excretion patterns leading to inferred lung retention patterns also indicative of Type M (Guilmette *et al.* 1994; Hickman *et al.* 1995). On the other hand, some cases of exposure to ^{238}Pu oxide have been more consistent with data from workers exposed to $^{239}PuO_2$, i.e. more consistent with Type S solubility (Fleming and Hall, 1978; Newton *et al.*, 1983).

(265) Plutonium can have different lung clearance characteristics when inhaled as a mixed metal oxide. A higher rate of absorption of plutonium to blood was observed in rats exposed to oxides containing plutonium mixed with sodium, potassium, calcium or magnesium (Stather *et al.*, 1979; Métivier *et al.*, 1980). The extent of increased dissolution/clearance depended on the metal and the relative proportions of plutonium to metal. In general these data support the assignment of Type M.

(266) In contrast, plutonium inhaled as a mixed plutonium–uranium oxide may be absorbed no more readily than from high-fired pure PuO_2. Results of experiments in which rats, dogs and monkeys inhaled aerosols consisting of mixtures of UO_2 and PuO_2 particles derived from feedstock for a mixed oxide reactor fuel were consistent with assignment of the plutonium present to Type S, even though the PuO_2 had been heat treated at different temperatures ranging from 750–1 750°C (Stanley *et al.*, 1980a, 1980b, 1982). Similarly, inhalation of uranium–plutonium mixed oxides in solid solution by monkeys, dogs and rats (Mewhinney and Eidson, 1983) or by baboons and rats (Lataillade *et al.*, 1995) resulted in lung clearance patterns indistinguishable from those for PuO_2, therefore also supporting Type S behaviour.

(b) *Environmental forms*

(267) There have been a number of studies of plutonium released into the environment. Plutonium discharged to sea can become attached to sediment, which has potential for resuspension in air. Following intra-tracheal instillation of ^{239}Pu-labelled sediment into rats and hamsters, the behaviour of the plutonium was consistent with assignment to Type M (Stather *et al.*, 1978; Morgan *et al.*, 1988b, 1990).

(268) Numerous measurements have been made of the concentration of ^{239}Pu, resulting from the atmospheric testing of nuclear weapons, in tissues (notably lung, liver, skeleton and

tracheo-bronchial lymph nodes) taken at autopsy from non-occupationally exposed people. Comparisons with levels predicted from measured air concentrations using the then current ICRP models were broadly consistent with Class Y (Bennett, 1976; McInroy *et al.*, 1981; ICRP, 1986).

(269) Soils and dusts contaminated in the 1960s with plutonium from nuclear weapons tests, and from a weapons accident (Iranzo *et al.*, 1987), have recently been administered by intra-tracheal instillation and/or inhalation into rats (Stradling *et al.*, 1992, 1993). Rates of absorption of plutonium from the dusts varied considerably. Of three different dust samples contaminated with plutonium and americium obtained from a nuclear weapons testing site in South Australia, behaviour of the plutonium in two was consistent with assignment to Type S, and that in the third to Type M (Stradling *et al.*, 1992). It is of interest that in these studies the plutonium remained mainly in insoluble forms even after two or three decades of environmental exposure. Mewhinney *et al.* (1987) found with *in vitro* dissolution tests, that alternate wet–dry cycling, simulating that occurring under environmental conditions such as intermittent rainfall in an otherwise arid climate, led to much faster dissolution than during continuous immersion in the same solvents.

Dose coefficients

(270) Studies of common chemical forms showing characteristics of absorption Types M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.29.2–5) were derived for the f_1 values given in Table 5.29.1 and the biokinetic data given in *ICRP Publication 67* (ICRP, 1993).

Table 5.29.1. Values of f_1 for inhaled particulate compounds of plutonium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.005	5×10^{-4}
M[b]	0.005	5×10^{-4}
S	1×10^{-4}	1×10^{-5}

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.
[b] Default Type M is recommended for use in the absence of specific information.

Table 5.29.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-238 (T½ = 87.7 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Bladder Wall	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Bone Surface	3.4E-03	3.6E-03	3.0E-03	2.8E-03	3.0E-03	3.6E-03
Brain	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Breast	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
GI-Tract						
Oesophagus	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
St Wall	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
SI Wall	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
ULI Wall	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
LLI Wall	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Colon	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Kidneys	7.5E-05	6.3E-05	3.5E-05	2.4E-05	1.8E-05	1.5E-05
Liver	1.3E-03	1.3E-03	1.1E-03	8.4E-04	7.1E-04	7.5E-04
Muscle	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Ovaries	7.2E-05	7.5E-05	6.8E-05	6.0E-05	5.5E-05	4.7E-05
Pancreas	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Red Marrow	5.6E-04	5.0E-04	2.7E-04	1.9E-04	1.6E-04	1.8E-04
Respiratory Tract						
ET Airways	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Lungs	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.4E-06	6.3E-06
Skin	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Spleen	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Testes	8.3E-05	8.7E-05	6.4E-05	5.3E-05	5.6E-05	4.8E-05
Thymus	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Thyroid	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Uterus	2.6E-05	2.3E-05	1.4E-05	9.7E-06	7.3E-06	6.2E-06
Remainder	2.7E-05	2.4E-05	1.4E-05	9.8E-06	7.4E-06	6.3E-06
Effective Dose	2.0E-04	1.9E-04	1.4E-04	1.1E-04	1.0E-04	1.1E-04

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-238 (T½ = 87.7 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Bladder Wall	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Bone Surface	1.1E-03	1.2E-03	1.0E-03	9.8E-04	1.1E-03	1.4E-03
Brain	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Breast	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
GI-Tract						
Oesophagus	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
St Wall	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
SI Wall	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
ULI Wall	7.9E-06	7.4E-06	4.8E-06	3.3E-06	2.8E-06	2.4E-06
LLI Wall	8.0E-06	7.4E-06	4.8E-06	3.3E-06	2.8E-06	2.4E-06
Colon	7.9E-06	7.4E-06	4.8E-06	3.3E-06	2.8E-06	2.4E-06
Kidneys	2.2E-05	2.0E-05	1.2E-05	8.2E-06	6.8E-06	6.0E-06
Liver	4.0E-04	4.1E-04	3.7E-04	2.9E-04	2.7E-04	2.9E-04
Muscle	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Ovaries	2.3E-05	2.5E-05	2.4E-05	2.1E-05	2.1E-05	1.8E-05
Pancreas	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Red Marrow	1.7E-04	1.5E-04	9.3E-05	6.6E-05	6.1E-05	6.9E-05
Respiratory Tract						
ET Airways	6.1E-05	4.9E-05	2.3E-05	1.5E-05	9.4E-06	8.9E-06
Lungs	1.5E-04	1.2E-04	7.3E-05	5.1E-05	4.4E-05	3.7E-05
Skin	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Spleen	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Testes	2.6E-05	2.8E-05	2.2E-05	1.9E-05	2.1E-05	1.9E-05
Thymus	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Thyroid	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Uterus	7.8E-06	7.3E-06	4.7E-06	3.3E-06	2.8E-06	2.4E-06
Remainder	8.0E-06	7.5E-06	4.8E-06	3.3E-06	2.8E-06	2.5E-06
Effective Dose	7.8E-05	7.4E-05	5.6E-05	4.4E-05	4.3E-05	4.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-238 (T½ = 87.7 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.0001	0.00001	0.00001	0.00001	0.00001	0.00001
Adrenals	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Bladder Wall	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Bone Surface	1.2E-04	1.3E-04	1.3E-04	1.2E-04	1.5E-04	1.6E-04
Brain	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Breast	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
GI-Tract						
Oesophagus	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
St Wall	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
SI Wall	6.1E-07	6.2E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
ULI Wall	6.8E-07	6.6E-07	4.7E-07	3.4E-07	3.1E-07	2.8E-07
LLI Wall	8.2E-07	7.6E-07	5.2E-07	3.7E-07	3.2E-07	2.9E-07
Colon	7.4E-07	7.1E-07	4.9E-07	3.5E-07	3.1E-07	2.9E-07
Kidneys	1.6E-06	1.6E-06	1.1E-06	8.2E-07	7.6E-07	7.3E-07
Liver	4.0E-05	4.3E-05	3.9E-05	3.2E-05	3.2E-05	3.4E-05
Muscle	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Ovaries	2.5E-06	2.7E-06	2.6E-06	2.3E-06	2.3E-06	2.1E-06
Pancreas	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Red Marrow	1.3E-05	1.3E-05	9.3E-06	7.3E-06	7.5E-06	8.3E-06
Respiratory Tract						
ET Airways	2.2E-04	1.9E-04	9.3E-05	6.4E-05	3.9E-05	3.9E-05
Lungs	3.3E-04	2.9E-04	1.8E-04	1.2E-04	1.0E-04	9.3E-05
Skin	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Spleen	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Testes	2.6E-06	2.8E-06	2.5E-06	2.3E-06	2.3E-06	2.2E-06
Thymus	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Thyroid	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Uterus	6.0E-07	6.1E-07	4.5E-07	3.3E-07	3.0E-07	2.8E-07
Remainder	7.3E-07	7.0E-07	5.0E-07	3.6E-07	3.2E-07	3.0E-07
Effective Dose	4.5E-05	4.0E-05	2.7E-05	1.9E-05	1.7E-05	1.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-239 (T½ = 2.41E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Bladder Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Bone Surface	3.8E-03	4.0E-03	3.4E-03	3.2E-03	3.4E-03	4.0E-03
Brain	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Breast	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
GI-Tract						
Oesophagus	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
St Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
SI Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
ULI Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
LLI Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Colon	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Kidneys	7.4E-05	6.3E-05	3.6E-05	2.5E-05	1.9E-05	1.6E-05
Liver	1.4E-03	1.4E-03	1.2E-03	9.4E-04	8.0E-04	8.4E-04
Muscle	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Ovaries	7.8E-05	8.2E-05	7.5E-05	6.7E-05	6.1E-05	5.2E-05
Pancreas	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Red Marrow	5.6E-04	5.0E-04	2.8E-04	2.1E-04	1.7E-04	1.9E-04
Respiratory Tract						
ET Airways	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Lungs	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Skin	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Spleen	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Testes	8.9E-05	9.3E-05	7.0E-05	5.9E-05	6.1E-05	5.3E-05
Thymus	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Thyroid	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Uterus	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Remainder	2.9E-05	2.6E-05	1.6E-05	1.1E-05	8.4E-06	7.1E-06
Effective Dose	2.1E-04	2.0E-04	1.5E-04	1.2E-04	1.1E-04	1.2E-04

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-239 (T½ = 2.41E+04 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Bladder Wall	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Bone Surface	1.2E-03	1.3E-03	1.2E-03	1.1E-03	1.3E-03	1.5E-03
Brain	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Breast	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
GI-Tract						
Oesophagus	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
St Wall	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
SI Wall	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
ULI Wall	8.5E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
LLI Wall	8.6E-06	8.1E-06	5.4E-06	3.8E-06	3.2E-06	2.7E-06
Colon	8.5E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Kidneys	2.2E-05	2.0E-05	1.2E-05	8.5E-06	7.1E-06	6.4E-06
Liver	4.3E-04	4.5E-04	4.1E-04	3.2E-04	3.0E-04	3.3E-04
Muscle	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Ovaries	2.5E-05	2.7E-05	2.6E-05	2.3E-05	2.3E-05	2.0E-05
Pancreas	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Red Marrow	1.7E-04	1.6E-04	9.8E-05	7.1E-05	6.6E-05	7.4E-05
Respiratory Tract						
ET Airways	6.0E-05	4.8E-05	2.3E-05	1.5E-05	9.6E-06	9.0E-06
Lungs	1.4E-04	1.1E-04	6.8E-05	4.6E-05	4.0E-05	3.3E-05
Skin	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Spleen	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Testes	2.8E-05	3.0E-05	2.4E-05	2.1E-05	2.3E-05	2.1E-05
Thymus	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Thyroid	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Uterus	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Remainder	8.6E-06	8.1E-06	5.4E-06	3.8E-06	3.2E-06	2.8E-06
Effective Dose	8.0E-05	7.7E-05	6.0E-05	4.8E-05	4.7E-05	5.0E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-239 (T½ = 2.41E+04 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.0001	0.00001	0.00001	0.00001	0.00001	0.00001
Adrenals	6.8E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Bladder Wall	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Bone Surface	1.4E-04	1.6E-04	1.5E-04	1.5E-04	1.7E-04	1.8E-04
Brain	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Breast	6.8E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
GI-Tract						
Oesophagus	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
St Wall	6.8E-07	7.0E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
SI Wall	6.9E-07	7.0E-07	5.2E-07	3.9E-07	3.5E-07	3.2E-07
ULI Wall	7.5E-07	7.4E-07	5.4E-07	4.0E-07	3.6E-07	3.2E-07
LLI Wall	8.9E-07	8.4E-07	5.8E-07	4.2E-07	3.7E-07	3.3E-07
Colon	8.1E-07	7.8E-07	5.6E-07	4.1E-07	3.6E-07	3.3E-07
Kidneys	1.7E-06	1.7E-06	1.2E-06	9.0E-07	8.3E-07	8.0E-07
Liver	4.6E-05	5.0E-05	4.5E-05	3.7E-05	3.7E-05	3.9E-05
Muscle	6.8E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Ovaries	2.9E-06	3.2E-06	3.0E-06	2.6E-06	2.6E-06	2.4E-06
Pancreas	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Red Marrow	1.3E-05	1.4E-05	1.0E-05	8.3E-06	8.5E-06	9.1E-06
Respiratory Tract						
ET Airways	2.2E-04	1.8E-04	9.1E-05	6.3E-05	3.8E-05	3.8E-05
Lungs	3.1E-04	2.7E-04	1.7E-04	1.1E-04	9.6E-05	8.7E-05
Skin	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Spleen	6.8E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Testes	2.9E-06	3.2E-06	2.8E-06	2.6E-06	2.6E-06	2.5E-06
Thymus	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Thyroid	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Uterus	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Remainder	8.0E-07	7.8E-07	5.7E-07	4.2E-07	3.7E-07	3.4E-07
Effective Dose	4.3E-05	3.9E-05	2.7E-05	1.9E-05	1.7E-05	1.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.4(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-240 (T½ = 6.54E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Bladder Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Bone Surface	3.8E-03	4.0E-03	3.4E-03	3.2E-03	3.4E-03	4.0E-03
Brain	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Breast	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
GI-Tract						
Oesophagus	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
St Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
SI Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
ULI Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
LLI Wall	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Colon	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Kidneys	7.4E-05	6.3E-05	3.6E-05	2.5E-05	1.9E-05	1.6E-05
Liver	1.4E-03	1.4E-03	1.2E-03	9.4E-04	8.0E-04	8.4E-04
Muscle	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Ovaries	7.8E-05	8.2E-05	7.5E-05	6.7E-05	6.1E-05	5.2E-05
Pancreas	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Red Marrow	5.6E-04	5.0E-04	2.8E-04	2.1E-04	1.7E-04	1.9E-04
Respiratory Tract						
ET Airways	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Lungs	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Skin	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Spleen	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Testes	8.9E-05	9.3E-05	7.0E-05	5.9E-05	6.1E-05	5.3E-05
Thymus	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Thyroid	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Uterus	2.8E-05	2.5E-05	1.5E-05	1.1E-05	8.3E-06	7.0E-06
Remainder	2.9E-05	2.6E-05	1.6E-05	1.1E-05	8.4E-06	7.1E-06
Effective Dose	2.1E-04	2.0E-04	1.5E-04	1.2E-04	1.1E-04	1.2E-04

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.4(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-240 (T½ = 6.54E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Bladder Wall	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Bone Surface	1.2E-03	1.3E-03	1.2E-03	1.1E-03	1.3E-03	1.5E-03
Brain	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Breast	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
GI-Tract						
Oesophagus	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
St Wall	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
SI Wall	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
ULI Wall	8.5E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
LLI Wall	8.6E-06	8.1E-06	5.3E-06	3.8E-06	3.2E-06	2.7E-06
Colon	8.5E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Kidneys	2.2E-05	2.0E-05	1.2E-05	8.5E-06	7.1E-06	6.4E-06
Liver	4.3E-04	4.5E-04	4.1E-04	3.2E-04	3.0E-04	3.3E-04
Muscle	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Ovaries	2.5E-05	2.7E-05	2.6E-05	2.3E-05	2.3E-05	2.0E-05
Pancreas	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Red Marrow	1.7E-04	1.6E-04	9.8E-05	7.1E-05	6.6E-05	7.4E-05
Respiratory Tract						
ET Airways	6.0E-05	4.8E-05	2.3E-05	1.5E-05	9.6E-06	9.0E-06
Lungs	1.4E-04	1.1E-04	6.8E-05	4.6E-05	4.0E-05	3.3E-05
Skin	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Spleen	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Testes	2.8E-05	3.0E-05	2.4E-05	2.1E-05	2.3E-05	2.1E-05
Thymus	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Thyroid	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Uterus	8.4E-06	8.0E-06	5.3E-06	3.7E-06	3.1E-06	2.7E-06
Remainder	8.6E-06	8.1E-06	5.4E-06	3.8E-06	3.2E-06	2.8E-06
Effective Dose	8.0E-05	7.7E-05	6.0E-05	4.8E-05	4.7E-05	5.0E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.4(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-240 (T½ = 6.54E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.0001	0.00001	0.00001	0.00001	0.00001	0.00001
Adrenals	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Bladder Wall	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Bone Surface	1.4E-04	1.6E-04	1.5E-04	1.5E-04	1.7E-04	1.8E-04
Brain	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Breast	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
GI-Tract						
Oesophagus	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
St Wall	6.8E-07	7.0E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
SI Wall	6.9E-07	7.0E-07	5.2E-07	3.9E-07	3.5E-07	3.2E-07
ULI Wall	7.5E-07	7.4E-07	5.4E-07	4.0E-07	3.5E-07	3.2E-07
LLI Wall	8.9E-07	8.4E-07	5.8E-07	4.2E-07	3.7E-07	3.3E-07
Colon	8.1E-07	7.8E-07	5.6E-07	4.1E-07	3.6E-07	3.3E-07
Kidneys	1.7E-06	1.7E-06	1.2E-06	9.0E-07	8.3E-07	8.0E-07
Liver	4.6E-05	5.0E-05	4.5E-05	3.7E-05	3.7E-05	3.9E-05
Muscle	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Ovaries	2.9E-06	3.2E-06	3.0E-06	2.6E-06	2.6E-06	2.4E-06
Pancreas	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Red Marrow	1.3E-05	1.4E-05	1.0E-05	8.3E-06	8.5E-06	9.1E-06
Respiratory Tract						
ET Airways	2.2E-04	1.8E-04	9.1E-05	6.3E-05	3.8E-05	3.8E-05
Lungs	3.1E-04	2.7E-04	1.7E-04	1.1E-04	9.6E-05	8.8E-05
Skin	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Spleen	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Testes	2.9E-06	3.2E-06	2.8E-06	2.6E-06	2.6E-06	2.5E-06
Thymus	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Thyroid	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Uterus	6.7E-07	6.9E-07	5.2E-07	3.8E-07	3.5E-07	3.2E-07
Remainder	8.0E-07	7.8E-07	5.7E-07	4.2E-07	3.7E-07	3.4E-07
Effective Dose	4.3E-05	3.9E-05	2.7E-05	1.9E-05	1.7E-05	1.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages $\geq$ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.5(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-241 (T½ = 14.4 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Bladder Wall	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Bone Surface	6.0E-05	6.4E-05	6.4E-05	6.7E-05	7.0E-05	7.9E-05
Brain	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Breast	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
GI-Tract						
Oesophagus	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
St Wall	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
SI Wall	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
ULI Wall	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
LLI Wall	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Colon	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Kidneys	5.3E-07	5.1E-07	3.7E-07	3.1E-07	2.6E-07	2.4E-07
Liver	2.3E-05	2.4E-05	2.2E-05	1.9E-05	1.6E-05	1.6E-05
Muscle	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Ovaries	1.4E-06	1.5E-06	1.4E-06	1.3E-06	1.2E-06	1.0E-06
Pancreas	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Red Marrow	4.3E-06	4.4E-06	3.5E-06	3.2E-06	3.0E-06	3.1E-06
Respiratory Tract						
ET Airways	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Lungs	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Skin	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Spleen	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Testes	1.4E-06	1.5E-06	1.2E-06	1.1E-06	1.2E-06	1.1E-06
Thymus	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Thyroid	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Uterus	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Remainder	4.1E-07	4.0E-07	2.8E-07	2.2E-07	1.7E-07	1.4E-07
Effective Dose	2.8E-06	2.9E-06	2.6E-06	2.4E-06	2.2E-06	2.3E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.5(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-241 (T½ = 14.4 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Bladder Wall	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Bone Surface	2.0E-05	2.2E-05	2.3E-05	2.4E-05	2.7E-05	3.1E-05
Brain	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Breast	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
GI-Tract						
Oesophagus	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
St Wall	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
SI Wall	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
ULI Wall	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
LLI Wall	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Colon	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Kidneys	1.7E-07	1.7E-07	1.3E-07	1.1E-07	1.0E-07	9.6E-08
Liver	7.5E-06	8.0E-06	7.6E-06	6.5E-06	6.3E-06	6.5E-06
Muscle	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Ovaries	4.4E-07	4.8E-07	4.9E-07	4.5E-07	4.6E-07	4.1E-07
Pancreas	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Red Marrow	1.4E-06	1.5E-06	1.3E-06	1.1E-06	1.1E-06	1.2E-06
Respiratory Tract						
ET Airways	1.6E-07	1.6E-07	1.1E-07	8.4E-08	7.0E-08	6.1E-08
Lungs	1.7E-07	1.7E-07	1.2E-07	8.9E-08	7.6E-08	6.6E-08
Skin	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Spleen	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Testes	4.5E-07	4.8E-07	4.3E-07	4.0E-07	4.5E-07	4.2E-07
Thymus	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Thyroid	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Uterus	1.3E-07	1.3E-07	9.8E-08	7.5E-08	6.5E-08	5.6E-08
Remainder	1.3E-07	1.3E-07	9.9E-08	7.6E-08	6.6E-08	5.7E-08
Effective Dose	9.1E-07	9.7E-07	9.2E-07	8.3E-07	8.6E-07	9.0E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.29.5(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Pu-241 (T½ = 14.4 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.0001	0.00001	0.00001	0.00001	0.00001	0.00001
Adrenals	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Bladder Wall	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Bone Surface	3.1E-06	3.4E-06	3.6E-06	3.5E-06	3.9E-06	4.1E-06
Brain	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Breast	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
GI-Tract						
Oesophagus	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
St Wall	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
SI Wall	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
ULI Wall	1.3E-08	1.4E-08	1.1E-08	8.8E-09	8.0E-09	7.1E-09
LLI Wall	1.4E-08	1.5E-08	1.2E-08	8.9E-09	8.1E-09	7.2E-09
Colon	1.4E-08	1.4E-08	1.1E-08	8.8E-09	8.0E-09	7.2E-09
Kidneys	2.1E-08	2.3E-08	1.9E-08	1.5E-08	1.5E-08	1.5E-08
Liver	9.6E-07	1.1E-06	9.9E-07	8.5E-07	8.6E-07	8.6E-07
Muscle	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Ovaries	6.1E-08	6.8E-08	6.6E-08	5.9E-08	5.9E-08	5.4E-08
Pancreas	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Red Marrow	1.9E-07	2.1E-07	1.9E-07	1.7E-07	1.7E-07	1.8E-07
Respiratory Tract						
ET Airways	5.9E-07	5.3E-07	3.0E-07	2.2E-07	1.5E-07	1.5E-07
Lungs	8.5E-07	8.7E-07	6.4E-07	4.6E-07	4.5E-07	4.6E-07
Skin	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Spleen	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Testes	5.9E-08	6.4E-08	6.1E-08	5.6E-08	5.8E-08	5.5E-08
Thymus	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Thyroid	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Uterus	1.3E-08	1.4E-08	1.1E-08	8.7E-09	8.0E-09	7.1E-09
Remainder	1.3E-08	1.4E-08	1.1E-08	8.9E-09	8.1E-09	7.3E-09
Effective Dose	2.2E-07	2.3E-07	2.0E-07	1.7E-07	1.7E-07	1.7E-07

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Pu parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.30. Americium

(271) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides, oxides and hydroxides of americium (Am) to inhalation Class Y, and nitrates to Class W. By default, other unspecified compounds were assigned to Class D (see Paragraph 54).

(272) *ICRP Publication 30*, Part 1 (ICRP, 1979) assigned all compounds of americium to Class W, based primarily on animal data summarized in *ICRP Publication 19* and the review by Durbin (1973). Only the inhalation studies of Scott *et al.* (1948), Lafuma *et al.* (1974) and Craig *et al.* (1975) were available at that time.

(273) *ICRP Publication 48* (ICRP, 1986) provided a further review of the biokinetics of americium, and included the substantial amount of more recent data from both animal studies and reported human exposure cases. The results indicated that for all americium compounds measured, the americium translocated to blood with half-times of several tens of days, in broad agreement with the definition of a Class W compound.

Absorption Types

(a) *Simple compounds*

(274) Several cases of known inhalation exposure to americium-containing aerosols have been reported (Jeanmaire and Ballada, 1970; Rundo *et al.*, 1971; Sanders, 1974; Edvardsson and Lindgren, 1976; Fry, 1976; Cohen *et al.*, 1979; Toohey and Essling, 1980; Newton *et al.*, 1983; Robinson *et al.*, 1983); however, some results are of limited value because the *in vivo* measurements were not begun until months to years after the exposures were likely to have occurred (Rundo *et al.*, 1971; Cohen *et al.*, 1979, Toohey and Essling, 1980). Most of the human exposure cases for which there are early bioassay measurements, involved the inhalation of oxide forms of americium. The large majority ($\geq$80%) of the ^{241}Am lung contents were stated to have cleared from the lung with half-times of tens of days (Jeanmaire and Ballada, 1970; Newton *et al.*, 1983; Edvardsson and Lindgren, 1976; Sanders, 1974). The remainder of the lung contents were said to clear with half-times on the order of hundreds of days (Jeanmaire and Ballada, 1970; Fry, 1976) and/or thousands of days (Fry, 1976; Toohey and Essling, 1980).

(275) One other exposure case has been described in which a worker received a combination of wound and inhalation exposure to ^{241}Am in nitric acid, presumably a nitrate form (Robinson *et al.*, 1983). In this case, the lung retention was described as 86% being associated with a half-time of 1.8 d, 13% with a half-time of 27 d and 1% with a half-time of 170 d. However, the interpretation of these data is complicated by the DTPA decorporation therapy employed.

(276) Lung retention data for ^{241}Am inhaled or instilled in various chemical forms by several species of experimental animals have been published, including $^{241}Am(NO_3)_3$ in rats (Tseveleva and Yerokhin, 1969; Lyubchanskiy and Nifatov, 1972; Crawley and Goddard, 1976; Ballou and Gies, 1978) and dogs (Buldakov and Kalmykova, 1979), $^{241}AmCl_3$ in rats (Zalikin and Popov, 1977), ^{241}Am citrate in rats (Lyubchanskiy and Nifatov, 1972; Crawley and Goddard, 1976), $^{241}Am(OH)_3$ polymers in rats (Taya *et al.*,1988), and $^{241}AmO_2$ in rats (Stradling *et al.*, 1978; Sanders and Mahaffey, 1983), hamsters (Mewhinney *et al.*, 1976; James *et al.*, 1977), dogs (Thomas *et al.*, 1972; Craig *et al.*, 1979; Mewhinney *et al.*, 1982) and monkeys (Mewhinney and Muggenburg, 1985). In addition, Mewhinney and Muggenburg (1985) have studied the influence of age at inhalation on the biokinetics of deposited $^{241}AmO_2$ in beagles. In general, the animal experiments support the *in vivo* human data. Clearance of the more soluble forms such as the nitrate, chloride, citrate and hydroxide is relatively rapid

(half-times of 3–7 d), and involves the major fraction of the lung content, usually 70–95% (Lyubchanskiy and Nifatov, 1972; Tseveleva and Yerkhin, 1969; Zalikin and Popov, 1977; Ballou and Gies, 1978; Taya *et al.*, 1988). In some cases, a more rapid clearance component with half-times on the order of hours was also described (Lyubchanskiy and Nifatov, 1972; Tseveleva and Yerokhin, 1969; Stradling *et al.*, 1978). However, these latter data are difficult to interpret quantitatively, as they appear to involve both particle transport of americium deposited on ciliated airways as well as dissolution/absorption to blood. Nevertheless, for these soluble forms, there appears to be a fraction of the deposited americium that is available for rapid absorption to blood. In general the experimental data support assignments of either Type F or M.

(277) In the studies of americium oxides, the lung retention data have usually shown 70–90% clearance with half-times of 10–30 d (James *et al.*, 1977; Mewhinney *et al.*, 1976; Craig *et al.*, 1979; Mewhinney *et al.*, 1982). One exception was the clearance of ^{241}Am from monkeys in which 32% of the lung content cleared with a 0.1-d half-time. The second clearance component was on the order of hundreds of days, involving varying fractions of the lung content. These data are consistent with Type M.

(b) *Environmental forms*

(278) Americium is ubiquitously present in most plutonium-bearing materials as well as unprocessed nuclear waste materials that have undergone substantial neutron irradiation. As such, it is most probable that exposure of the general population to americium from environmental contamination will involve americium as a trace radioactive contaminant of other matrices, which may contain other radionuclide elements. There are significantly fewer studies that have been done using materials with americium as a minor component compared to the data that exist with americium in relatively pure chemical form. This includes measurements of americium in humans exposed to fallout during the 1960s, in which ^{241}Pu, the radioactive parent of ^{241}Am, was a measurable constituent.

(279) The results of animal studies indicate that the availability of ^{241}Am for absorption to blood depends on the solubility characteristics of the major chemical components of the matrix in which the ^{241}Am is present. Stanley *et al.* (1982) measured no differences in the relative amounts of plutonium or americium absorbed from the lung to blood in either rats, dogs or monkeys that inhaled an aerosol consisting of a mixture of UO_2 and PuO_2 particles derived from feedstock for a mixed oxide reactor fuel. These results indicated that the americium in this form could be characterized as Type S. Stradling *et al.* (1987) found that plutonium and americium maintained a constant ratio when rats inhaled or were intratracheally instilled with one of several site-specific industrial dusts containing plutonium and americium, provided the matrix was relatively insoluble. For the PuO_2 dust, this was the case as only 0.9% of the initial lung deposit had been absorbed to blood by 365 d after exposure. For more soluble dusts, there was a trend toward increasing enrichment of americium relative to plutonium in the systemic compartments with time, such that, with residues from a plutonium electrorefining process, 26% of the americium had been absorbed to blood compared to <2% of the plutonium. Thus, in this experiment, the solubilities of the different dusts varied between M and S. Similar findings were obtained by Stradling *et al.* (1992) using samples of three different dust samples contaminated with plutonium and americium obtained from a nuclear weapons testing site in South Australia. The transfer rates to blood differed between samples by 50-fold, with the most transportable being described as 25% Class W and 75% Class Y; the least transportable was virtually all Class Y. In all cases, the

americium and plutonium ratios *in vivo* were constant, indicating that the trace contaminant ^{241}Am behaved similarly to the bulk material, plutonium.

Dose coefficients

(280) Studies of common chemical forms showing characteristics of absorption Types M and S have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.30.2 and 5.30.3) were derived using the f_1 values given in Table 5.30.1, and the biokinetic data in *ICRP Publication 67* (ICRP, 1993).

Table 5.30.1. Values of f_1 for particulate compounds of americium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.005	5×10^{-4}
M[b]	0.005	5×10^{-4}
S	0.005	5×10^{-4}

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.30.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Am-241 (T½ = 4.32E+02 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.1E-05	2.0E-05	1.4E-05	1.1E-05	8.2E-06	7.4E-06
Bladder Wall	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Bone Surface	4.2E-03	4.3E-03	3.5E-03	3.5E-03	3.7E-03	4.4E-03
Brain	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Breast	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
GI-Tract						
Oesophagus	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
St Wall	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
SI Wall	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
ULI Wall	2.1E-05	2.0E-05	1.4E-05	1.1E-05	8.2E-06	7.4E-06
LLI Wall	2.1E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.4E-06
Colon	2.1E-05	2.0E-05	1.4E-05	1.1E-05	8.2E-06	7.4E-06
Kidneys	8.6E-05	7.5E-05	4.5E-05	3.1E-05	2.4E-05	2.2E-05
Liver	4.6E-04	4.6E-04	4.0E-04	2.9E-04	2.4E-04	2.7E-04
Muscle	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Ovaries	1.1E-04	1.2E-04	1.1E-04	9.8E-05	9.2E-05	8.5E-05
Pancreas	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Red Marrow	6.8E-04	6.0E-04	3.0E-04	2.0E-04	1.6E-04	1.5E-04
Respiratory Tract						
ET Airways	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.4E-06
Lungs	2.1E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.4E-06
Skin	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Spleen	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Testes	1.2E-04	1.3E-04	9.9E-05	8.9E-05	9.0E-05	8.4E-05
Thymus	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Thyroid	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Uterus	2.1E-05	2.0E-05	1.4E-05	1.0E-05	8.2E-06	7.4E-06
Remainder	2.2E-05	2.1E-05	1.4E-05	1.1E-05	8.4E-06	7.5E-06
Effective Dose	1.8E-04	1.8E-04	1.2E-04	1.0E-04	9.2E-05	9.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Am parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.30.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Am-241 (T½ = 4.32E+02 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Bladder Wall	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Bone Surface	1.3E-03	1.4E-03	1.2E-03	1.2E-03	1.4E-03	1.7E-03
Brain	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Breast	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
GI-Tract						
Oesophagus	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
St Wall	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
SI Wall	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
ULI Wall	6.6E-06	6.5E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
LLI Wall	6.7E-06	6.6E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Colon	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Kidneys	2.6E-05	2.4E-05	1.6E-05	1.1E-05	9.1E-06	8.7E-06
Liver	1.4E-04	1.5E-04	1.4E-04	9.9E-05	9.0E-05	1.0E-04
Muscle	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Ovaries	3.5E-05	3.9E-05	3.8E-05	3.4E-05	3.5E-05	3.3E-05
Pancreas	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Red Marrow	2.0E-04	1.9E-04	1.0E-04	7.0E-05	6.1E-05	5.8E-05
Respiratory Tract						
ET Airways	6.0E-05	4.8E-05	2.3E-05	1.6E-05	9.8E-06	9.4E-06
Lungs	1.5E-04	1.2E-04	7.3E-05	5.1E-05	4.4E-05	3.7E-05
Skin	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Spleen	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Testes	3.9E-05	4.2E-05	3.5E-05	3.2E-05	3.4E-05	3.3E-05
Thymus	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Thyroid	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Uterus	6.5E-06	6.4E-06	4.8E-06	3.6E-06	3.1E-06	2.9E-06
Remainder	6.8E-06	6.7E-06	5.0E-06	3.7E-06	3.2E-06	2.9E-06
Effective Dose	7.3E-05	6.9E-05	5.1E-05	4.0E-05	4.0E-05	4.2E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Am parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.30.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Am-241 (T½ = 4.32E+02 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Bladder Wall	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Bone Surface	1.8E-04	1.7E-04	1.7E-04	1.6E-04	1.9E-04	2.1E-04
Brain	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Breast	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
GI-Tract						
Oesophagus	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
St Wall	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
SI Wall	7.2E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
ULI Wall	7.9E-07	6.7E-07	5.2E-07	3.9E-07	3.6E-07	3.4E-07
LLI Wall	9.4E-07	7.7E-07	5.7E-07	4.2E-07	3.7E-07	3.5E-07
Colon	8.6E-07	7.2E-07	5.4E-07	4.1E-07	3.6E-07	3.4E-07
Kidneys	2.6E-06	2.1E-06	1.6E-06	1.2E-06	1.1E-06	1.1E-06
Liver	1.8E-05	1.7E-05	1.5E-05	1.2E-05	1.2E-05	1.3E-05
Muscle	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Ovaries	4.8E-06	4.7E-06	4.5E-06	4.0E-06	4.1E-06	4.1E-06
Pancreas	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Red Marrow	1.9E-05	1.5E-05	1.0E-05	7.7E-06	7.4E-06	7.4E-06
Respiratory Tract						
ET Airways	2.2E-04	1.9E-04	9.4E-05	6.5E-05	4.0E-05	3.9E-05
Lungs	3.3E-04	2.9E-04	1.9E-04	1.2E-04	1.1E-04	9.5E-05
Skin	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Spleen	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Testes	4.9E-06	4.6E-06	4.2E-06	3.9E-06	4.0E-06	4.0E-06
Thymus	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Thyroid	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Uterus	7.1E-07	6.2E-07	5.0E-07	3.8E-07	3.5E-07	3.3E-07
Remainder	8.5E-07	7.1E-07	5.5E-07	4.2E-07	3.8E-07	3.6E-07
Effective Dose	4.6E-05	4.0E-05	2.7E-05	1.9E-05	1.7E-05	1.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Am parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.30.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Am-243 (T½ = 7.38E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.4E-06	7.5E-06
Bladder Wall	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.4E-06
Bone Surface	4.1E-03	4.3E-03	3.5E-03	3.5E-03	3.7E-03	4.3E-03
Brain	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Breast	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.4E-06
GI-Tract						
Oesophagus	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
St Wall	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
SI Wall	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
ULI Wall	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
LLI Wall	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.4E-06	7.5E-06
Colon	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Kidneys	8.4E-05	7.3E-05	4.5E-05	3.1E-05	2.4E-05	2.2E-05
Liver	4.5E-04	4.5E-04	3.9E-04	2.8E-04	2.3E-04	2.6E-04
Muscle	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Ovaries	1.1E-04	1.2E-04	1.1E-04	9.8E-05	9.1E-05	8.4E-05
Pancreas	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.4E-06	7.5E-06
Red Marrow	6.7E-04	5.8E-04	2.9E-04	2.0E-04	1.6E-04	1.5E-04
Respiratory Tract						
ET Airways	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Lungs	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.4E-06	7.5E-06
Skin	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.4E-06
Spleen	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Testes	1.2E-04	1.3E-04	9.9E-05	8.9E-05	9.0E-05	8.4E-05
Thymus	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Thyroid	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Uterus	2.2E-05	2.0E-05	1.4E-05	1.1E-05	8.3E-06	7.5E-06
Remainder	2.2E-05	2.1E-05	1.4E-05	1.1E-05	8.5E-06	7.6E-06
Effective Dose	1.8E-04	1.7E-04	1.2E-04	1.0E-04	9.1E-05	9.6E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Am parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.30.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Am-243 (T½ = 7.38E+03 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.2E-06	2.9E-06
Bladder Wall	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Bone Surface	1.3E-03	1.4E-03	1.2E-03	1.2E-03	1.4E-03	1.7E-03
Brain	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.2E-06	2.9E-06
Breast	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
GI-Tract						
Oesophagus	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
St Wall	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
SI Wall	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.2E-06	2.9E-06
ULI Wall	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.2E-06	2.9E-06
LLI Wall	6.8E-06	6.6E-06	4.9E-06	3.7E-06	3.2E-06	2.9E-06
Colon	6.7E-06	6.6E-06	4.9E-06	3.7E-06	3.2E-06	2.9E-06
Kidneys	2.5E-05	2.3E-05	1.5E-05	1.1E-05	9.0E-06	8.6E-06
Liver	1.4E-04	1.5E-04	1.4E-04	9.7E-05	8.9E-05	1.0E-04
Muscle	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Ovaries	3.5E-05	3.8E-05	3.8E-05	3.4E-05	3.5E-05	3.3E-05
Pancreas	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.2E-06	2.9E-06
Red Marrow	2.0E-04	1.8E-04	1.0E-04	6.9E-05	6.0E-05	5.7E-05
Respiratory Tract						
ET Airways	5.9E-05	4.7E-05	2.2E-05	1.5E-05	9.7E-06	9.2E-06
Lungs	1.4E-04	1.1E-04	6.9E-05	4.8E-05	4.2E-05	3.5E-05
Skin	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Spleen	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Testes	3.8E-05	4.1E-05	3.5E-05	3.1E-05	3.4E-05	3.3E-05
Thymus	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Thyroid	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Uterus	6.6E-06	6.5E-06	4.9E-06	3.6E-06	3.1E-06	2.9E-06
Remainder	6.8E-06	6.7E-06	5.0E-06	3.7E-06	3.2E-06	3.0E-06
Effective Dose	7.2E-05	6.8E-05	5.0E-05	4.0E-05	4.0E-05	4.1E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Am parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

TAble 5.30.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Am-243 (T½ = 7.38E+03 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	7.3E-07	6.4E-07	5.2E-07	3.9E-07	3.6E-07	3.4E-07
Bladder Wall	7.2E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.3E-07
Bone Surface	1.8E-04	1.7E-04	1.7E-04	1.7E-04	1.9E-04	2.1E-04
Brain	7.2E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.3E-07
Breast	7.3E-07	6.4E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
GI-Tract						
Oesophagus	7.3E-07	6.4E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
St Wall	7.3E-07	6.4E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
SI Wall	7.3E-07	6.4E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
ULI Wall	8.0E-07	6.9E-07	5.3E-07	4.0E-07	3.7E-07	3.4E-07
LLI Wall	9.7E-07	8.0E-07	5.8E-07	4.3E-07	3.8E-07	3.5E-07
Colon	8.8E-07	7.3E-07	5.5E-07	4.2E-07	3.7E-07	3.5E-07
Kidneys	2.5E-06	2.1E-06	1.6E-06	1.2E-06	1.1E-06	1.1E-06
Liver	1.8E-05	1.7E-05	1.5E-05	1.2E-05	1.2E-05	1.3E-05
Muscle	7.2E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
Ovaries	4.9E-06	4.7E-06	4.6E-06	4.1E-06	4.2E-06	4.1E-06
Pancreas	7.3E-07	6.4E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
Red Marrow	1.9E-05	1.5E-05	1.0E-05	7.7E-06	7.4E-06	7.3E-06
Respiratory Tract						
ET Airways	2.2E-04	1.9E-04	9.3E-05	6.4E-05	3.9E-05	3.9E-05
Lungs	3.2E-04	2.8E-04	1.8E-04	1.2E-04	1.0E-04	9.1E-05
Skin	7.2E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.3E-07
Spleen	7.3E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
Testes	4.9E-06	4.6E-06	4.2E-06	4.0E-06	4.0E-06	4.0E-06
Thymus	7.3E-07	6.4E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
Thyroid	7.2E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.4E-07
Uterus	7.2E-07	6.3E-07	5.1E-07	3.9E-07	3.6E-07	3.3E-07
Remainder	8.6E-07	7.3E-07	5.6E-07	4.3E-07	3.8E-07	3.6E-07
Effective Dose	4.4E-05	3.9E-05	2.6E-05	1.8E-05	1.6E-05	1.5E-05

GI-Tract Gastrointestinal Tract
St Stomach
SI Small Intestine
ULI Upper Large Intestine
LLI Lower Large Intestine
ET Airways Extrathoracic airways
Lungs Thoracic airways

* In the biokinetic model for Am parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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5.31. Curium

(281) The ICRP Task Group on Lung Dynamics (TGLD, 1966) assigned carbides, oxides and hydroxides of curium (Cm) to inhalation Class Y, and nitrates to Class W. By default, other unspecified compounds of curium were assigned to Class D (see Paragraph 54).

(282) *ICRP Publication 30*, Part 1 (ICRP, 1979), assigned all curium compounds to Class W on the basis of experimental data in animals summarized in *ICRP Publication 19* (ICRP, 1972), and a review by Durbin (1973). Compounds of curium were found to be cleared from the lung faster than corresponding plutonium (Pu) compounds (McClellan *et al.*, 1972; Craig *et al.*, 1975; Sanders, 1975).

(283) *ICRP Publication 48* (ICRP, 1986), reviewed more recent data from animal studies and human exposure cases. It stated in conclusion that, for all the curium compounds studied, translocation to blood took place with half-times of several tens of days, in broad agreement with the definition of Class W compounds.

Absorption Types

(284) The few reported incidents of occupational curium intakes in man have clearly shown high rates of curium urinary excretion soon after intake, and studies in animals have shown that clearance from lung to blood is appreciably greater than predicted by the TGLD model (Bair, 1976; Métivier, 1988). Curium retention is lower than that of plutonium, and closer to that of americium (Am) (Stather and Priest, 1977).

(285) Several studies of the inhalation of curium oxides have been made with rats. Following inhalation of aerosols of ^{244}Cm oxides, (Guilmette *et al.*, 1984) curium cleared from lungs with half-times of 8–12 d, depending upon particle size (0.7–2.6 μm), but showed similar lung retention after 1 month, for all sizes. Stradling *et al.* (1979) found that lung retention varied from 6 to 12% at 60 days after exposure, depending on the age of the preparation and hence on the size of the particles. With pure ^{244}Cm dioxide, only 8% was retained in the lung at 70 d (Rhoads, 1986) but retention was higher, at 20%, with mixed plutonium–curium oxides. Sanders and Mahaffey (1990) reported that, for inhalation of a 0.7 μm aerosol, lung retention could be represented by a three-component exponential function, with half times of 0.5 d for 77%, 11.7 d for 22%, and 407 d for 1% of the initial lung deposit (ILD).

(286) Following inhalation of a 0.5 μm $^{244}CmO_x$ aerosol by dogs, the translocation to blood of curium at 30 d, was 80% (Craig *et al.*, 1976). In dogs, lung retention following inhalation of $^{244}Cm_2O_3$ was described by a three-component exponential function, with half-times of 7.6 d for 78% ILD, 99 d for 19% and 770 d for 3% (Guilmette and Kanapilly, 1988). McClellan *et al.* (1972) found that curium oxide ($^{244}CmO_{1.73}$) inhaled by dogs, was rapidly absorbed into body fluids, and that by 30 d lung retention was about 11% ILD. These results were in agreement with the urinary excretion data obtained after accidental human exposure (Bernard and Poston, 1976). Guilmette and Mewhinney (1989) showed that models based on the dog studies of Guilmette and Kanapilly (1988) are in fairly good agreement with bioassay measurements in human accidental inhalation cases of ^{242}Cm oxides reported by Parker *et al.* (1960) and by Vaane and De Ros (1971), of "relatively soluble" oxides by Sanders (1974) and a mixture of nitrate, chloride and oxide of ^{244}Cm, by Parkinson *et al.* (1976). These different studies on curium oxides give a range of values of absorption rates from respiratory tract to body fluids, some indicating Type M and others Type F behaviour.

(287) In rats, Morin *et al.* (1971) reported that 30% of inhaled ^{242}Cm nitrate was transferred to blood after 30 d. In dogs, absorption to body fluids following inhalation of

$^{244}Cm(NO_3)_3$ was very similar to that of $^{244}Cm_2O_3$ (Guilmette and Kanapilly, 1988). Lung retention was described by a three-component exponential function, with half-times of 0.6 d for 42%, 23.9 d for 48% and 364 d for 10% ILD.

(288) McClellan *et al.* (1972) found that curium chloride ($^{244}CmCl_3$) inhaled by dogs was rapidly absorbed into body fluids, at a similar rate to that of the oxide ($^{244}CmO_{1.73}$), and that by 30 d, lung retention was about 11% ILD. This was in marked contrast to the differences observed between various forms of inhaled plutonium.

(289) The animal data and human observations cited above suggest that rates of absorption to body fluids, of oxides, nitrates and chlorides of curium are similar, and indicate Type M behaviour for all these compounds.

Dose coefficients

(290) Studies of common chemical forms showing characteristics of absorption Types F and M have been found in the literature. A default Type M is recommended for use in the absence of specific information (see Paragraph 58). Dose coefficients (given in Tables 5.31.2 and 5.31.3) were derived for the f_1 values given in Table 5.31.1, and the biokinetic data given for americium in *ICRP Publication 67* (ICRP, 1993), see Annexe B.

Table 5.31.1. Values of f_1 for inhaled particulate compounds of curium

	f_1[a]	
Absorption Type	3 mo	1 y–adult
F	0.005	5×10^{-4}
M[b]	0.005	5×10^{-4}
S	0.005	5×10^{-4}

[a] f_1 values for 1 y–adult are taken from Table 2. Those for 3 mo are derived according to the procedure described in Paragraph 14.

[b] Default Type M is recommended for use in the absence of specific information.

Table 5.31.2(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cm-242 ($T½$ = 163 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Bladder Wall	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.3E-07	1.1E-07
Bone Surface	5.1E-04	5.1E-04	2.7E-04	1.7E-04	1.1E-04	9.0E-05
Brain	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Breast	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
GI-Tract						
Oesophagus	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
St Wall	9.2E-07	6.6E-07	3.3E-07	2.0E-07	1.3E-07	1.1E-07
SI Wall	9.2E-07	6.6E-07	3.3E-07	2.0E-07	1.3E-07	1.1E-07
ULI Wall	9.5E-07	6.8E-07	3.3E-07	2.0E-07	1.3E-07	1.1E-07
LLI Wall	1.0E-06	7.2E-07	3.5E-07	2.1E-07	1.3E-07	1.2E-07
Colon	9.8E-07	7.0E-07	3.4E-07	2.1E-07	1.3E-07	1.2E-07
Kidneys	1.4E-05	9.7E-06	5.0E-06	3.3E-06	2.2E-06	1.9E-06
Liver	4.3E-05	3.4E-05	4.5E-05	2.9E-05	1.8E-05	2.5E-05
Muscle	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Ovaries	3.2E-06	3.2E-06	3.1E-06	2.8E-06	1.6E-06	1.6E-06
Pancreas	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Red Marrow	1.5E-04	1.1E-04	3.7E-05	2.0E-05	1.2E-05	6.4E-06
Respiratory Tract						
ET Airways	3.9E-06	2.7E-06	1.1E-06	7.5E-07	4.2E-07	4.0E-07
Lungs	1.0E-06	7.2E-07	3.7E-07	2.3E-07	1.6E-07	1.4E-07
Skin	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Spleen	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Testes	3.3E-06	3.7E-06	2.9E-06	2.8E-06	2.6E-06	1.6E-06
Thymus	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Thyroid	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Uterus	9.1E-07	6.6E-07	3.3E-07	2.0E-07	1.2E-07	1.1E-07
Remainder	1.1E-06	7.7E-07	3.8E-07	2.3E-07	1.5E-07	1.3E-07
Effective Dose	2.7E-05	2.1E-05	1.0E-05	6.1E-06	4.0E-06	3.3E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Cm parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.31.2(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cm-242 (T½ = 163 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Bladder Wall	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Bone Surface	1.2E-04	1.2E-04	7.0E-05	4.3E-05	3.2E-05	2.7E-05
Brain	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Breast	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
GI-Tract						
Oesophagus	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
St Wall	2.1E-07	1.6E-07	8.9E-08	5.4E-08	3.8E-08	3.5E-08
SI Wall	2.2E-07	1.7E-07	9.1E-08	5.5E-08	3.9E-08	3.5E-08
ULI Wall	2.8E-07	2.1E-07	1.1E-07	6.6E-08	4.4E-08	4.0E-08
LLI Wall	4.2E-07	3.0E-07	1.5E-07	8.9E-08	5.5E-08	4.9E-08
Colon	3.4E-07	2.5E-07	1.3E-07	7.6E-08	4.9E-08	4.4E-08
Kidneys	3.0E-06	2.3E-06	1.3E-06	8.2E-07	6.2E-07	5.5E-07
Liver	9.8E-06	8.4E-06	1.1E-05	7.2E-06	5.0E-06	7.1E-06
Muscle	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Ovaries	7.9E-07	8.1E-07	8.5E-07	7.3E-07	4.9E-07	4.8E-07
Pancreas	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Red Marrow	3.4E-05	2.5E-05	9.4E-06	5.0E-06	3.3E-06	1.9E-06
Respiratory Tract						
ET Airways	3.8E-05	2.9E-05	1.2E-05	8.1E-06	4.4E-06	4.3E-06
Lungs	1.4E-04	1.1E-04	6.7E-05	4.8E-05	4.4E-05	3.5E-05
Skin	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Spleen	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Testes	8.2E-07	9.4E-07	7.9E-07	8.1E-07	7.4E-07	4.8E-07
Thymus	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Thyroid	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Uterus	2.1E-07	1.6E-07	8.8E-08	5.3E-08	3.8E-08	3.5E-08
Remainder	2.6E-07	2.0E-07	1.1E-07	6.6E-08	4.6E-08	4.2E-08
Effective Dose	2.2E-05	1.8E-05	1.1E-05	7.3E-06	6.4E-06	5.2E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Cm parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.31.2(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cm-242 (T½ = 163 d).

Particulate Aerosol: AMAD = 1 µm, Absorption Type S.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Bladder Wall	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Bone Surface	6.9E-06	4.1E-06	2.7E-06	1.8E-06	1.6E-06	1.5E-06
Brain	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Breast	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
GI-Tract						
Oesophagus	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
St Wall	1.8E-08	9.6E-09	5.4E-09	3.5E-09	2.7E-09	2.5E-09
SI Wall	2.6E-08	1.5E-08	7.9E-09	5.0E-09	3.3E-09	3.0E-09
ULI Wall	9.5E-08	6.1E-08	2.7E-08	1.7E-08	9.0E-09	7.7E-09
LLI Wall	2.5E-07	1.6E-07	7.0E-08	4.2E-08	2.2E-08	1.8E-08
Colon	1.6E-07	1.0E-07	4.6E-08	2.8E-08	1.5E-08	1.2E-08
Kidneys	1.7E-07	7.3E-08	4.4E-08	2.9E-08	2.3E-08	2.1E-08
Liver	5.7E-07	3.2E-07	3.9E-07	2.6E-07	2.0E-07	2.7E-07
Muscle	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Ovaries	5.5E-08	4.0E-08	4.1E-08	3.5E-08	2.8E-08	2.8E-08
Pancreas	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Red Marrow	1.8E-06	7.6E-07	3.1E-07	1.7E-07	1.2E-07	8.3E-08
Respiratory Tract						
ET Airways	7.2E-05	5.6E-05	2.4E-05	1.6E-05	9.1E-06	8.9E-06
Lungs	1.9E-04	1.5E-04	9.6E-05	6.7E-05	6.0E-05	4.9E-05
Skin	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Spleen	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Testes	5.6E-08	4.3E-08	3.8E-08	4.0E-08	3.5E-08	2.8E-08
Thymus	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Thyroid	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Uterus	1.2E-08	6.4E-09	4.1E-09	2.7E-09	2.2E-09	2.1E-09
Remainder	5.4E-08	3.1E-08	1.5E-08	1.1E-08	6.7E-09	6.6E-09
Effective Dose	2.4E-05	1.9E-05	1.2E-05	8.2E-06	7.3E-06	5.9E-06

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Cm parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.31.3(a).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cm-244 (T½ = 18.1 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type F.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Bladder Wall	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Bone Surface	3.0E-03	3.0E-03	2.1E-03	1.9E-03	2.0E-03	2.4E-03
Brain	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Breast	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
GI-Tract						
Oesophagus	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
St Wall	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
SI Wall	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
ULI Wall	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
LLI Wall	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Colon	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Kidneys	7.5E-05	6.4E-05	3.7E-05	2.4E-05	1.7E-05	1.6E-05
Liver	3.7E-04	3.6E-04	3.2E-04	2.1E-04	1.6E-04	1.9E-04
Muscle	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Ovaries	6.9E-05	7.1E-05	6.5E-05	5.4E-05	5.0E-05	4.7E-05
Pancreas	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Red Marrow	6.2E-04	5.3E-04	2.4E-04	1.5E-04	1.1E-04	1.0E-04
Respiratory Tract						
ET Airways	1.2E-05	1.0E-05	6.4E-06	4.6E-06	3.6E-06	3.4E-06
Lungs	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.4E-06
Skin	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Spleen	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Testes	8.3E-05	8.7E-05	6.3E-05	5.2E-05	5.0E-05	4.7E-05
Thymus	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Thyroid	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Uterus	1.1E-05	9.7E-06	6.1E-06	4.4E-06	3.5E-06	3.3E-06
Remainder	1.2E-05	1.0E-05	6.5E-06	4.6E-06	3.6E-06	3.5E-06
Effective Dose	1.5E-04	1.3E-04	8.3E-05	6.1E-05	5.3E-05	5.7E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Cm parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.31.3(b).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cm-244 (T½ = 18.1 y).

Particulate Aerosol: AMAD = 1 µm, Absorption Type M.

Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Bladder Wall	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Bone Surface	9.3E-04	9.6E-04	7.4E-04	6.4E-04	7.4E-04	9.2E-04
Brain	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Breast	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
GI-Tract						
Oesophagus	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
St Wall	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
SI Wall	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
ULI Wall	3.3E-06	3.1E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
LLI Wall	3.4E-06	3.2E-06	2.2E-06	1.5E-06	1.3E-06	1.3E-06
Colon	3.3E-06	3.1E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Kidneys	2.2E-05	2.0E-05	1.3E-05	8.0E-06	6.5E-06	6.2E-06
Liver	1.1E-04	1.2E-04	1.1E-04	7.0E-05	6.0E-05	7.5E-05
Muscle	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Ovaries	2.1E-05	2.3E-05	2.2E-05	1.8E-05	1.9E-05	1.8E-05
Pancreas	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Red Marrow	1.8E-04	1.6E-04	8.3E-05	5.1E-05	4.1E-05	3.9E-05
Respiratory Tract						
ET Airways	5.8E-05	4.5E-05	2.0E-05	1.4E-05	8.1E-06	7.9E-06
Lungs	1.6E-04	1.2E-04	7.7E-05	5.4E-05	4.8E-05	3.9E-05
Skin	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Spleen	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Testes	2.6E-05	2.8E-05	2.2E-05	1.8E-05	1.9E-05	1.8E-05
Thymus	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Thyroid	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Uterus	3.2E-06	3.0E-06	2.1E-06	1.5E-06	1.3E-06	1.3E-06
Remainder	3.5E-06	3.3E-06	2.2E-06	1.6E-06	1.4E-06	1.3E-06
Effective Dose	6.2E-05	5.7E-05	3.7E-05	2.7E-05	2.6E-05	2.7E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Cm parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

Table 5.31.3(c).

Inhalation Dose Coefficients: Committed Equivalent and Effective Doses per Unit Intake (Sv/Bq) for Cm-244 (T½ = 18.1 y).

Particulate Aerosol: AMAD = 1 μm, Absorption Type S.						
Age at intake	3 Months	1 Year	5 Years	10 Years	15 Years	Adult*
f1	0.005	0.0005	0.0005	0.0005	0.0005	0.0005
Adrenals	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Bladder Wall	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Bone Surface	9.8E-05	8.7E-05	7.6E-05	7.2E-05	8.6E-05	9.9E-05
Brain	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Breast	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
GI-Tract						
Oesophagus	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
St Wall	3.1E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.3E-07
SI Wall	3.1E-07	2.5E-07	1.9E-07	1.4E-07	1.3E-07	1.4E-07
ULI Wall	3.8E-07	3.0E-07	2.1E-07	1.5E-07	1.4E-07	1.4E-07
LLI Wall	5.4E-07	4.1E-07	2.6E-07	1.8E-07	1.6E-07	1.5E-07
Colon	4.5E-07	3.5E-07	2.3E-07	1.7E-07	1.5E-07	1.5E-07
Kidneys	1.9E-06	1.5E-06	1.1E-06	7.2E-07	6.6E-07	6.8E-07
Liver	1.2E-05	1.1E-05	9.4E-06	6.7E-06	6.8E-06	8.2E-06
Muscle	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Ovaries	2.5E-06	2.3E-06	2.2E-06	1.9E-06	1.9E-06	2.0E-06
Pancreas	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Red Marrow	1.5E-05	1.1E-05	6.8E-06	4.6E-06	4.2E-06	4.2E-06
Respiratory Tract						
ET Airways	2.2E-04	1.8E-04	9.0E-05	6.1E-05	3.7E-05	3.7E-05
Lungs	3.4E-04	2.9E-04	1.9E-04	1.2E-04	1.0E-04	9.2E-05
Skin	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Spleen	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Testes	2.8E-06	2.5E-06	2.1E-06	1.9E-06	1.9E-06	1.9E-06
Thymus	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Thyroid	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Uterus	3.0E-07	2.5E-07	1.8E-07	1.4E-07	1.3E-07	1.3E-07
Remainder	4.4E-07	3.4E-07	2.4E-07	1.7E-07	1.6E-07	1.6E-07
Effective Dose	4.4E-05	3.8E-05	2.5E-05	1.7E-05	1.5E-05	1.3E-05

GI-Tract	Gastrointestinal Tract
St	Stomach
SI	Small Intestine
ULI	Upper Large Intestine
LLI	Lower Large Intestine
ET Airways	Extrathoracic airways
Lungs	Thoracic airways

* In the biokinetic model for Cm parameter values for the adult apply to ages ≥ 25 y. For radioisotopes of this element the dose coefficients for the adult are based on the 50-y integrated doses following an acute intake at age 25 y.

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ANNEXE A. AGE-DEPENDENT BIOKINETIC MODEL FOR CALCIUM

A.1. Uptake to blood

Adults

(A1) Calcium (Ca) absorption has been measured in numerous volunteer studies and in most cases the reported mean absorption values were in the range 0.2–0.5 (Samachson, 1963; DeGrazia and Rich, 1964; Lutwak, 1969; Mautalen, 1969; Jovanovic, 1978; Cochet *et al.*, 1983; Marchandise *et al.*, 1986; Spencer *et al.*, 1987; Harvey *et al.*, 1988; Heaney *et al.*, 1989). Calcium absorption is generally increased by high intakes of vitamin D, by calcium deficiency or low calcium intake, by pregnancy or lactation and is decreased in old age (Allen, 1982; Spencer *et al.*, 1987; Heaney *et al.*, 1989).

(A2) In *ICRP Publication 30* (1980), an f_1 value of 0.3 was recommended for calcium and the chemically similar alkaline earth element, strontium. In *ICRP Publication 67* (1993), the value of 0.3 for strontium was used for adult members of the public. This value is adopted here for calcium absorption in adults.

Children

(A3) There are a number of reports of measurements of calcium absorption in infants and children, using stable isotope techniques. Hillman *et al.* (1988) obtained a mean value of 0.5 for seven infants, about 2 weeks of age, with a range of 0.4–0.6. Values of up to 0.8 have been measured for premature infants (Ehrenkrantz *et al.*, 1985, Liu *et al.*, 1989). For six children ranging in age from 11 to 17 y, mean absorption was estimated as 0.4 with a range of 0.3–0.5 (Miller *et al.*, 1989).

(A4) The f_1 values used for strontium in *ICRP Publication 67* (1993) were 0.6 for 3-mo-old infants and 0.4 for 1-, 5-, 10- and 15-y-old children. These values are adopted here for calcium.

A.2. Structure of the biokinetic model for calcium

(A5) A generic model structure (Fig. A.1) for bone-volume-seeking radionuclides was applied in *ICRP Publication 67* (ICRP, 1993) to radioisotopes of strontium, barium, radium, and lead and in *ICRP Publication 69* (ICRP, 1995) to radioisotopes of uranium. This model structure is applied in this document to calcium.

(A6) The model structure was originally designed for application to the alkaline earth elements (Leggett, 1992a) but was generalized for application to less complete physiological analogues of calcium, such as lead and uranium (ICRP, 1993, 1995).

(A7) In the model for calcium, the liver and kidneys are included implicitly in "other soft tissues". Blood plasma is treated as a uniformly mixed pool that contains all calcium in blood and exchanges calcium with soft tissues and bone surfaces. The red blood cell compartment in Fig. 1 is not used in this model. In reality, a small amount of calcium is found in red blood cells, and nearly half of calcium in plasma is not exchangeable with extravascular calcium but is bound to non-diffusible proteins (Borle, 1981). For the purposes of this document, however, it is not useful to model the nonuniform distribution of calcium in blood.

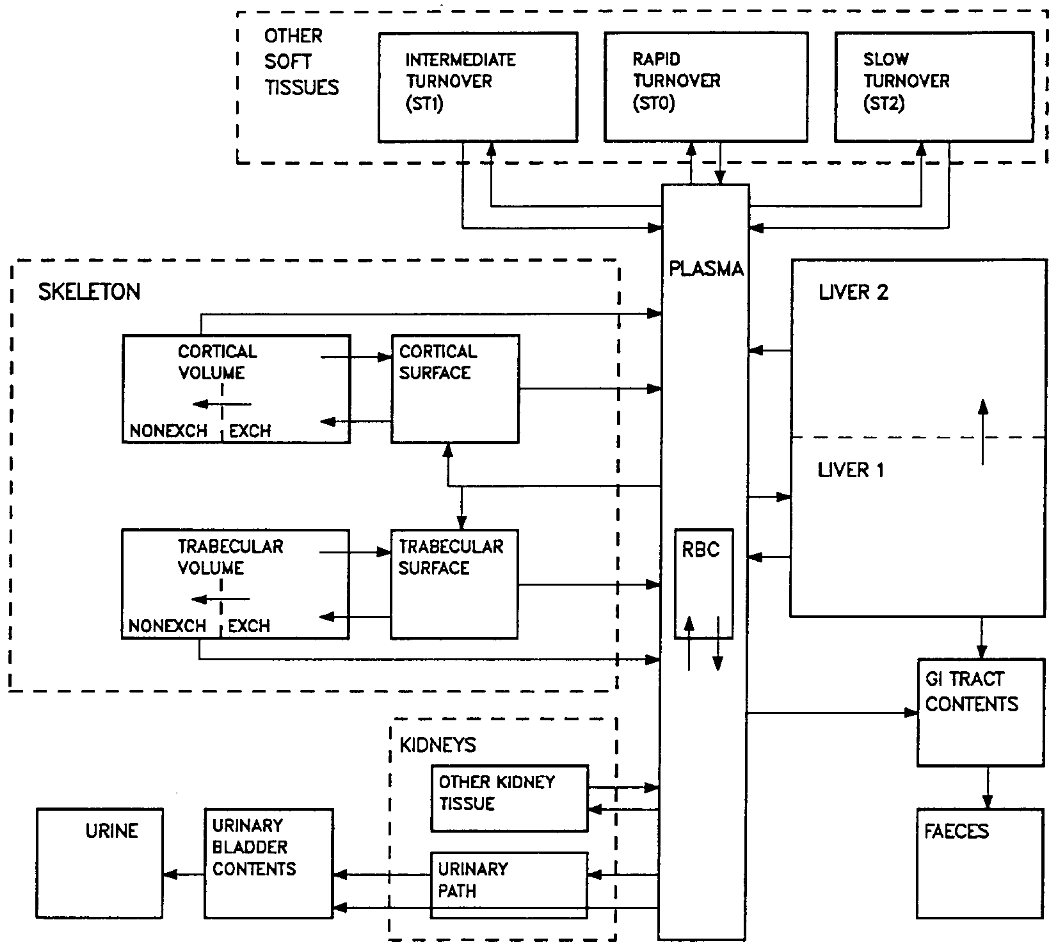

Fig. A.1. Diagram of the generic model structure for alkaline earth and physiologically similar elements. Not all compartments shown are used for calcium.

(A8) Soft tissues are divided into three compartments corresponding to fast, intermediate, and slow rates of return of activity to plasma (compartments ST0, ST1, and ST2, respectively). Although these compartments cannot be given precise anatomical definitions, ST0 may consist largely of interstitial fluids plus some rapidly exchangeable cellular calcium (Heaney, 1964; Harrison *et al.*, 1967; Hart and Spencer, 1976); ST1 may be a composite of several pools with slower exchange rates, including mitochondrial calcium, cartilage calcium, and exchangeable dystrophic calcium (e.g. arterial plaque and calcified nodes) (Heaney, 1964; Borle, 1981); and ST2 may be associated with relatively nonexchangeable dystrophic calcium that gradually accumulates in the human body (Heaney, 1964).

(A9) The compartments and paths of movement within the skeleton (Fig. A.1) have the same interpretation for all alkaline earth elements as well as for lead and uranium, although some of the transfer rates are element-specific. As in the alkaline earth model described in *ICRP Publication 20* (ICRP, 1973), bone is divided into cortical surface, cortical volume, trabecular surface, and trabecular volume. Also, as in that model, the rapidly exchangeable activity in bone is assumed to reside on bone surfaces. Bone surfaces are equated with anatomical surfaces of bone as an organ and include bone surface cells and fluids. The model in *ICRP Publication 20* has a power-function component that accounts for most of the biological removal from bone that occurs from a few weeks to several months after injection (ICRP, 1973). In the present model, activity is assumed to be removed from all pools by first-order processes. Cortical and trabecular bone volume are each viewed as consisting of two pools, referred to here and in *ICRP Publications 67* and *69* (ICRP, 1993, 1995) as exchangeable and nonexchangeable bone volume and called shallow and deep bone volume in the original description of the model (Leggett, 1992a). Activity moving from bone surfaces to bone volume is assumed to enter the exchangeable pool and to leave this pool with an element-specific half-time ranging from a few weeks to a few months. Part of the activity leaving exchangeable bone volume is assigned to rapidly exchanging bone surfaces, and the remainder is assigned to nonexchangeable bone volume. Activity is transferred from nonexchangeable bone volume to plasma at the rate of bone remodelling, which is assumed to vary with age and to be higher for trabecular bone than for cortical bone in persons older than 1 year.

(A10) Calcium is assumed to be lost from the body only by urinary or faecal excretion. Activity going to urine is first transferred from plasma to the urinary bladder contents, and activity going to faeces is first transferred from plasma to the contents of the upper large intestines. The biliary excretion pathway is of limited importance for the alkaline earth elements and is not addressed explicitly in the model for calcium.

(A11) Transfer rates for the model are given in Table A.1. The selection of transfer rates is described briefly in the following and explained in greater detail in the paper by Leggett (1992a). Figures A.2 and A.3 give the predicted skeleton and soft tissue content of calcium as a function of time after entry into the systemic circulation of infants, 10-y-old children, and mature adults, based on the parameter values given in Table A.1.

A.3. Parameter values

Adults

(A12) Persons younger than about 25 y appear to retain the alkaline earth elements to a greater extent than do older persons (ICRP, 1973; Likhtarev *et al.*, 1975). For this reason, a "mature adult" is defined here to be a person at least 25 years old (see Paragraph 19).

(A13) In the following, the "removal half-time" from a compartment refers to the biological half-time that would be observed if there were no recycling to that compartment. This will generally differ from the apparent (or net, or externally viewed) half-time that may be estimated at any given time in the presence of recycling. The "deposition fraction" for a compartment fed by plasma is the fraction of instantaneous outflow from plasma that is transferred to that compartment. For example, the deposition fraction for ST1 is 0.1; this means that ST1 receives 10% of activity leaving plasma over a period of a few seconds.

(A14) Kinetic analysis of plasma disappearance curves for normal subjects intravenously injected with radioisotopes of the alkaline earth elements indicates that these elements initially leave plasma at a rate of several hundred plasma volumes d^{-1} and equilibrate rapidly with an extravascular pool (presumably consisting largely of interstitial fluids), roughly three times the size of the plasma pool (Heaney, 1964; Harrison *et al.*, 1967; Hart and Spencer, 1976). The present model does not depict the rapid exchange of calcium between plasma and this extravascular pool within the first few minutes after introduction of calcium into blood. However, the model includes a soft-tissue compartment (ST0) that receives more than half of

Table A.1. Age-specific transfer rates (d^{-1}) for calcium model[a]

Pathway[b]	Age					
	3 mo	1 y	5 y	10 y	15 y	Adult[c]
Plasma to UB content	2.000E−01	4.400E−01	4.800E−01	3.520E−01	2.080E−01	6.000E−01
Plasma to ULI content	1.500E−01	3.300E−01	3.600E−01	2.640E−01	1.560E−01	4.500E−01
Plasma to trab. surf.	2.250E+00	1.350E+00	1.330E+00	2.120E+00	3.100E+00	2.080E+00
Plasma to cort. surf.	9.000E+00	5.400E+00	4.670E+00	6.280E+00	8.000E+00	1.670E+00
Plasma to ST0	2.900E+00	6.380E+00	6.960E+00	5.104E+00	3.016E+00	8.700E+00
Plasma to ST1	5.000E−01	1.100E+00	1.200E+00	8.800E−01	5.200E−01	1.500E+00
Plasma to ST2	2.500E−04	5.500E−04	6.000E−04	4.400E−04	2.600E−04	7.500E−04
Trab. surf. to plasma	5.780E−01	5.780E−01	5.780E−01	5.780E−01	5.780E−01	5.780E−01
Trab. surf. to exch. trab. vol.	1.160E−01	1.160E−01	1.160E−01	1.160E−01	1.160E−01	8.000E−04
Cort. surf. to plasma	5.780E−01	5.780E−01	5.780E−01	5.780E−01	5.780E−01	5.780E−01
Cort. surf. to exch. cort. vol.	1.160E−01	1.160E−01	1.160E−01	1.160E−01	1.160E−01	1.160E−01
ST0 to plasma	9.667E−01	2.127E+00	2.320E+00	1.701E+00	1.005E+00	2.900E+00
ST1 to plasma	1.733E−01	1.733E−01	1.733E−01	1.733E−01	1.733E−01	1.733E−01
ST2 to plasma	3.800E−04	3.800E−04	3.800E−04	3.800E−04	3.800E−04	3.800E−04
Exch. trab. vol. to trab. surf.	2.773E−03	2.773E−03	2.773E−03	2.773E−03	2.773E−03	2.773E−03
Exch. to nonexch. trab. vol.	4.159E−03	4.159E−03	4.159E−03	4.159E−03	4.159E−03	4.159E−03
Exch. cort. vol. to cort. surf.	2.773E−03	2.773E−03	2.773E−03	2.773E−03	2.773E−03	2.773E−03
Exch. to nonexch. cort. vol.	4.159E−03	4.159E−03	4.159E−03	4.159E−03	4.159E−03	4.159E−03
Nonexch. trab. vol. to plasma	8.220E−03	2.880E−03	1.810E−03	1.320E−03	9.590E−04	4.932E−04
Nonexch. cort. vol. to plasma	8.220E−03	2.880E−03	1.530E−03	9.040E−04	5.210E−04	8.219E−05
f_1	6.000E−01	4.000E−01	4.000E−01	4.000E−01	4.000E−01	3.000E−01

[a] Parameters are given to sufficient precision for calculational purposes. This may be more precise than the biological data would support.
[b] UB, urinary bladder; ULI, upper large intestine; trab., trabecular; cort., cortical; surf., surface; exch., exchangeable; nonexch., nonexchangeable; vol., volume.
[c] In the model for calcium, mature adulthood is assumed to be reached at age 25 years.

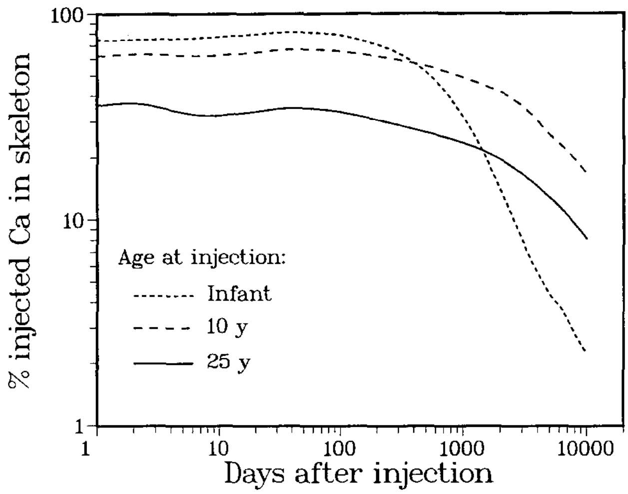

Fig. A.2. Model predictions of the calcium content of the skeleton as a function of age at injection and time after injection.

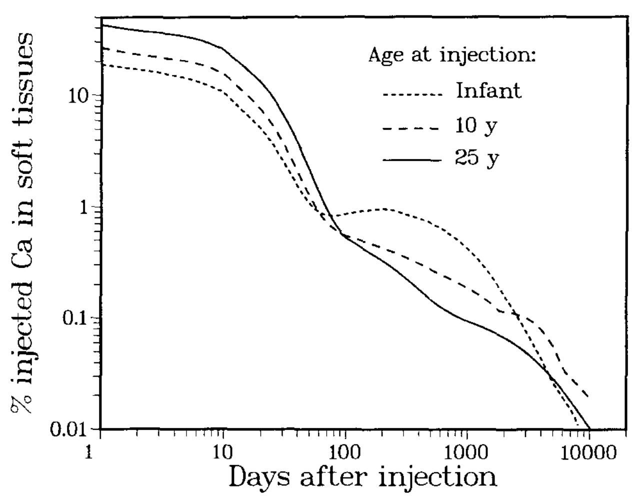

Fig. A.3. Model predictions of the calcium content of soft tissues as a function of age at injection and time after injection.

activity leaving plasma, returns activity to plasma with a half-time of a few hours, and contains three times as much activity as plasma at times more than a few hours after introduction of calcium to blood. This compartment is used to account for relatively high concentrations of calcium tracers observed in soft tissues during the first few hours after injection. A total transfer rate from plasma of 15 d^{-1} (i.e. a removal half-time of [ln(2)/15] d= 0.04621 d) yields reasonable fits to plasma disappearance curves for calcium or strontium tracers at times beyond 1–2 h after injection into human subjects (e.g. Barnes *et al.*, 1961; Heaney, 1964; Heaney *et al.*, 1964; Harrison *et al.*, 1967; Neer *et al.*, 1967; ICRP, 1973; Newton *et al.*, 1990).

(A15) Fractional deposition in the fast-turnover soft-tissue compartment ST0 is assumed to be 0.58. This value was determined as the remainder after other deposition fractions for calcium had been assigned. The corresponding transfer rate from plasma to ST0 is $0.58 \times 15\ d^{-1} = 8.7\ d^{-1}$. Based on the assumed relative amounts of calcium in ST0 and plasma, the transfer rate from ST0 to plasma was set at one-third the transfer rate from plasma to ST0, or $2.9\ d^{-1}$.

(A16) Readily exchangeable calcium in soft tissues, meaning calcium that is turned over to a substantial extent in a period of hours or days, is represented in this model as the sum of calcium in compartments ST0 and ST1. The amount of readily exchangeable calcium in soft tissues is approximately 0.35% of total-body calcium in a middle-aged adult human (Heaney, 1964; Borle, 1981). Since plasma contains about 0.03% of total-body calcium in the adult (ICRP, 1975), the three-fold larger compartment ST0 would contain 0.09% and ST1 would contain $0.35\% - 0.09\% = 0.26\%$ of total-body calcium during chronic intake. Parameter values for ST1 were set to reproduce these steady-state conditions while achieving a close approximation to soft-tissue retention data for terminally ill human subjects intravenously injected with ^{45}Ca at times ranging from a few hours to 124 days before death (Schulert *et al.*, 1959). This was accomplished by assigning to ST1 a deposition fraction of 0.1 and a removal half time (to plasma) of 4 d. The resulting transfer rate from plasma to ST1 is $0.1 \times 15\ d^{-1} = 1.5\ d^{-1}$, and the transfer rate from ST1 to plasma is $\ln(2)/4\ d = 0.1733\ d^{-1}$.

(A17) Parameter values for compartment ST2 were set to achieve reasonable agreement with: an estimate of the amount of relatively nonexchangeable calcium that gradually accumulates in soft tissues of humans (Heaney, 1964); an estimate of the fraction of total-body calcium in soft tissues under conditions of chronic exposure (Schlenker *et al.*, 1982); and the observed retention of ^{45}Ca in soft tissues at 3 months after injection (Schulert *et al.*, 1959). Reasonable agreement with these three values was achieved by assuming that ST2 receives 0.005% of outflow from plasma and that the removal half time from ST2 to plasma is 5 y. The resulting transfer rate from plasma to ST2 is $0.00005 \times 15\ d^{-1} = 0.00075\ d^{-1}$, and the transfer rate from ST1 to plasma is $\ln(2)/(5 \times 365\ d) = 0.00038\ d^{-1}$.

(A18) Data for laboratory animals indicate that fractional deposition on bone surfaces is similar for calcium, strontium, barium, and radium. This is inferred from the similar skeletal contents of these elements in the first few hours after injection (Bligh and Taylor, 1963; Kshirsagar *et al.*, 1966; Domanski *et al.*, 1969, 1980). Use of a common bone-surface deposition fraction for all four elements is consistent with available human data, which includes: autoradiographic measurements of surface activity in bone samples taken at autopsy from subjects injected with radiocalcium at 0.6 days or longer before death (Riggs *et al.*, 1971; ICRP, 1973); measurements of radiocalcium and radiostrontium in bone samples from subjects injected 3 hours or longer before death (Schulert *et al.*, 1959); and external measurements of the buildup of radiocalcium (Anderson *et al.*, 1970; Heard and Chamberlain, 1984) and radiobarium (Korsunskii *et al.*, 1981) after intravenous injection. Based on these data, it is assumed that 25% of calcium, strontium, barium, or radium leaving plasma is deposited on bone surfaces of the mature adult. Therefore, the transfer rate from plasma to cortical and trabecular bone surfaces combined is $0.25 \times 15\ d^{-1} = 3.75\ d^{-1}$.

(A19) The initial distribution between different bones of the skeleton and between the two bone types (cortical and trabecular) also appears to be similar for calcium, strontium, barium, and radium (Ellsasser *et al.*, 1969; Wood *et al.*, 1970; Liniecki, 1971; Stather, 1974; Lloyd *et al.*, 1976). As discussed below, relative deposition of alkaline earth elements on cortical and trabecular bone surfaces is based on the estimated calcium turnover rate of each bone type. This approach agrees with measurements on laboratory animals (Kshirsagar *et al.*, 1966; Nordin and Arnold, 1980). As an average over adult ages, deposition on trabecular bone is estimated to be 1.25 times that on cortical bone (Leggett *et al.*, 1982). Therefore, the transfer rate from plasma to trabecular bone surface is $(1.25/2.25) \times 3.75\ d^{-1} = 2.08\ d^{-1}$ and from plasma to cortical bone surface is $(3.75-2.08)\ d^{-1} = 1.67\ d^{-1}$.

(A20) The removal half-time of calcium from bone surfaces is estimated as 1 d. This estimate is based on autoradiographic measurements of surface activity in human and canine bone samples taken at times ranging from a few hours to a few days after intravenous injection of ^{45}Ca (Riggs *et al.*, 1971; Groer *et al.*, 1972; Groer and Marshall, 1973; ICRP, 1973). The same value was used in the models for strontium, barium and radium (Leggett, 1992a; ICRP, 1993).

(A21) Parameter values for exchangeable bone volume are estimated from whole-body measurements using data for times after bone surfaces and soft tissues have largely cleared of activity, but before loss from bone resorption becomes an important consideration. Based on whole-body retention curves for human subjects injected with radioisotopes of calcium, strontium, barium, or radium (Spencer *et al.*, 1960; Bishop *et al.*, 1960; Heaney *et al.*, 1964; Harrison *et al.*, 1967; Maletskos *et al.*, 1969; Phang *et al.*, 1969; Carr *et al.*, 1973; Likhtarev *et al.*, 1975; Malluche *et al.*, 1978; Henrichs *et al.*, 1984; Newton *et al.*, 1990, 1991), it was estimated that the fraction of injected activity released from bone over the intermediate term is roughly the same for all four elements. Specifically, it was estimated that 1/6 of activity leaving bone surfaces moves to exchangeable bone volume. Therefore, the transfer rate from trabecular or cortical bone surface to the corresponding exchangeable bone volume compartment is $(1/6) \times \ln(2)/1\ d = 0.116\ d^{-1}$, and the transfer rate from trabecular or cortical bone surface to plasma is $(5/6) \times \ln(2)/1\ d = 0.578\ d^{-1}$.

(A22) Element-specific removal half-times from the exchangeable bone volume compartments were based in part on fits to the intermediate-term retention data indicated above. However, it was also observed that the half-times increase roughly in proportion to the likelihood of entering nonexchangeable sites in bone mineral, as judged either by *in vitro* experiments with hydroxyapatite crystals or by data on whole-body retention of alkaline earth elements in human subjects. A removal half-time of 100 d was estimated for calcium, compared with values of 80 d for strontium, 50 d for barium, and 30 d for radium (Leggett, 1992a; ICRP, 1993). The data did not allow the derivation of removal half-times as a function of bone type, i.e. the same half-time was assumed to apply both to cortical and trabecular exchangeable bone volume compartments.

(A23) Discrimination among the alkaline earth elements by bone is accounted for by fractional transfer of activity from exchangeable to nonexchangeable bone volume. It is assumed, in effect, that calcium, strontium, barium, and radium are all equally likely to become temporarily incorporated in bone mineral after injection into plasma but that the likelihood of reaching a non-exchangeable site in bone crystal decreases in the order calcium>strontium>barium>radium. Fractional transfers of calcium, strontium, barium, and radium from exchangeable to nonexchangeable bone volume were set at 0.6, 0.5, 0.3, and 0.2, respectively, for consistency with whole-body and skeletal retention data on these elements (Spencer *et al.*, 1960; Bishop *et al.*, 1960; Heaney *et al.*, 1964; Harrison *et al.*, 1967; Phang *et al.*, 1969; Maletskos *et al.*, 1969; Carr *et al.*, 1973; Likhtarev *et al.*, 1975; Malluche *et al.*, 1978; Henrichs *et al.*, 1984; Newton *et al.*, 1990, 1991) as well as results of *in vitro* measurements on hydroxyapatite crystals (Neuman, 1964; Stark, 1968). Therefore, the transfer rate from the exchangeable bone volume compartment of trabecular or cortical bone to the corresponding nonexchangeable bone volume compartment is

$0.6 \times \ln(2)/100\ d = 0.004159\ d^{-1}$ and to the corresponding bone surface compartment is $0.4 \times \ln(2)/100\ d = 0.002773\ d^{-1}$.

(A24) Biological removal from the nonexchangeable bone volume compartments of cortical and trabecular bone is assumed to result from bone turnover. The age-specific bone turnover rates used in this model are given in *ICRP Publication 67* (1993). For adults, the assumed turnover rates are 3% y^{-1} and 18% y^{-1} for cortical and trabecular bone, respectively. Therefore, the transfer rates from the nonexchangeable bone volume compartments of cortical and trabecular bone to plasma are 0.00008219 and 0.0004932 d^{-1}, respectively.

(A25) Clearance of calcium from plasma to urine and faeces has been studied in a large number of human subjects, many of them healthy (Bishop *et al.*, 1960; Spencer *et al.*, 1960; Barnes *et al.*, 1961; Cohn *et al.*, 1963; Heaney *et al.*, 1964; Samachson, 1966; Phang *et al.*, 1969; Carr *et al.*, 1973; Newton *et al.*, 1990). Based on results of these studies, it is assumed that 4% of calcium leaving plasma is transferred to the contents of the urinary bladder contents and subsequently to urine and 3% is transferred to the contents of the upper large intestine and subsequently to faeces. Therefore, the transfer rate from plasma to urinary bladder contents is $0.04 \times 15\ d^{-1} = 0.6\ d^{-1}$ and from plasma to the contents of the upper large intestine is $0.03 \times 15\ d^{-1} = 0.45\ d^{-1}$.

Children

(A26) The method of extension of parameter values for calcium from mature adults to children is completely analogous to the method applied in *ICRP Publication 67* (1993) to lead, strontium, barium, and radium. Based on studies of the age-specific behaviour of alkaline earth elements in laboratory animals and humans (Bronner *et al.*, 1956; Bauer *et al.*, 1957; Glad *et al.*, 1960; Kulp and Schulert, 1962; Decker *et al.*, 1964; MacDonald *et al.*, 1965; Atherton, 1965; Lee *et al.*, 1965; Kereiakes *et al.*, 1966; Anderson and Comar, 1968; Wellman *et al.*, 1969; Osanov *et al.*, 1971; Kallfelz and Wentworth, 1970; Woodard and Dwyer, 1972; Stather, 1974; Likhtarev *et al.*, 1975; Parks *et al.*, 1978; Domanski *et al.*, 1980; Parks and Keane, 1983; Lloyd *et al.*, 1983; Bruenger *et al.*, 1983; Henrichs *et al.*, 1984; Bruenger *et al.*, 1989), deposition fractions for cortical and trabecular bone surfaces are assumed to vary with age in proportion to the calcium addition rate (g Ca/d) for the given bone type and hence are assumed to be higher in children than in adults. Deposition fractions for soft tissues and excretion pathways in children are reduced uniformly to balance the increased skeletal deposition fractions relative to the adult. The basis and implementation of the method are described in detail in the paper by Leggett (1992a) and in Appendix A to *ICRP Publication 67* (1993).

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ANNEXE B. AGE-DEPENDENT BIOKINETIC MODEL FOR CURIUM

B.1. Uptake to blood

Adults

(B1) Human data are available on the absorption of curium (Cm) from one study (Popplewell *et al.*, 1991). The absorption of ^{239}Np and ^{242}Cm was measured in five adult male volunteers by comparing urinary excretion after oral and intravenous administration. In each case the elements were administered as the citrate complexes; the solutions were ingested with a midday meal. The mean f_1 value obtained was 2×10^{-4} for both Np(V) and Cm(III) with a range of 1×10^{-4} to 3×10^{-4} in both cases.

(B2) Curium absorption has also been measured in animals. Values for rats were in the range 3×10^{-5} to 7×10^{-4} (Semenov, 1971; Semenov *et al.*, 1973; Sullivan and Crosby, 1975). In guinea-pigs given ^{242}Cm prepared in the same way as for the volunteer study of Popplewell *et al.* (1991), absorption was about 10^{-4} (Naylor *et al.*, 1991). Leaving ^{244}Cm oxide in water for 4 d prior to administration to rats, increased absorption from 4×10^{-5} to 5×10^{-4} (Sullivan, 1980).

(B3) In *ICRP Publication 30* (ICRP, 1979), an f_1 value of 5×10^{-4} was recommended by analogy with americium. In *ICRP Publication 48* (ICRP, 1986), a general value of 1×10^{-3} for actinides was used. In *ICRP Publication 67* (ICRP, 1993), the recent human data for neptunium, plutonium, americium and curium were reviewed, together with human data for thorium and available animal data. A general value of 5×10^{-4} was adopted for all actinides other than uranium. An f_1 value of 5×10^{-4} is also adopted here for curium absorption in adults.

Children

(B4) There is strong experimental evidence that the absorption of actinide elements may be increased by at least an order of magnitude in the immediate postnatal period (ICRP, 1986). High values of curium uptake have been observed in newborn rats and pigs (Sullivan and Gorham, 1982; Sullivan *et al.*, 1985). The age at which absorption will decrease to adult levels in humans is not known but animal data on actinides, principally for plutonium and americium, show a progressive reduction over the suckling period to reach adult values at about the time of weaning.

(B5) In *ICRP Publication 48* (1986), an f_1 value of 10^{-2} was recommended as a general value for the absorption of actinides in the first year of life. In *ICRP Publication 56* (1989), this value was used to calculate doses to 3-mo-old infants from isotopes of plutonium, americium and neptunium; the adult value of 10^{-3} was used for children from 1 year of age. In *ICRP Publication 67* (1993), the infant value was changed to 5×10^{-3} in line with the change in adult value to 5×10^{-4}. The f_1 value of 5×10^{-3} is adopted here for curium absorption in 3-mo-old infants.

B.2. Biokinetic model

(B6) The biological behaviour of curium is closely related to that of the chemically similar element americium, particularly with regard to activity that reaches the systemic circulation.

This is indicated by results of relatively detailed experimental studies on rats and is supported by more limited experimental data on larger animals, including dogs, baboons and sheep.

(B7) In an investigation of the transport of different actinides in the blood of rats, Turner and Taylor (1968) observed virtually identical rates of circulatory clearance of ^{244}Cm and ^{241}Am during the first day after intravenous injection of ^{244}Cm nitrate, ^{241}Am nitrate, or ^{241}Am citrate. Collective data of Scott, Durbin and co-workers (Scott *et al.*, 1948, 1949; Durbin *et al.*, 1969; Durbin, 1973) for ^{241}Am and ^{242}Cm show similar initial distributions and nearly identical patterns of excretion of these two radionuclides over a period of several months after intramuscular injection of relatively soluble forms into rats. In rats injected with ^{241}Am citrate or ^{242}Cm citrate, the concentration of ^{242}Cm at 6 d after administration was virtually the same as that of ^{241}Am in all measured tissues (skeleton, liver, spleen, kidneys, lung, thyroid, adrenals, ovaries), but chelation therapy appeared to be slightly more effective for ^{242}Cm than ^{241}Am (Seidel and Volf, 1972). Stather and Priest (1976) observed similar tissue distributions of ^{241}Am and ^{242}Cm in adult rats at 1 week, 1 month, and 5 months after pulmonary intubation of these radionuclides as nitrates, but ^{242}Cm appeared to be lost from the body at a slightly higher rate than ^{241}Am at 1–5 months after administration. Crawley and Goddard (1976) found virtually identical systemic distribution and retention of Am and Cm in rats during the first week after intubation of these elements into each of three regions of the respiratory tract. Nenot *et al.* (1972) observed similar behaviour of ^{241}Am and ^{242}Cm in rats after administration by inhalation or intramuscular injection of these radionuclides as nitrates, with regard to cumulative urinary excretion, levels of uptake and retention by bone, and sites of binding in bone. In a study of comparative retention of bone-seeking radionuclides in rats, Taylor (1983) found that uptake and long-term retention of ^{244}Cm in bone was similar to that of ^{241}Am.

(B8) Some comparative information on the biokinetics of systemic curium and americium is available for dogs but is limited by the relatively small numbers of animals used, particularly in the curium studies, and potentially important differences in the ages of animals used in different experiments. A series of studies at the University of Utah (Lloyd *et al.*, 1970, 1974; Atherton *et al.*, 1973; Bruenger *et al.*, 1976) gave results that indicate that the biokinetics of Cm in beagles is similar to that of Am but that the initial liver-to-skeleton concentration ratio and rate of faecal excretion may be slightly greater for Cm than for Am. Data of Craig *et al.* (1976) indicate that the time-dependent division of ^{244}Cm between liver and skeleton in beagles is roughly the same as that of ^{241}Am at 10–270 days after inhalation of $^{241}AmO_2$ or $^{244}CmO_x$ aerosols. In an investigation of the biological behaviour of inhaled ^{244}Cm compounds in beagles, Guilmette and Mewhinney (1989) found that a biokinetic model for americium developed earlier from data on inhaled $^{241}AmO_2$ in beagles (Mewhinney and Griffith, 1983) applied nearly equally well to ^{244}Cm with regard to the behaviour of absorbed activity.

(B9) Experimental data on a small number of baboons injected with ^{241}Am citrate (Rosen *et al.*, 1972; Cohen and Wrenn, 1973; Guilmette *et al.*, 1980) or $^{243/244}$Cm citrate (Lo Sasso *et al.*, 1981) indicate similar patterns of systemic distribution and retention of these radionuclides. Mean cumulative excretion was greater for ^{241}Am than $^{243/244}$Cm, but individual cumulative urinary excretion curves for $^{2413/244}$Cm appear to be within the range of variability of urinary excretion data on ^{241}Am.

(B10) McClellan *et al.* (1962) studied the transfer of ^{45}Ca, ^{233}U, ^{237}Np, ^{239}Pu, ^{241}Am and ^{244}Cm from plasma to milk following intravenous injection into lactating ewes. All radionuclides were administered as nitrate except for ^{241}Am, which was administered as chloride. Rates of circulatory clearance and milk-to-plasma ratios were found to be similar for ^{241}Am and ^{244}Cm. Much different milk-to-plasma ratios were determined for the other radionuclides.

(B11) In summary, results of a variety of experimental studies on laboratory animals indicate that the chemically similar elements americium and curium are also close physiological analogues. Although quantitative differences in the biokinetics of systemic curium and americium have been observed in some studies, such differences generally have not been statistically significant and in most cases are contradicted by results of separate investigations. In this report, the systemic biokinetic model adopted earlier for americium in *ICRP Publication 67* (ICRP, 1993) is applied here to curium without change.

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ANNEXE C. BIOKINETICS OF DECAY PRODUCTS OF TELLURIUM AND MEMBERS OF THORIUM AND URANIUM DECAY CHAINS

(C1) In this report, and in *ICRP Publications 67* and *69* (ICRP, 1993, 1995), doses from decay products formed within the body following the intake of radioisotopes of tellurium, lead, radium, thorium, and uranium were evaluated based on the biokinetic behaviour of the specific decay product; so-called independent kinetics. Decay products of other radioelements were evaluated in the manner of *ICRP Publication 30* (ICRP, 1979); i.e. the kinetics of the parent of the chain was assigned to the decay products—referred to as shared kinetics. The independent behaviour of the decay products was discussed in *ICRP Publications 67* and *69* however the biokinetic data were not tabulated. It is the purpose of this annexe to tabulate these data and to discuss the manner in which the "Other" tissue region is addressed when its anatomical identity varies among the decay chain members.

C.1. Radioiodine decay product of tellurium

(C2) The biokinetic behaviour of radioisotopes of iodine produced by the decay of systemic tellurium was discussed in Paragraph 95 of *ICRP Publication 67.* Iodine formed by nuclear transformations of tellurium (other than in the thyroid) is translocated instantaneously (implemented using a transfer rate of 1 000 d^{-1}) to the transfer compartment in the inorganic form where it then has the biokinetic behaviour of systemic iodine. Iodine produced within the thyroid is retained as organic iodine and that produced within the stomach and small intestine is absorbed according to normal gastrointestinal (GI) tract kinetics. Radioiodine formed in the lower segments of the GI-tract is excreted.

(C3) The biokinetic behaviour of iodine as a decay product of tellurium is given in Table C.1. In the tables of this annexe, compartments are named according to their anatomical identity. The entries "C_Bone-S" and "T_Bone-S" in Table C.1 represent the surface compartments of cortical and trabecular bone, respectively, as specified in the tellurium biokinetic model. "Blood", "Kidneys", and "Other" refer to the transfer

Table C.1. Kinetics of iodine as a decay product of tellurium

		Age-dependent transfer rate (d^{-1})					
		3 months	1 year	5 years	10 years	15 years	Adult
C_Bone-S	-> Blood	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
T_Bone-S	-> Blood	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
Kidneys	-> Blood	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
Other	-> Blood	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
Blood	-> Thyroid	8.3178E-01	8.3178E-01	8.3178E-01	8.3178E-01	8.3178E-01	8.3178E-01
Blood	-> UB_Cont	1.9408E+00	1.9408E+00	1.9408E+00	1.9408E+00	1.9408E+00	1.9408E+00
Thyroid	-> Other_I	6.1888E-02	4.6210E-02	3.0137E-02	1.1951E-02	1.0345E-02	8.6643E-03
Other_I	-> Blood	4.9511E-01	3.6968E-01	2.4109E-01	9.5606E-02	8.2764E-02	4.6210E-02
Other_I	-> ULI_Cont	1.2378E-01	9.2420E-02	6.0274E-02	2.3902E-02	2.0691E-02	1.1552E-02

See iodine biokinetic discussion for applicable f_1 values.

compartment, the kidneys and other systemic tissues, respectively, of the tellurium model. The first four transfers in Table C.1 remove iodine from the compartments of its birth in the tellurium biokinetic model to the transfer compartment ("Blood"). The remaining transfers describe the biokinetic behaviour of systemic iodine. The compartment labelled "Other_I" represents the distribution of extra-thyroid organic iodine; the notation "_I" serves to distinguish this compartment from the "Other" compartment in the tellurium biokinetic model.

C.2. Decay products of members of the thorium and uranium decay chains

(C4) The biokinetic behaviour of the decay products of lead and radium were discussed in Paragraphs 109–111 and 126–131, respectively, of *ICRP Publication 67* and further discussed as decay products of thorium and uranium in Paragraphs 120 and 159, respectively, of *ICRP Publication 69*. The description of the behaviour is determined, in part, by the structure of the generic age-specific biokinetic models for calcium-like elements (uranium, radium and lead) and for plutonium-like elements (thorium) presented in Appendices A and B of *ICRP Publication 67*. The biokinetic behaviour of the decay products are given in Tables C.2–C.11.

(C5) The description of the biokinetic behaviour of the decay products includes consideration of the exchangeable and non-exchangeable bone volume compartments in the model for the calcium-like elements (the exchangeable compartments of cortical and trabecular bone volume are denoted as "C_Bone-V_e" and "T_Bone-V_e", respectively), the non-exchangeable compartments (denoted as "C_Bone-V" and "T_Bone-V"), the plasma (denoted as "Blood"), and red blood cells (denoted as "Blood_1"). The surface compartment of cortical and trabecular bone are denoted as "C_Bone-S" and "T_Bone-S", respectively. Systemic material is lost through urinary excretion (contents of the

Table C.2. Kinetics of thallium, astatine, and francium as decay products in thorium and uranium chains

	Age-dependent transfer rate (d^{-1})					
	3 months	1 year	5 years	10 years	15 years	Adult
Blood -> Other_1	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Blood_1 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
T_Bone-S -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
C_Bone-S -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Other_0 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Other_1 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Other_2 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
T_Bone-V_e-> T_Bone-S	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
T_Bone-V_e-> T_Bone-V	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
C_Bone-V_e-> C_Bone-S	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
C_Bone-V_e-> C_Bone-V	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
C_Bone-V -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
T_Bone-V -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Liver_1 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Liver_2 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Kidneys_1 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Kidneys_2 -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Spleen -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
R_Marrow -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
C_Bone-S_1-> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Testes -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Ovaries -> Blood	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
f_1	1.0	1.0	1.0	1.0	1.0	1.0

Table C.3. Kinetics of lead as a decay product in thorium and uranium chains

		Age-dependent transfer rate (d^{-1})					
		3 months	1 year	5 years	10 years	15 years	Adult
Blood	->UB_Cont	1.2500E+00	1.5500E+00	1.6000E+00	1.4400E+00	1.2600E+00	1.7500E+00
Blood	->ULI_Cont	5.0000E-01	6.2000E-01	6.4000E-01	5.7600E-01	5.0400E-01	7.0000E-01
Blood	->T_Bone-S	5.2500E+00	3.1500E+00	3.1100E+00	4.9400E+00	7.2300E+00	4.8600E+00
Blood	->C_Bone-S	2.1000E+01	1.2600E+01	1.0890E+01	1.4660E+01	1.8670E+01	3.8900E+00
Blood	->Other_0	1.5830E+01	1.9630E+01	2.0260E+01	1.8230E+01	1.5960E+01	2.2160E+01
Blood	->Other_1	5.0000E-01	6.2000E-01	6.4000E-01	5.7600E-01	5.0400E-01	7.0000E-01
Blood	->Other_2	1.0000E-01	1.2400E-01	1.2800E-01	1.1500E-01	1.0100E-01	1.4000E-01
Blood	->Liver_1	3.5000E+00	4.3400E+00	4.4800E+00	4.0300E+00	3.5300E+00	4.9000E+00
Blood	->Kidneys_1	1.7500E+00	2.1700E+00	2.2400E+00	2.0200E+00	1.7600E+00	2.4500E+00
Blood	->Kidneys_2	1.7500E-02	2.1700E-02	2.2400E-02	2.0200E-02	1.7600E-02	2.4500E-02
Blood	->Blood_1	2.0000E+01	2.4800E+01	2.5600E+01	2.3040E+01	2.0160E+01	2.8000E+01
Blood	->Excreta	3.0000E-01	3.7200E-01	3.8400E-01	3.4600E-01	3.0200E-01	4.2000E-01
Blood_1	->Blood	1.3900E-01	1.3900E-01	1.3900E-01	1.3900E-01	1.3900E-01	1.3900E-01
T_Bone-S	->Blood	6.5000E-01	6.5000E-01	6.5000E-01	6.5000E-01	6.5000E-01	5.0000E-01
T_Bone-S	->T_Bone-V_e	3.5000E-01	3.5000E-01	3.5000E-01	3.5000E-01	3.5000E-01	5.0000E-01
C_Bone-S	->Blood	6.5000E-01	6.5000E-01	6.5000E-01	6.5000E-01	6.5000E-01	5.0000E-01
C_Bone-S	->C_Bone-V_e	3.5000E-01	3.5000E-01	3.5000E-01	3.5000E-01	3.5000E-01	5.0000E-01
Other_0	->Blood	5.2800E+00	6.5400E+00	6.7500E+00	6.0800E+00	5.3200E+00	7.3900E+00
Other_1	->Blood	4.1600E-03	4.1600E-03	4.1600E-03	4.1600E-03	4.1600E-03	4.1600E-03
Other_1	->Excreta	2.7700E-03	2.7700E-03	2.7700E-03	2.7700E-03	2.7700E-03	2.7700E-03
Other_2	->Blood	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04
T_Bone-V_e	->T_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
T_Bone-V_e	->T_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V_e	->C_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
C_Bone-V_e	->C_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V	->Blood	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
T_Bone-V	->Blood	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Liver_1	->Blood	3.1200E-02	3.1200E-02	3.1200E-02	3.1200E-02	3.1200E-02	3.1200E-02
Liver_1	->Liver_2	6.9300E-03	6.9300E-03	6.9300E-03	6.9300E-03	6.9300E-03	6.9300E-03
Liver_1	->SI_Cont	3.1200E-02	3.1200E-02	3.1200E-02	3.1200E-02	3.1200E-02	3.1200E-02
Liver_2	->Blood	6.9300E-03	6.9300E-03	6.9300E-03	1.9000E-03	1.9000E-03	1.9000E-03
Kidneys_1	->UB_Cont	1.3900E-01	1.3900E-01	1.3900E-01	1.3900E-01	1.3900E-01	1.3900E-01
Kidneys_2	->Blood	6.9300E-03	6.9300E-03	6.9300E-03	1.9000E-03	1.9000E-03	1.9000E-03
Spleen	->Blood	0.693	0.693	0.693	0.693	0.693	0.693
Testes	->Blood	0.693	0.693	0.693	0.693	0.693	0.693
Ovaries	->Blood	0.693	0.693	0.693	0.693	0.693	0.693
R_Marrow	->Blood	0.693	0.693	0.693	0.693	0.693	0.693
C_Bone-S_1	->Blood	0.693	0.693	0.693	0.693	0.693	0.693

See lead biokinetic discussion for applicable f_1 values.

urinary bladder is denoted as "UB_Cont"), endogenous excretion (contents of the upper large intestine is denoted as "ULI_Cont"), and non-specified pathways (denoted as "Excreta"). In some instances, material is transferred to the contents of the small intestine (denoted as "SI_Cont"), from which a fraction is reabsorbed in accordance with conventional GI-tract kinetics. The soft-tissue compartments referred to as ST0, ST1, and ST2 in the generic models for calcium-like and plutonium-like elements are denoted as "Other_0", "Other_1", and "Other_2", respectively in the tables. Trabecular and cortical marrow are denoted as "R_Marrow" and "C_Bone-S_1", respectively; transformations in the latter compartment are associated with the surface of cortical bone. The "Urinary path" compartment of the kidneys, specified in the generic models, is denoted as "Kidneys_1", and "Kidneys_2" denotes the other kidney compartment in the generic models. The identity of the remaining compartments in the tables is generally self-evident. Note that compartments are named according to their anatomical identity with an appended "_X" used to distinguish, when necessary, different compartments of the same anatomical identity.

Table C.4. Kinetics of bismuth as a decay product in thorium and uranium chains

		Age-dependent transfer rate (d^{-1})					
		3 months	1 year	5 years	10 years	15 years	Adult
Blood	-> UB_Cont	1.7500E+01	1.7500E+01	1.7500E+01	1.7500E+01	1.7500E+01	1.7500E+01
Blood	-> ULI_Cont	3.5000E+00	3.5000E+00	3.5000E+00	3.5000E+00	3.5000E+00	3.5000E+00
Blood	-> Other_1	9.0000E+00	9.0000E+00	9.0000E+00	9.0000E+00	9.0000E+00	9.0000E+00
Blood	-> Liver_1	2.5000E+00	2.5000E+00	2.5000E+00	2.5000E+00	2.5000E+00	2.5000E+00
Blood	-> Kidneys_2	1.7500E+01	1.7500E+01	1.7500E+01	1.7500E+01	1.7500E+01	1.7500E+01
Blood_1	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
T_Bone-S	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
C_Bone-S	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Other_0	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Other_1	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Other_2	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
T_Bone-V_e	-> T_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
T_Bone-V_e	-> T_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V_e	-> C_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
C_Bone-V_e	-> C_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-S_1	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
C_Bone-V	-> Blood	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
T_Bone-V	-> Blood	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Liver_1	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Liver_2	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Spleen	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Kidneys_1	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Kidneys_2	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
R_Marrow	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Testes	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
Ovaries	-> Blood	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02	3.5000E-02
	f_1	0.1	0.05	0.05	0.05	0.05	0.05

Table C.5. Kinetics of polonium as a decay product in thorium and uranium chains

		Age-dependent transfer rate (d^{-1})					
		3 months	1 year	5 years	10 years	15 years	Adult
Blood	-> UB_Cont	5.0000E+00	5.0000E+00	5.0000E+00	5.0000E+00	5.0000E+00	5.0000E+00
Blood	-> ULI_Cont	1.0000E+01	1.0000E+01	1.0000E+01	1.0000E+01	1.0000E+01	1.0000E+01
Blood	-> Other_1	3.8250E+01	3.8250E+01	3.8250E+01	3.8250E+01	3.8250E+01	3.8250E+01
Blood	-> Liver_1	2.5500E+01	2.5500E+01	2.5500E+01	2.5500E+01	2.5500E+01	2.5500E+01
Blood	-> Kidneys_2	8.5000E+00	8.5000E+00	8.5000E+00	8.5000E+00	8.5000E+00	8.5000E+00
Blood	-> Spleen	4.2500E+00	4.2500E+00	4.2500E+00	4.2500E+00	4.2500E+00	4.2500E+00
Blood	-> R_Marrow	8.5000E+00	8.5000E+00	8.5000E+00	8.5000E+00	8.5000E+00	8.5000E+00
Blood_1	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
T_Bone-S	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
C_Bone-S	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Other_0	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Other_1	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Other_2	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
T_Bone-V_e	-> T_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
T_Bone-V_e	-> T_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V_e	-> C_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
C_Bone-V_e	-> C_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V	-> Blood	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
C_Bone-S_1	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
T_Bone-V	-> Blood	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Spleen	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Liver_1	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Liver_2	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Kidneys_1	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Kidneys_2	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
R_Marrow	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Testes	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01
Ovaries	-> Blood	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01	1.0000E-01

See polonium biokinetic discussion for applicable f_1 values.

Table C.6. Kinetics of radon as a decay product in thorium and uranium chains

	Age-dependent transfer rate (d^{-1})					
	3 months	1 year	5 years	10 years	15 years	Adult
Blood -> Excreta	1.4400E+03	1.4400E+03	1.4400E+03	1.4400E+03	1.4400E+03	1.4400E+03
T_Bone-S -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
C_Bone-S -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Other_0 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Other_1 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Other_2 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
T_Bone-V_e-> Blood	1.5000E+00	1.5000E+00	1.5000E+00	1.5000E+00	1.5000E+00	1.5000E+00
C_Bone-V_e-> Blood	1.5000E+00	1.5000E+00	1.5000E+00	1.5000E+00	1.5000E+00	1.5000E+00
C_Bone-V -> Blood	3.6000E-01	3.6000E-01	3.6000E-01	3.6000E-01	3.6000E-01	3.6000E-01
T_Bone-V -> Blood	3.6000E-01	3.6000E-01	3.6000E-01	3.6000E-01	3.6000E-01	3.6000E-01
Liver_1 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Liver_2 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Kidneys_1 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Kidneys_2 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
R_Marrow -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Spleen -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Testes -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Ovaries -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
C_Bone-S_1-> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02
Blood_1 -> Blood	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02	1.0000E+02

No uptake of radon from the GI-tract is considered.

Table C.7. Kinetics of radium as a decay product in thorium and uranium chains

	Age-dependent transfer rate (d^{-1})					
	3 months	1 year	5 years	10 years	15 years	Adult
Blood -> Liver_1	1.1700E-01	2.5700E-01	2.8000E-01	2.0500E-01	1.2100E-01	3.5000E-01
Blood -> C_Bone-S	4.2000E+01	2.5200E+01	2.1780E+01	2.9320E+01	3.7350E+01	7.7800E+00
Blood -> T_Bone-S	1.0500E+01	6.3000E+00	6.2200E+00	9.8800E+00	1.4450E+01	9.7200E+00
Blood -> UB_Cont	2.0200E-01	4.4400E-01	4.8800E-01	3.5500E-01	2.1000E-01	6.0600E-01
Blood -> ULI_Cont	7.2600E+00	1.6000E+01	1.7430E+01	1.2780E+01	7.5500E+00	2.1790E+01
Blood -> Other_0	7.5600E+00	1.6630E+01	1.8140E+01	1.3310E+01	7.8600E+00	2.2680E+01
Blood -> Other_1	2.3300E+00	5.1300E+00	5.6000E+00	4.1100E+00	2.4300E+00	7.0000E+00
Blood -> Other_2	2.3300E-02	5.1300E-02	5.6000E-02	4.1100E-02	2.4300E-02	7.0000E-02
T_Bone-S -> Blood	5.7800E-01	5.7800E-01	5.7800E-01	5.7800E-01	5.7800E-01	5.7800E-01
T_Bone-S -> T_Bone-V_e	1.1600E-01	1.1600E-01	1.1600E-01	1.1600E-01	1.1600E-01	1.1600E-01
C_Bone-S -> Blood	5.7800E-01	5.7800E-01	5.7800E-01	5.7800E-01	5.7800E-01	5.7800E-01
C_Bone-S -> C_Bone-V_e	1.1600E-01	1.1600E-01	1.1600E-01	1.1600E-01	1.1600E-01	1.1600E-01
Kidneys_1 -> UB_Cont	0.693	0.693	0.693	0.693	0.693	0.693
Kidneys_2 -> Blood	0.693	0.693	0.693	0.693	0.693	0.693
Testes -> Blood	0.693	0.693	0.693	0.693	0.693	0.693
Ovaries -> Blood	0.693	0.693	0.693	0.693	0.693	0.693
Other_0 -> Blood	2.5200E+00	5.5400E+00	6.0500E+00	4.4400E+00	2.6200E+00	7.5600E+00
Other_1 -> Blood	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01
Other_2 -> Blood	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04
T_Bone-V_e-> T_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
T_Bone-V_e-> T_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V_e-> C_Bone-S	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02	1.8500E-02
C_Bone-V_e-> C_Bone-V	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03	4.6000E-03
C_Bone-V -> Blood	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
T_Bone-V -> Blood	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Liver_2 -> Blood	1.3900E-02	1.3900E-02	1.3900E-02	1.3900E-02	1.3900E-02	1.3900E-02
Liver_1 -> Blood	1.3900E-02	1.3900E-02	1.3900E-02	1.3900E-02	1.3900E-02	1.3900E-02
C_Bone-S_1-> Blood	0.693	0.693	0.693	0.693	0.693	0.693
R_Marrow -> Blood	0.693	0.693	0.693	0.693	0.693	0.693
Blood_1 -> Blood	0.693	0.693	0.693	0.693	0.693	0.693

See radium biokinetic discussion for applicable f_1 values.

Table C.8. Kinetics of actinium as a decay product in thorium and uranium chains

	Age-dependent transfer rate (d^{-1})					
	3 months	1 year	5 years	10 years	15 years	Adult
Blood -> Liver_1	6.4700E-02	6.4700E-02	6.4700E-02	6.4700E-02	6.4700E-02	9.7000E-02
Blood -> C_Bone-S	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	6.7930E-01
Blood -> T_Bone-S	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	6.7930E-01
Blood -> UB_Cont	7.1100E-02	7.1100E-02	7.1100E-02	7.1100E-02	7.1100E-02	1.0670E-01
Blood -> Kidneys_1	4.5300E-02	4.5300E-02	4.5300E-02	4.5300E-02	4.5300E-02	6.7900E-02
Blood -> Kidneys_2	1.2900E-02	1.2900E-02	1.2900E-02	1.2900E-02	1.2900E-02	1.9400E-02
Blood -> ULI_Cont	6.4700E-03	6.4700E-03	6.4700E-03	6.4700E-03	6.4700E-03	9.7000E-03
Blood -> Testes	3.9000E-05	5.8000E-05	6.6000E-05	7.7000E-05	6.2000E-04	6.8000E-04
Blood -> Ovaries	2.3000E-05	3.0000E-05	7.6000E-05	1.3000E-04	2.3000E-04	2.1000E-04
Blood -> Other_0	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01
Blood -> Other_1	1.6200E-01	1.6200E-01	1.6200E-01	1.6200E-01	1.6200E-01	2.4300E-01
Blood -> Other_2	2.5900E-02	2.5900E-02	2.5900E-02	2.5900E-02	2.5900E-02	3.8800E-02
T_Bone-V_e-> T_Bone-V	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
C_Bone-V_e-> C_Bone-V	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
Liver_1 -> Blood	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04
Liver_1 -> Liver_2	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04
Liver_1 -> SI_Cont	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04
C_Bone-S -> C_Bone-S_1	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
C_Bone-S -> C_Bone-V	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	4.1100E-05
T_Bone-S -> R_Marrow	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
T_Bone-S -> T_Bone-V	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	2.4700E-04
Kidneys_1 -> UB_Cont	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02
Kidneys_2 -> Blood	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04
Testes -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Ovaries -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Other_0 -> Blood	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01
Other_1 -> Blood	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04
Other_2 -> Blood	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05
Liver_2 -> Blood	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04
C_Bone-S_1-> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
C_Bone-V -> C_Bone-S_1	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
R_Marrow -> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
T_Bone-V -> R_Marrow	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Blood_1 -> Blood	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01
f_1	0.01	0.001	0.001	0.001	0.001	0.001

(C6) The isotopes of thallium, astatine, and francium in the decay chains included in *ICRP Publications 67* and *69* are sufficiently short-lived that these decay products are assumed to decay at their point of birth (implemented by a transfer of 10^{-4} d^{-1} in Table C.2). Radon produced in soft-tissues or on bone surfaces is assumed to be removed to blood at the rate of 100 d^{-1}. Radon is assumed to migrate from the exchangeable and non-exchangeable bone volume compartments to blood at rates of 1.5 and 0.36 d^{-1}, respectively. Radon entering blood from all compartments is rapidly removed from the body by exhalation; a removal rate of 1 min^{-1} has been arbitrarily assigned. The isotopes of actinium and protactinium have been assigned the kinetics of thorium. Isotopes of bismuth produced *in vivo* are considered to be transferred from all tissues (other than bone volume) to plasma at a rate of 0.035 d^{-1}. Removal rates from the bone volume compartments are assumed to be those specified in the generic model for calcium-like elements. Of bismuth reaching plasma, 35% goes to urine, 7% to the upper large intestine, 35% to the kidneys, 5% to the liver, and 18% to other tissues. The rate of removal from plasma is 50 d^{-1}. The biokinetics of thorium as a decay product presented in Table C.11 are based on the thorium model of *ICRP Publication 69* and differ somewhat from the model used in calculating the ingestion dose coefficients for ^{228}Ra, which appeared in *ICRP Publication 67*. The data of Table C.11 have been used in this publication.

Table C.9. Kinetics of thorium as a decay product in thorium and uranium chains

	Age-dependent transfer rate (d^{-1})					
	3 months	1 year	5 years	10 years	15 years	Adult
Blood -> Liver_1	6.4700E-02	6.4700E-02	6.4700E-02	6.4700E-02	6.4700E-02	9.7000E-02
Blood -> C_Bone-S	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	6.7930E-01
Blood -> T_Bone-S	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	6.7930E-01
Blood -> UB_Cont	7.1100E-02	7.1100E-02	7.1100E-02	7.1100E-02	7.1100E-02	1.0670E-01
Blood -> Kidneys_1	4.5300E-02	4.5300E-02	4.5300E-02	4.5300E-02	4.5300E-02	6.7900E-02
Blood -> Kidneys_2	1.2900E-02	1.2900E-02	1.2900E-02	1.2900E-02	1.2900E-02	1.9400E-02
Blood -> ULI_Cont	6.4700E-03	6.4700E-03	6.4700E-03	6.4700E-03	6.4700E-03	9.7000E-03
Blood -> Testes	3.9000E-05	5.8000E-05	6.6000E-05	7.7000E-05	6.2000E-04	6.8000E-04
Blood -> Ovaries	2.3000E-05	3.0000E-05	7.6000E-05	1.3000E-04	2.3000E-04	2.1000E-04
Blood -> Other_0	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01
Blood -> Other_1	1.6200E-01	1.6200E-01	1.6200E-01	1.6200E-01	1.6200E-01	2.4300E-01
Blood -> Other_2	2.5900E-02	2.5900E-02	2.5900E-02	2.5900E-02	2.5900E-02	3.8800E-02
T_Bone-V_e-> T_Bone-V	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
C_Bone-V_e-> C_Bone-V	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
Liver_1 -> Blood	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04
Liver_1 -> Liver_2	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04
Liver_1 -> SI_Cont	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04
C_Bone-S -> C_Bone-S_1	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
C_Bone-S -> C_Bone-V	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	4.1100E-05
T_Bone-S -> R_Marrow	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
T_Bone-S -> T_Bone-V	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	2.4700E-04
Kidneys_1 -> UB_Cont	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02
Kidneys_2 -> Blood	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04
Testes -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Ovaries -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Other_0 -> Blood	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01
Other_1 -> Blood	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04
Other_2 -> Blood	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05
Liver_2 -> Blood	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04
C_Bone-S_1-> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
C_Bone-V -> C_Bone-S_1	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
R_Marrow -> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
T_Bone-V -> R_Marrow	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Blood_1 -> Blood	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01

See thorium biokinetic discussion for applicable f_1 values.

C.3. "Other" tissue considerations

(C7) The biokinetic data of Tables C.1–C.11 specify the transfer of the decay products from their sites of birth, their removal from the systemic region, and their deposition in systemic tissues. The latter includes deposition in unspecified tissues collectively referred to as "Other" tissue. The anatomical identity of "Other" tissue varies among the chain members as it represents systemic tissues not explicitly noted as tissues of deposition in the description of the biokinetic behaviour, i.e. not receiving the decay product from blood or from tissues fed by blood. Thus, for example, "Other" in the kinetics of thallium (see Table C.2) represents the entire systemic region of the body as no systemic tissues are indicated to receive thallium from blood. This is in contrast to the behaviour of lead (Table C.3) where bone (cortical and trabecular), liver, and kidneys are systemic tissues of deposition and thus "Other" represents the systemic tissues of the body other than bone, liver, and kidneys.

(C8) In the computations it is convenient to establish a set of organs and tissues common to the entire chain which will serve as the source regions in the dosimetric evaluation. This can be accomplished by two different approaches:

(1) The number of nuclear transformations for each chain member is calculated using the biokinetic descriptions given in Tables C.1–C.11. Transformations within the

Table C.10. Kinetics of protactinium as a decay product in thorium and uranium chains

		Age-dependent transfer rate (d^{-1})					
		3 months	1 year	5 years	10 years	15 years	Adult
Blood	-> Liver_1	6.4700E-02	6.4700E-02	6.4700E-02	6.4700E-02	6.4700E-02	9.7000E-02
Blood	-> C_Bone-S	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	6.7930E-01
Blood	-> T_Bone-S	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	7.7630E-01	6.7930E-01
Blood	-> UB_Cont	7.1100E-02	7.1100E-02	7.1100E-02	7.1100E-02	7.1100E-02	1.0670E-01
Blood	-> Kidneys_1	4.5300E-02	4.5300E-02	4.5300E-02	4.5300E-02	4.5300E-02	6.7900E-02
Blood	-> Kidneys_2	1.2900E-02	1.2900E-02	1.2900E-02	1.2900E-02	1.2900E-02	1.9400E-02
Blood	-> ULI_Cont	6.4700E-03	6.4700E-03	6.47C0E-03	6.4700E-03	6.4700E-03	9.7000E-03
Blood	-> Testes	3.9000E-05	5.8000E-05	6.6000E-05	7.7000E-05	6.2000E-04	6.8000E-04
Blood	-> Ovaries	2.3000E-05	3.0000E-05	7.6000E-05	1.3000E-04	2.3000E-04	2.1000E-04
Blood	-> Other_0	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01	8.3200E-01
Blood	-> Other_1	1.6200E-01	1.6200E-01	1.6200E-01	1.6200E-01	1.6200E-01	2.4300E-01
Blood	-> Other_2	2.5900E-02	2.5900E-02	2.5900E-02	2.5900E-02	2.5900E-02	3.8800E-02
T_Bone-V_e	-> T_Bone-V	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
C_Bone-V_e	-> C_Bone-V	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03	1.0000E+03
Liver_1	-> Blood	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04
Liver_1	-> Liver_2	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04
Liver_1	-> SI_Cont	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04	4.7500E-04
C_Bone-S	-> C_Bone-S_1	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
C_Bone-S	-> C_Bone-V	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	4.1100E-05
T_Bone-S	-> R_Marrow	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
T_Bone-S	-> T_Bone-V	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	2.4700E-04
Kidneys_1	-> UB_Cont	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02	4.6200E-02
Kidneys_2	-> Blood	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04
Testes	-> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Ovaries	-> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Other_0	-> Blood	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01	4.6200E-01
Other_1	-> Blood	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04	9.5000E-04
Other_2	-> Blood	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05
Liver_2	-> Blood	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04	2.1100E-04
C_Bone-S_1	-> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
C_Bone-V	-> C_Bone-S_1	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
R_Marrow	-> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
T_Bone-V	-> R_Marrow	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
Blood_1	-> Blood	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01	6.9300E-01
	f_1	0.01	0.001	0.001	0.001	0.001	0.001

member's "Other" tissues are partitioned, by mass fraction, among the source regions of the chain not present in the member's kinetics. Also, source regions present in the kinetics of the member, but not in the kinetics of the parent of the chain, should receive a portion of the transformations calculated in the member's "Other". The number of transformation in "Other" is reduced by the number allocated to the specific source regions, thus conserving transformations.

(2) The alternative computational procedure assigns kinetic parameters to source regions of the chain not included in the member's biokinetic behaviour. The unidentified source regions in the member's biokinetic data are assigned the biokinetics of "Other", with transfer rates into the compartments based on a mass fraction of the transfer rate from blood to the corresponding "Other" compartments. Transfer rates from blood to the "Other" compartments are reduced accordingly. The removal rates of the "Other" compartments are also assigned to the corresponding source region compartments. Computation of the number of nuclear transformations can then be performed.

The two procedures yield similar results (differences are less than 5%) when the masses of the unspecified source regions are small relative to the mass of "Other".

Table C.11. Kinetics of uranium as a decay product in thorium and uranium chains

	Age-dependent transfer rate (d^{-1})					
	3 months	1 year	5 years	10 years	15 years	Adult
Blood -> Other_0	1.0500E+01	1.0500E+01	1.0500E+01	1.0500E+01	1.0500E+01	1.0500E+01
Blood -> Blood_1	1.5900E-01	2.1000E-01	2.1900E-01	1.9100E-01	1.6000E-01	2.4500E-01
Blood -> UB_Cont	9.9900E+00	1.3260E+01	1.3800E+01	1.2060E+01	1.0100E+01	1.5430E+01
Blood -> Kidneys_1	1.9000E+00	2.5200E+00	2.6300E+00	2.3000E+00	1.9200E+00	2.9400E+00
Blood -> Kidneys_2	7.9000E-03	1.0500E-02	1.1000E-02	9.6000E-03	8.0000E-03	1.2200E-02
Blood -> ULI_Cont	7.9000E-02	1.0500E-01	1.1000E-01	9.6000E-02	8.0000E-02	1.2200E-01
Blood -> Liver_1	2.3800E-01	3.1600E-01	3.2900E-01	2.8700E-01	2.4000E-01	3.6700E-01
Blood -> Other_1	1.0500E+00	1.4000E+00	1.4600E+00	1.2700E+00	1.0700E+00	1.6300E+00
Blood -> Other_2	4.7600E-02	6.3100E-02	6.5700E-02	5.7400E-02	4.8100E-02	7.3500E-02
Blood -> T_Bone-S	2.2000E+00	1.3200E+00	1.3100E+00	2.0700E+00	3.0300E+00	2.0400E+00
Blood -> C_Bone-S	8.8200E+00	5.2900E+00	4.5700E+00	6.1600E+00	7.8400E+00	1.6300E+00
Other_0 -> Blood	8.3200E+00	8.3200E+00	8.3200E+00	8.3200E+00	8.3200E+00	8.3200E+00
Blood_1 -> Blood	3.4700E-01	3.4700E-01	3.4700E-01	3.4700E-01	3.4700E-01	3.4700E-01
Kidneys_1 -> UB_Cont	9.9000E-02	9.9000E-02	9.9000E-02	9.9000E-02	9.9000E-02	9.9000E-02
Kidneys_2 -> Blood	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04	3.8000E-04
Liver_1 -> Blood	9.2000E-02	9.2000E-02	9.2000E-02	9.2000E-02	9.2000E-02	9.2000E-02
Liver_1 -> Liver_2	6.9300E-03	6.9300E-03	6.9300E-03	6.9300E-03	6.9300E-03	6.9300E-03
Other_1 -> Blood	3.4700E-02	3.4700E-02	3.4700E-02	3.4700E-02	3.4700E-02	3.4700E-02
Other_2 -> Blood	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05	1.9000E-05
T_Bone-S -> Blood	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02
T_Bone-S -> T_Bone-V_e	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02
C_Bone-S -> Blood	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02
C_Bone-S -> C_Bone-V_e	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02	6.9300E-02
Liver_2 -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
T_Bone-V -> Blood	8.2200E-03	2.8800E-03	1.8100E-03	1.3200E-03	9.5900E-04	4.9300E-04
C_Bone-V -> Blood	8.2200E-03	2.8800E-03	1.5300E-03	9.0400E-04	5.2100E-04	8.2100E-05
T_Bone-V_e-> T_Bone-S	1.7300E-02	1.7300E-02	1.7300E-02	1.7300E-02	1.7300E-02	1.7300E-02
T_Bone-V_e-> T_Bone-V	5.7800E-03	5.7800E-03	5.7800E-03	5.7800E-03	5.7800E-03	5.7800E-03
C_Bone-V_e-> C_Bone-S	1.7300E-02	1.7300E-02	1.7300E-02	1.7300E-02	1.7300E-02	1.7300E-02
C_Bone-V_e-> C_Bone-V	5.7800E-03	5.7800E-03	5.7800E-03	5.7800E-03	5.7800E-03	5.7800E-03
Testes -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
Ovaries -> Blood	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04	1.9000E-04
C_Bone-S_1-> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03
R_Marrow -> Blood	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03	7.6000E-03

See uranium biokinetic discussion for applicable f_1 values.

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ANNEXE D. ASSIGNMENT OF COMPOUNDS TO ABSORPTION TYPES FROM EXPERIMENTAL DATA

D.1. Introduction

(D1) It is recommended in *ICRP Publication 66* (ICRP, 1994a), that material-specific rates of absorption should be used in the model for compounds for which reliable human or animal experimental data exist. For other compounds, default values of parameters are recommended, according to whether the absorption is considered to be fast (Type F), moderate (M) or slow (S). These three types correspond broadly to inhalation Classes D, W and Y in the *ICRP Publication 30* model (ICRP, 1979). However, there have been few studies of respiratory tract clearance of radionuclides administered in forms chosen to be representative of environmental exposure, and in general the physico-chemical forms of the inhaled radionuclides are less well defined than in the workplace. Thus it is not feasible to specify absorption parameters for most of the chemical forms likely to be encountered in the environment. In this report, guidance is therefore given for each element on which of the default absorption Types should be chosen for environmental exposure, according to the information available.

(D2) In *ICRP Publication 68* (ICRP, 1994b), to expedite the publication of inhalation dose coefficients for workers, compounds for which clearance was given as Class D, W or Y in *ICRP Publication 30*, were assigned to Type F, M or S respectively. For the purpose of this report it was not feasible to follow this procedure, since in the environment radionuclides are often present as a minor constituent of the inhaled particles, and absorption to body fluids may then be controlled by dissolution of the particle matrix. Thus the radionuclide may well be in a form that was not covered by *ICRP Publication 30*, which was concerned with workplace exposure.

(D3) *ICRP Publication 66* does not give criteria for assigning compounds to absorption Types on the basis of experimental results, since it was considered that where such information was available it should be used to determine values of the absorption parameters. Since that approach could not be applied in this report, such criteria are given here. Details of their derivation and application are given in Sections D.2 and D.3, respectively.

D.2. Derivation of criteria

(D4) Experience in preparing this report showed that it is not always obvious from the results of a study to which absorption Type a compound should be assigned, and therefore quantitative criteria are given to assign materials to Types F and S, rather than the default Type M. So that they can be applied uniformly to different mammalian species and different initial patterns of deposition throughout the respiratory tract, they are defined in terms of the fraction of the deposit in the respiratory tract absorbed into body fluids in a given time, as described below.

(D5) The approach taken to assigning compounds to inhalation Classes by the Task Group on Lung Dynamics (TGLD, 1966) and adopted in *ICRP Publication 30* was to use the retention time in the pulmonary region as the basis. Thus compounds were assigned to Class D (days) if the retention half time in the pulmonary region was less than 10 d; to Class W (weeks) if it was 10–100 d; and to Class Y (years) if it was more than 100 d. The pulmonary region in the TGLD model is the main long-term retention site in the lungs, equivalent to the alveolar-interstitial (AI) region in the new model. This approach has the great virtue of simplicity, but with the benefit of current understanding of the kinetics of respiratory tract clearance, there are problems in applying it consistently.

(D6) In the new ICRP respiratory tract model, clearance is treated as resulting mainly from the sum of particle transport to the GI tract and absorption to body fluids (Section 2.3). The rate of particle transport to the GI tract from the AI region decreases with time: hence the AI region is represented by three compartments. Thus, even if the rate of absorption to body fluids is constant, unless absorption dominates lung clearance, the overall rate of clearance from AI will decrease with time, and so the retention half-time will increase with the duration of the measurements. Furthermore, rates of particle transport to the GI tract from the AI region vary markedly between animal species (*ICRP Publication 66*, Annexe E, Paragraphs E2 and E5). In rats and mice the rate is several times higher than in man and dog, and so for materials that do not dissolve rapidly, the alveolar (pulmonary) retention half-time is much shorter in rats and mice.

(D7) Allowance can be made for the dependence of particle transport rates on time and animal species by using the rate of absorption to body fluids as the basis for assigning compounds to absorption types, rather than the overall lung retention or clearance rate. In general, however, the rate of absorption also changes with time (Paragraphs 42–43), and therefore different results might be obtained from measurements on the same material, made over different periods of time after deposition. The problem may be likened to attempting to classify a sample consisting of a mixture of radionuclides, according to whether the overall decay is fast, moderate or slow. For a single radionuclide this can be done simply on the basis of decay half-time, but for a mixture the criteria have to reflect both the decay rates of the radionuclides and their proportions in the mixture. Furthermore, when the material is deposited in the respiratory tract it is also being lost by particle transport. To continue the analogy with the mixed radionuclide sample, this is like measuring the remaining radioactivity of a sample which is simultaneously leaking away at a rate that varies with time, but which can be estimated. To avoid these problems the criteria are based on the amounts (fraction of initial lung deposits) absorbed into body fluids by specific times after deposition.

(D8) Figure D.1 shows the lung retention of materials with absorption characteristics corresponding to the default values given for Types F, M and S (Table 8). For simplicity, retention is shown in the absence of particle transport. The extreme difference between Types F and S is apparent. For Type F the rate of absorption is 100 d^{-1}, corresponding to a half time of about 10 min: virtually all material is absorbed within a few hours. For Type S the rate of absorption of most of the material is 0.0001 d^{-1}, corresponding to a half time of about 7 000 d: even after 1 year only about 4% of the material has been absorbed. Type M shows two distinct phases: 10% is dissolved very rapidly, at the same rate as Type F, the rest at a moderate rate of 0.005 d^{-1}, corresponding to a half-time of about 140 d: after 1 year about 85% has been absorbed.

(D9) Figure D.2 shows the retention of the same materials, but after deposition in the alveolar region of the human lung, from which material is also cleared by particle transport. According to the *ICRP Publication 66* model, as shown in Fig. 3, alveolar retention in the absence of absorption, $A(t)$ at time t d, is represented by three compartments (neglecting, for simplicity, transport to the thoracic lymph nodes):

$$A(t) = 0.3\ e^{-0.03t} + 0.6\ e^{-0.001t} + 0.1\ e^{-0.0001t} \tag{D.1}$$

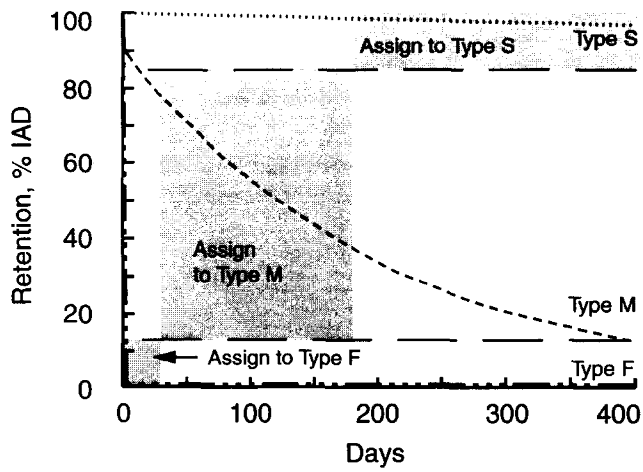

Fig. D.1. Retention of materials in lung as a percentage of the initial alveolar deposit (IAD), following deposition in the alveolar region. For simplicity, retention is shown in the absence of particle transport, as for example in an *in vitro* dissolution experiment simulating respiratory tract absorption, where the "retention" represents the amount that has not dissolved. The curves show retention of hypothetical materials with absorption characteristics according to the default values for Types F, M and S (Table 8). The shaded areas show where observations can be used to assign materials to each type according to the F/M and M/S criteria. In this situation (1) retention below 13% at 30 d, or earlier, would assign the material to Type F (retention above 13% after 30 d would exclude Type F); (2) retention above 87% at 180 d, or later, would assign the material to Type S (retention below 87% before 180 d would exclude Type S); (3) retention in the range 13–87% between 30 and 180 d would positively assign the material to Type M. Otherwise the material would be assigned to Type M by default. However, for studies where the results point towards a particular type, but it is not possible to apply the criteria to make a positive assignment, it could be said that the results "indicate Type F (M or S) behaviour" (see Paragraph D25).

The lower retention, (compared to that shown in Fig. D.1) resulting from particle transport to the GI tract is apparent for Types M and S. The amounts remaining at a year are reduced from 96 to 49% for Type S and from 15 to 7% for Type M.

(D10) Figure D.3 shows the amounts absorbed into body fluids as functions of time, for the same materials deposited in the alveolar region of the human lung, as in Fig. D.2. For simplicity, these results are for deposition exclusively in the alveolar region, and with no absorption in the GI tract of material cleared to it by particle transport, i.e. $f_1 = 0$. (Deposition throughout the respiratory tract, and uptake to body fluids in the GI tract from material in transit, are considered in Section D.3, below.)

(D11) In selecting the numerical values, consideration was given to the *ICRP Publication 30* criteria for distinguishing between inhalation Classes D, W and Y. As noted above, in *ICRP Publication 68*, compounds for which clearance was given as Class D, W or Y in *ICRP Publication 30*, were assigned to Types F, M or S, respectively. It is therefore desirable that the criteria for distinguishing between absorption Types F, M and S should be broadly consistent with those used for inhalation Classes D, W and Y (Paragraph D5). An exact equivalence is not possible, because whereas D, W and Y define overall clearance, F, M and S apply only to absorption into blood; particle transport rates are assumed to be the same for the three Types. Furthermore, lung retention given by the Type M and S parameters is greater than that for Classes W and Y, respectively.

(D12) In setting the criterion for assigning a material to Type F, it was considered that there should be no "significant" component of "long-term" lung retention. More specifically, in man there should not be more than about 10% of the deposit in the alveolar region

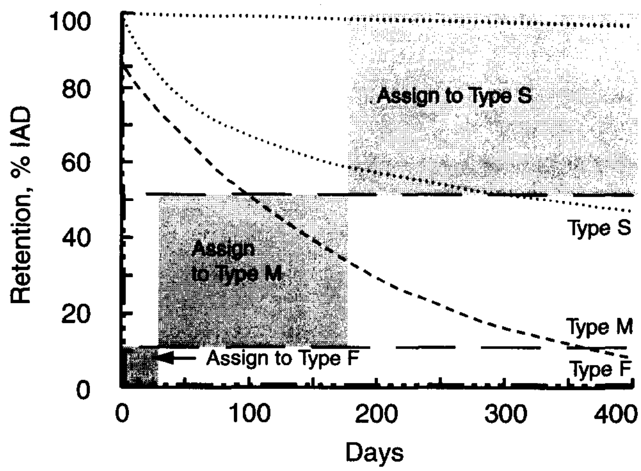

Fig. D.2. Retention of materials in lung as a percentage of the initial alveolar deposit (IAD), following deposition in the alveolar region of the human lung. The curves show retention of hypothetical materials with absorption characteristics according to the default values for Types F, M and S (Table 8). The shaded areas show where observations can be used to assign materials to each type according to the F/M and M/S criteria. In this situation (1) retention below 11% at 30 d, or earlier, would assign the material to Type F (retention above 11% after 30 d would exclude Type F); (2) retention above 51% at 180 d, or later, would assign the material to Type S (retention below 51% before 180 d would exclude Type S); (3) retention in the range 11–51% between 30 and 180 d would positively assign the material to Type M. Otherwise the material would be assigned to Type M by default. However, for studies where the results point towards a particular type, but it is not possible to apply the criteria to make a positive assignment, it could be said that the results "indicate Type F (M or S) behaviour" (see Paragraph D25).

retained for more than a month. To provide a quantitative criterion that can be applied uniformly to different mammalian species and different initial patterns of deposition throughout the respiratory tract, this needs to be related to a specified constant rate of absorption.

(D13) The *ICRP Publication 30* criterion for distinguishing between inhalation Classes D and W is a pulmonary retention half time of 10 d. For a material with a rate of absorption to body fluids of 0.069 d^{-1} (corresponding to a half-time of 10 d), the amount remaining in the alveolar region of the human lung at 30 d after deposition is about 11% of the initial alveolar deposit (IAD). Since this is close to the target of 10%, an absorption rate of 0.069 d^{-1} was adopted. (Note, however, that if the rate of absorption is 0.069 d^{-1}, the pulmonary retention half-time would only be 10 d if there were no particle transport. The actual pulmonary retention half-time will be less than 10 d, its value depending on the animal species and duration of measurements.)

(D14) A material is assigned here to Type F if the amount absorbed into body fluids by 30 d after an acute intake is *greater* than the amount that would be absorbed over the same period, from a hypothetical material with a constant rate of absorption, of 0.069 d^{-1} (corresponding to a half-time of 10 d), deposited in the respiratory tract under exactly the same conditions.

(D15) This criterion is illustrated in Figs D.1–D.3. In the static system (Fig. D.1) there would be 13% retention at 30 d of a material with a constant rate of absorption, of 0.069 d^{-1}, and correspondingly, 87% absorbed. Thus a material in this system would be assigned to Type F if at 30 d the amount retained in the lung was less than 13%, or the amount absorbed greater than 87%. For a material with a constant rate of absorption of 0.069 d^{-1} deposited in

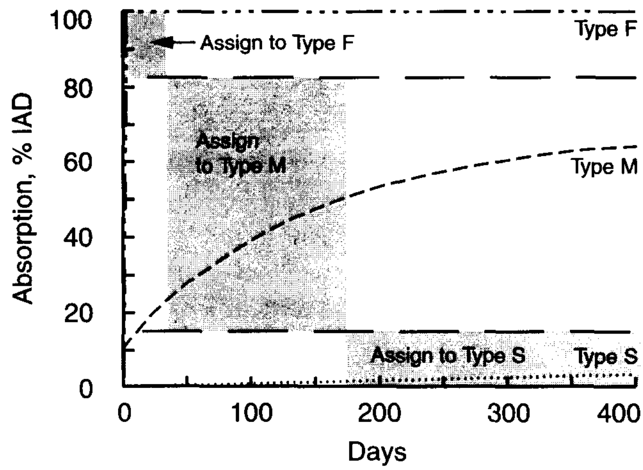

Fig. D.3. Absorption of materials to body fluids as a percentage of the initial alveolar deposit (IAD), following deposition in the alveolar region of the human lung, as in Fig. D.2. The curves show absorption of hypothetical materials with absorption characteristics according to the default values for Types F, M and S (Table 8). The shaded areas show where observations can be used to assign materials to each Type according to the F/M and M/S criteria. In this situation (1) absorption above 83% at 30 d, or earlier, would assign the material to Type F (absorption below 83% after 30 d would exclude Type F); (2) absorption below 12% at 180 d, or later, would assign the material to Type S (absorption above 12% before 180 d would exclude Type S); (3) absorption in the range 12–83% between 30 and 180 d would positively assign the material to Type M. Otherwise the material would be assigned to Type M by default. However, for studies where the results point towards a particular Type, but it is not possible to apply the criteria to make a positive assignment, it could be said that the results "indicate Type F (M or S) behaviour" (see Paragraph D25).

the alveolar region of the human lung, at 30 d there would be 11% retained (Fig. D.2) and 83% absorbed (Fig. D.3) (the remaining 6% is removed by particle transport).

(D16) In setting the criterion for assigning a material to Type S, it was considered that there should be "significant" lung retention for "years" after intake: less than about 10% of the deposit in the alveolar region should be absorbed into body fluids within 6 months.

(D17) The *ICRP Publication 30* criterion for distinguishing between inhalation Classes W and Y is a pulmonary retention half-time of 100 d. For a material with a rate of absorption to body fluids of 0.0069 d^{-1} (corresponding to a half-time of 100 d), the amount absorbed into body fluids within 6 months is about 55%. This is much greater than the target of 10%, and even greater than the amount that would be absorbed over this period from a material with the absorption characteristics given by the default values for Type M (50%), and therefore this absorption rate does not form a suitable basis for the M/S criterion.

(D18) For materials having absorption characteristics given by the default values for Types M and S, most of the respiratory tract deposit is absorbed at rates of 0.005 and 0.0001 d^{-1}, respectively. The M/S criterion needs to be based on a rate intermediate between these two values. A rate of 0.001 d^{-1} is a rounded value, which gives about 12% of the initial alveolar deposit absorbed by 180 d, close to the target of 10%.

(D19) A material is assigned here to Type S if the amount absorbed into body fluids by 180 d after an acute intake is *less* than the amount that would be absorbed over the same period, from a hypothetical material with a constant rate of absorption to body fluids, of 0.001 d^{-1} (corresponding to a half-time of about 700 d), deposited in the respiratory tract under exactly the same conditions.

(D20) This criterion is also illustrated in Figs D.1–D.3. In the absence of particle transport (Fig. D.1) there would be 84% retention at 180 d of a material with a constant absorption rate of 0.001 d^{-1}, and, correspondingly, 16% absorbed. Thus a material in this system would be assigned to Type S if at 180 d the amount retained was more than 84%, or the amount absorbed less than 16%. For a material with a constant rate of absorption of 0.001 d^{-1} deposited in the alveolar region of the human lung, at 180 d there would be 51% retained (Fig. D.2) and 12% absorbed (Fig. D.3) (the other 37% is removed by particle transport).

(D21) It should be noted that some compounds which would have been assigned to Class Y rather than Class W on the *ICRP Publication 30* criterion (pulmonary retention half-time >100 d), will be assigned to Type M rather than Type S. This is consistent with changes in the reference values of the clearance parameters: lung retention according to the Types M and S default parameters is greater than for Classes W and Y, respectively.

(D22) Table D.1 compares the behaviour of materials with absorption rates corresponding to the F/M and M/S criteria: 0.069 and 0.001 d^{-1}, respectively, with that of materials with absorption rates corresponding to the default values given for Types F, M and S (Table 8). Results are given for materials in three situations:

(1) A static system with no particle transport, corresponding to Fig. D.1, such as an *in vitro* experiment where the fraction dissolved (or remaining undissolved) is measured as a function of time.
(2) Deposition in the alveolar region of man, corresponding to Figs D.2 and D.3.
(3) Deposition in the alveolar region of rats. This is included since rats are currently most often used in inhalation biokinetics experiments, and alveolar particle transport rates in rats are much faster than in man. The effect of this is seen in reducing both the amounts retained and the amounts absorbed, compared to man, especially for more insoluble materials at 180 d. In this case alveolar retention was represented by two compartments, i.e. alveolar retention $A(t)$ at time t d, is given by

$$A(t) = 0.66\ e^{-0.023t} + 0.34\ e^{-0.0028t} \tag{D.2}$$

This expression was derived for HMT rats, (Birchall *et al.*, 1995), and is used here for illustrative purposes. Alveolar particle transport rates vary between rat strains (Bailey *et al.*, 1989).

For each case, Table D.1 gives at 30 and 180 d the percentage of the initial alveolar deposit (%IAD) remaining, and that absorbed into body fluids. However, it should be noted that the F/M criterion is applied only at 30 d, and the M/S criterion only at 180 d.

D.3. Application of the criteria

(D23) Tables D.2 and D.3 show, respectively, how the F/M and M/S criteria might apply in several of the most commonly occurring situations:

(1) An *in vitro* experiment where the fraction dissolved (or remaining undissolved) is measured as a function of time.
(2) An experiment in which a suspension of material is administered by intratracheal injection into the lungs of rats.
(3) Experiments in which aerosols of Activity Median Aerodynamic Diameter (AMAD) of about 1.5–2 μm are inhaled by rats or dogs.
(4) Inhalation of 1 and 5 μm AMAD aerosols by humans.

Table D.1. Lung retention and absorption to body fluids at 30 and 180 days after deposition in the alveolar region, according to absorption Type and to the criteria for assigning compounds to Types

	Absorption		Percentage of initial alveolar deposit (% IAD)					
			In vitro		Man		Rat	
Time (d)	Type	Rate (d^{-1})	Lung	Body fluids	Lung	Body fluids	Lung	Body fluids
30	F	100	0	100	0	100	0	100
	F/M	0.069	13	87	11	83	8.1	75
	M	100 (10%) + 0.005 (90%)	77	23	66	22	50	20
	M/S	0.001	97	3	82	2.7	62	2.4
	S	100 (0.1%) + 0.0001 (99.9%)	100	0	84	0	64	0
180	F	100	0	100	0	100	0	100
	F/M	0.069	0	100	0	93	0	82
	M	100 (10%) + 0.005 (90%)	37	63	22	50	7.9	35
	M/S	0.001	84	16	51	12	18	7.1
	S	100 (0.1%) + 0.0001 (99.9%)	98	1.9	60	1.4	21	0.9

Table D.2. Lung retention and absorption to body fluids for materials with absorption rates corresponding to the F/M criterion, in situations typical of studies of inhalation biokinetics[a]

			Type F/M (0.069 d^{-1}) at 30 d		
				Absorption	
Species	Mode of intake	f_1	Lung retention % ILD	% ILD	% IBB
In vitro	—	—	13	87	87
Rat	Instillation	1	6.4	94	94
		0.1	6.4	64	64
		0.01	6.4	61	61
		0	6.4	61	61
Rat	Inhalation	1	5.8	470	99
		0.1	5.8	96	20
		0.01	5.8	59	12
		0	5.8	55	11
Dog	Inhalation	1	9.4	160	95
		0.1	9.4	83	48
		0.01	9.4	75	44
		0	9.4	74	43
Man	Inhalation (1 μm AMAD)	1	8.8	250	97
		0.1	8.8	89	35
		0.01	8.8	73	28
		0	8.8	71	28
Man	Inhalation (5 μm AMAD)	1	7.5	580	99
		0.1	7.5	110	19
		0.01	7.5	68	12
		0	7.5	63	11

[a] ILD, initial lung deposit; IBB, initial body burden, i.e. initial deposit in respiratory tract.

For each case, Table D.2 gives the percentage of the initial lung deposit (%ILD) remaining at 30 d after intake for a material with a rate of absorption to blood of 0.069 d^{-1}, and Table D.3 gives the %ILD remaining at 180 d after intake for a material with a rate of absorption to blood of 0.001 d^{-1}. For each *in vivo* situation, Tables D.3 and D.4 give the corresponding amounts absorbed into blood as both %ILD and also as a percentage of the initial respiratory tract deposit ("initial body burden", IBB), since account may well need to be taken of deposition in the extrathoracic airways (ET), because of absorption both within ET and in the GI tract. To take account of the latter, which also applies to material cleared from the lungs, results are given for f_1 values of 1, 0.1, 0.01 and 0.

(D24) The following paragraphs give further information about the values of the deposition and clearance parameters chosen for this exercise. The values selected are illustrative, since specific parameters will depend on the experimental conditions.

(D25) Several examples are also given, drawn from those used in this report, to illustrate the assignment of compounds to the absorption Types using the criteria developed here. Examples have been chosen to illustrate several of the types of study included in Tables D.2 and D.3, and have been chosen from those that were relatively straightforward to interpret. In many cases it was not easy to apply the criteria, especially for studies following accidental intakes, since there are often major uncertainties related to the intake. In a number of experimental studies the criteria could not readily be applied, usually because the measurements were of insufficient duration, or because the results were not related to the

Table D.3. Lung retention and absorption to body fluids for materials with absorption rates corresponding to the M/S criterion, in situations typical of studies of inhalation biokinetics[a]

			Type M/S (0.001 d^{-1}) at 180 d		
				Absorption	
Species	Mode of intake	f_1	Lung retention % ILD	% ILD	% IBB
In vitro	—	—	84	16	16
Rat	Instillation	1	14	86	86
		0.1	14	14	14
		0.01	14	6.5	6.5
		0	14	5.7	5.7
Rat	Inhalation	1	13	460	97
		0.1	13	51	11
		0.01	13	9.7	2.0
		0	13	5.1	1.1
Dog	Inhalation	1	53	120	70
		0.1	53	22	13
		0.01	53	12	7.2
		0	53	11	6.6
Man	Inhalation (5 μm AMAD)	1	33	560	94
		0.1	33	63	11
		0.01	33	14	2.3
		0	33	8.3	1.4
Man	Inhalation (1 μm AMAD)	1	40	220	84
		0.1	40	30	12
		0.01	40	12	4.7
		0	40	9.9	3.9

[a] ILD, initial lung deposit; IBB, initial body burden, i.e. initial deposit in respiratory tract.

Table D.4. Regional deposition in rats and dogs for 1.5–2.0 μm AMAD polydisperse aerosols (Snipes *et al.*, 1983)

	Percentage of initial deposit			
Species	Nasopharynx	Tracheobronchial	Pulmonary	External contamination
Dog	40	5	50	5
Rat	63	5	12	20

initial lung or respiratory tract deposits. For studies where it was possible to apply the criteria (even though it was necessary to estimate the initial pattern of deposition), a statement is made to the effect that "results are consistent with assignment to Type F (M or S)...". For studies where the results point towards a particular type, but it was not possible to apply the criteria, a statement is made to the effect that "results indicate Type F (M or S) behaviour...".

In vitro dissolution

(D26) This may be regarded as 100% "lung" deposition with no particle transport, hence GI tract absorption is not applicable. Compared to *in vivo* studies, such measurements are relatively inexpensive and simple to set up, and if the amount of material available is very small may be the only ones feasible. They are also the easiest to interpret quantitatively, because the system is simple compared to the situation in the respiratory tract *in vivo*. However, there may well be doubts about the extent to which the results will reflect absorption from respiratory tract to body fluids *in vivo* (*ICRP Publication 66*, Annexe E, Paragraphs E38 and E39).

(D27) Cuddihy *et al.* (1989) measured for 60 d the dissolution rates in simulated lung fluid of radionuclides present in irradiated fuel fragments released from the Chernobyl accident. For all radionuclides, 10% dissolved in a few hours, and the rest with a half-time of 160 d. Hence "lung" retention $R(t)$ at time t d is given by:

$$R(t) = 0.9\ \mathrm{e}^{-0.00433t}$$

At 30 d there is 79% retained, whereas for Type F there would need to be less than 13% (Table D.2), so Type F is excluded. The duration of the experiment is much less than 180 d, and so it would not be possible to assign the material to Type S. However, at 60 days, the time of the last measurement, there is 69% retained, whereas for Type S there would need to be more than 84% retained at 180 d (Table D.3). Hence Type S is also excluded, and the material can be unambiguously assigned to Type M. It is therefore stated that the results are consistent with assignment to Type M.

Rat instillation

(D28) Experiments in which the material is administered by intratracheal instillation are the simplest *in vivo* experiments to interpret quantitatively, because the initial lung deposit (ILD) is well defined, and the complications of extrathoracic deposition and external contamination are not present. The pattern of deposition, however, is different from that produced by inhalation, and this may affect the initial clearance rates (Birchall *et al.*, 1995). The rat has been the species most frequently used in such studies of biokinetics. For this exercise it is only neccessary to treat the lungs as two regions: tracheobronchiolar (TB, as in the *ICRP Publication 30* model, i.e. the bronchial, BB, and bronchiolar, bb, regions combined), from which particle transport is relatively rapid, and alveolar-interstitial (AI). It is assumed here that deposition following instillation is 20% TB and 80% AI (Birchall *et al.*, 1995), and that alveolar retention is given by Equation D.2.

(D29) Stather *et al.* (1978) administered sediment labelled with ^{239}Pu and ^{241}Am by intratracheal instillation to rats and hamsters. In rats, at the time of the last measurement, 28 d, lung retention was 34% of the initial lung deposit (ILD) for ^{239}Pu and 45% for ^{241}Am, and for both radionuclides about 25% ILD had been absorbed to body fluids.

(D30) For Type F there would need to be less than 6% ILD retained in the lungs (Table D.2), and/or more than 61% ILD absorbed, so Type F is excluded. The duration of the experiment is much less than 180 days, and so it would not be possible to assign the material to Type S. Type S cannot be excluded on the basis of lung retention: at 28 days, the time of the last measurement, there is about 40% retained, which is not inconsistent with the requirement that for Type S there would need to be more than 14% retained at 180 d (Table D.3). This does not demonstrate consistency with Type S, since a considerable amount of clearance would be expected to take place between 28 and 180 d. However, at 28 d there is already about 25% ILD absorbed, whereas for Type S there would need to be less than 7% absorbed at 180 d, since the f_1 value is unlikely to be greater than 0.01 (Table D.3). Hence Type S is also excluded, and the material can be unambiguously assigned to Type M.

Rat inhalation

(D31) Administration by inhalation most closely resembles human exposure, and thus gives results most likely to be representative. It does, however, require elaborate facilities, and the results are more difficult to interpret quantitatively than those of *in vitro* studies, or instillations. Again the rat is the species usually employed in recent years, although several others have been frequently used. Snipes *et al.* (1983) gave estimates of the fractions of initial body burden (IBB) deposited in each respiratory tract region for dogs, rats (and mice) that inhaled monodisperse aerosols of aerodynamic diameter, d_{ae}, 0.7, 1.5 and 2.8 μm and a polydisperse aerosol of AMAD 1.5–2.0 μm. Their results for the polydisperse aerosol, which are very similar to those for d_{ae} 1.5 μm are given in Table D.4. For this exercise deposition in each region is needed as a fraction of the initial deposit in the respiratory tract, which is taken to be the initial body burden (IBB). To obtain this, the values in Table D.4 were re-normalized, neglecting the external contamination. The results used here are given in Table D.5. It is again assumed here that alveolar retention is given by eqn (D.1).

(D32) Stradling *et al.* (1992) administered dust samples contaminated with ^{239}Pu and ^{241}Am from the former nuclear test site in Maralinga to rats. Three materials were administered by intratracheal instillation, one of which, designated TM101, was also administered by inhalation.

(D33) For the inhaled material, at 28 d, lung retention of ^{239}Pu and ^{241}Am was 47 and 46% ILD, respectively, and absorption to body fluids was 0.32 and 0.66% ILD. For Type F there would need to be less than 6% ILD retained in the lungs (Table D.2), and/or more than 55% ILD absorbed, so Type F is excluded.

(D34) At 168 d, the nearest measurement point to 180 d, lung retention of ^{239}Pu and ^{241}Am was 13.7 and 13.2% ILD, respectively, and absorption was 0.37 and 0.84% ILD. For Type S there would need to be more than than 13% ILD retained in the lungs (Table D.3), and/or less than 5% ILD absorbed. The lung retention is very close to the M/S criterion, but the amounts absorbed are well below, and clearly demonstrate that both radionuclides should be assigned to Type S. It is likely to be the case for any relatively insoluble material, that the amounts absorbed at 180 d will provide a better guide to discriminating between absorption Types M and S, than will lung retention, as they are more sensitive to variations in absorption rate when the absorption rate is low.

Dog inhalation

(D35) Deposition is given in Table D.5. As for rats, alveolar retention, $A(t)$ at time t d, is represented by two compartments (Snipes, 1989):

$$A(t) = 0.30\ e^{-0.03t} + 0.70\ e^{-0.0001t} \tag{D.3}$$

Table D.5. Regional deposition in dogs and rats assumed for Tables D.2 and D.3

	Percentage of initial body burden (%IBB)		
Species	Nasopharynx (ET)	Tracheobronchial (TB)	Pulmonary (AI)
Dog	42	5	53
Rat	79	6	15

(D36) Cuddihy (1978) measured the disposition of ^{95}Nb following inhalation of ^{95}Nb-labelled zirconium oxalate and oxide by dogs. For the oxalate, lung retention was about 20% ILD at 30 d, whereas for Type F there would need to be less than 9% ILD retained (Table D.2), and so Type F is excluded. At 128 d, the time of the last measurement, there is 15% ILD retained, whereas for Type S there would need to be more than 53% retained at 180 d (Table D.3). Hence Type S is also excluded, and the material can be unambiguously assigned to Type M.

(D37) For the oxide, less than 1% ILD was absorbed by 128 d, the time of the last measurement. For Type F there would need to be more than 74% ILD absorbed at 30 d, (Table D.2), and so Type F is excluded. For Type S there would need to be less than 11% absorbed at 180 d (Table D.3). Even though measurements do not extend that far, the amount absorbed at 128 d is so much lower that it is reasonable to assign the oxide to Type S.

Human inhalation

(D38) Many studies with human volunteers have been conducted to investigate particle deposition in the respiratory tract and particle transport rates, since such measurements can be made with trace amounts of non-toxic substances, and the results are of general application (*ICRP Publication 66*, Annexes D and E). Material-specific respiratory tract clearance of radionuclides has rarely been the subject of human experiments, and most of the human studies cited in this report followed accidental intakes, for which there are almost always major uncertainties about the intake: the physical and chemical form of the material, the initial deposits, and, not infrequently, the time.

(D39) For Tables D.2 and D.3, which might provide some guidance for interpreting accidental intakes, deposition is taken from the *ICRP Publication 66* model for a reference worker, with time spent sitting and at light exercise in the ratio 2.5 : 5.5 (*ICRP Publication 66*, Table 6), but normalized to exclude deposition in ET_1, since there is no absorption to body fluids from material deposited in ET_1 (Table D.6). Particle transport is described by alveolar retention given in eqn (D.1).

Table D.6. Regional deposition in man

	% Inhaled[a]		% Initial body burden (%IBB)[a]	
Region	1	5	1	5
ET_2	21.12	39.91	61	83
TB (BB + bb)	2.89	2.87	8	6
AI	10.66	5.32	31	11

[a]Values are AMAD, μm.

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