6 External dosimetry

This chapter introduces the main protection and operational quantities in external dosimetry and describes the anthropomorphic models used for their calculations. Conversion coefficients i.e. mean organ equivalent doses normalised to the measurable quantity "air kerma free-in-air" are given for idealized geometries representing occupational exposures and for environmental source geometries.

6.1 Protection and operational quantities

6.1.1 Protection quantities

The International Commission on Radiological Protection (ICRP) for more than 50 years supports a system for radiological protection, based on concepts, quantities, and basic recommendations. The concept of radiation protection is based on the justification, optimisation and limitation of radiation exposure. This concept includes a dose limitation system for occupational and man-made environmental radiation exposures to ensure that the radiation risk would not exceed reasonable limits. The most recent set of protection quantities recommended in ICRP60 [91ICR] includes the organ or tissue equivalent doses H_T and the effective dose E (see Chap. 4). These quantities are not measurable but can be calculated if the exposure conditions are known. The quantity to be limited in radiation protection of occupationally exposed persons and members of the public is the effective dose E which is the weighted mean of equivalent doses of several organs and tissues of the body that are considered to be most sensitive.

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R D_{T,R} w_R$$

where H_T is the mean organ equivalent dose and w_T is the tissue weighting factor (with $\Sigma\ w_T = 1$) which takes into account the differences in the stochastic radiation risk of the different organs. It is derived from the mean organ absorbed dose D_T, i.e. the total amount of energy deposited in an organ (or tissue) T per mass of the organ, by multiplying with a radiation weighting factor w_R reflecting the relative biological effectiveness of the radiation incident on the body or emitted from radionuclides in the body. The sensitive organs and tissues together with their respective tissue weighting factors w_T were defined in ICRP Publication 60 [91ICR] (see Chap. 4).

6.1.2 Operational Quantities

The International Commission on Radiation Units and Measurements (ICRU) has defined a set of operational quantities for area and individual monitoring [85ICR, 92ICR1, 93ICR] in response to the recommendations of the International Commission on Radiological Protection [77ICR] which were designed to provide an estimate of the protection quantities defined by ICRP and to serve as calibration quantities for dosimeters used in monitoring. For area monitoring, the appropriate operational quantities are the ambient dose equivalent $H^*(d)$, and the directional dose equivalent, $H'(d,\Omega)$, both defined at a depth d, on the principal axis of the 30 cm diameter ICRU sphere. The recommended value of d for strongly penetrating radiation is 10 mm and for weakly penetrating radiation it is 0.07 mm (see Sect. 4.5.3.3).

For individual monitoring, the quantity "personal dose equivalent" $H_p(d)$ was proposed, which is the dose equivalent in soft tissue, at an appropriate depth d below a specified point on the body [92ICR1, 93ICR]. For weakly penetrating radiation, depths of 0.07 mm for the skin and 3 mm for the eye lens are used, denoted by $H_p(0.07)$ and $H_p(3)$, respectively; for strongly penetrating radiation, a depth of 10 mm is currently recommended by the ICRU, denoted by $H_p(10)$ (see Sect. 4.5.3.4).

Personal dose equivalent is defined in the human body and may, therefore, vary between individuals; furthermore, the depth d is specified but the position of the point below which it is defined is not fixed but only correlated to the position of the dosemeter worn on the body. Consequently, the personal dose equivalent can be expected to vary also between locations on any given individual and is, hence, anticipated to be a multi-valued quantity [96ICR, 98ICR, 99Zan]. To make this quantity single-valued in a given exposure situation, both a particular location on the human body and a particular phantom of the body need to be specified for evaluation.

For calibration purposes, "surrogate quantities" for $H_p(d)$ have been introduced: it is recommended that personal dosimeters normally worn on the trunk are calibrated on an ICRU tissue slab or PMMA (polymethylmethacrylate) slab with dimensions $30 \times 30 \times 15$ cm^3 [92ICR1]. Conversion coefficients for personal dose equivalent at the relevant depths d in the ICRU tissue slab $H_{p,slab}(d)$ have been calculated for calibration purposes [91Gro, 95ISO, 95Til] and have been recommended for use [96ICR, 98ICR, 98Cla].

The operational quantities used in measurement were designed to provide a reasonable estimate of the appropriate protection quantity. For external exposures of the body in a given field, it is desirable that the ratio of the value of the appropriate protection quantity to the value of the corresponding operational quantity is less than unity, i.e. the operational quantity should always provide a "conservative" estimate of the protection quantity.

More about the definitions of the operational quantities can be found in Chap. 4.

6.2 Dosimetric models

6.2.1 Models and phantoms of the human body

To estimate the protection quantities organ and tissue equivalent doses H_T there are two approaches, an experimental and a theoretical one. The experimental determination is very difficult whereas the mathematical modelling of an exposure has been proved to be extremely flexible and powerful. For this purpose, a series of computer models of the human body were designed in the past, together with computer codes simulating the radiation transport and energy deposition in the body.

The computer models used for the representation of the human body in dose calculations can range from simple geometric forms such as spheres, cylinders or slabs to complex representations of detailed anatomical features. Such complex models, used since 1966 for the estimation of organ doses are the so-called mathematical phantoms, which are models whose body organs and tissues are described by mathematical expressions representing planes or cylindrical, conical, elliptical or spherical surfaces. The mostly used model was the "MIRD" one, named after the initials of the Medical Internal Radiation Dose Committee of the US Society of Nuclear Medicine where it was initially developed [69Sny, 78Sny]. From this, several paediatric models were derived to represent infants and children of various ages, for example those from Cristy [80Cri]. As an improvement to these hermaphrodite models, separate male and female adult mathematical models have been introduced by Kramer *et al*. [82Kra] called Adam and Eva. For these models, the organ masses and volumes are in accordance with the ICRP data on Reference Man [75ICR]; in addition to a separation of the gender-specific organs, the phantom Eva is smaller than Adam, according to the difference in size of the male and female Reference Man. The oesophagus, an organ which had not originally been defined in these models, was incorporated in the form of an elliptical cylinder ranging in height from within the neck down to the top of the stomach and lying in front of the spine, slightly shifted to the left side [92Zan].

Adam and Eva contain all organs and tissues relevant for the evaluation of effective dose, with only few exceptions: since there is no specific representation of the "bone surface", the skeleton is modelled as a homogeneous mixture of all skeletal constituents, i.e., hard bone, bone marrow and certain peri-articular tissues. Commonly, the dose to this representation of the entire skeleton is taken to represent the dose to the bone surface. Although there may be certain differences, these are usually considered to be small in view of the small weighting factor (w_T=0.01) assigned to this tissue. The muscles were represented by that part of the body volume not attributed to any other organ or tissue of the models.

More recently, four models representing the adult female, non-pregnant and at 3 stages of pregnancy were elaborated by Stabin *et al* [99Sta]. A comprehensive review of models and phantoms of the human body can be found in ICRU Report 48 [92ICR2]. The term "model" refers to computational models, whereas "phantom" implies either a physical phantom or a computational one. Spherical and slab phantoms are convenient and simple approximations of the human body.

A spherical model of 30 cm diameter made of ICRU tissue-equivalent material (see Sect. 4.5.3.3) is used for the definition of the operational quantities. Various tissue substitutes are available for fabrication of corresponding physical phantoms, including tissue-equivalent material, water and perspex. For calibration purposes, slab tissue-substitute phantoms of $30 \times 30 \times 15$ cm^3 are used.

Recently a new generation of computational phantoms has become available which offer the prospect of increased realism and accuracy in dose calculations. These models use computed (CT) or magnetic resonance (MR) tomographic data of real persons to provide three-dimensional representations of the human body and comprise a large number of volume elements (voxels) all of the same size but with differing composition according to the organ to which they belong. The GSF-National Research Centre in Germany started since the mid eighties the development of voxel models covering various ages and anatomical statures [88Zan, 01Zan, 02Pet]. Due to their anatomical realism, such models have been the subject of increasing interest and acceptance, and others have been developed also elsewhere [94Zub, 96Dim, 00Xu].

Both MIRD-type and voxel models incorporate different densities and atomic compositions for the various body tissues. The number of organs simulated varies from model to model, however, the latest versions include all organs defined to be important. Fig. 1 shows views of selected organs of the mathematical model Eva [82Kra] and the adult female voxel model Donna, developed at GSF [02Pet].

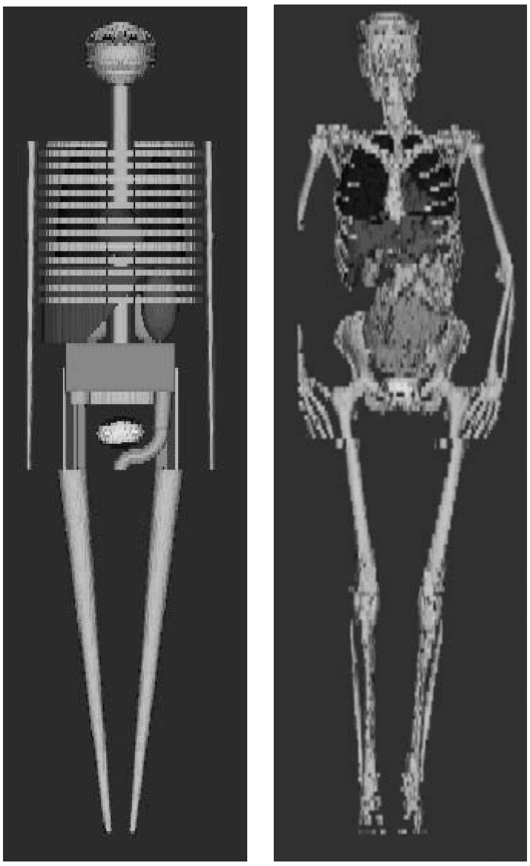

Fig. 6.1. View of selected organs of the mathematical model Eva [82Kra] and the adult female voxel model Donna, developed at GSF [02Pet].

6.2.2 Idealized geometries representing occupational exposures

To simulate occupational exposure conditions, whole-body irradiation with idealised geometries are conventionally taken into account. These include broad parallel beams and fully isotropic radiation incidence. The directions of incidence for the parallel beams considered are: anterior-posterior (AP), posterior-anterior (PA), left lateral (LLAT), right lateral (RLAT) and a full 360° rotation around the phantoms' longitudinal axis (ROT). Although these geometries are idealised, they may be taken as acceptable approximations to actual conditions of exposure. The AP, PA and both lateral geometries are supposed to approximate radiation fields from single sources and particular body orientations. The ROT geometry approximates the exposure of a person who moves randomly in the field of a single source irradiating at right angles to the longitudinal axis of the body. The fully isotropic (ISO) source simulates the geometry of a body suspended in a large cloud of radioactive gas.

6. 2. 3 Environmental source geometries

For external exposures to environmental sources the dosimetric quantities of interest are the radiation doses received by the radiosensitive organs and tissues of the body due to photons and electrons emitted by radionuclides distributed in soil and air. The radiation dose depends strongly on the temporal and spatial distribution of the radionuclide to which a human is exposed. The situation of radioactive release in water is more rare and is not covered here. The kinds of radiation of concern are those sufficiently penetrating to traverse the overlying tissues of the body and which deposit their energy in organs and tissues of the body. Penetrating radiations are limited to photons and electrons. Neutrons from cosmic radiation are not dealt here.

For simulating the exposure to environmental gamma-rays, the following three typical cases of environmental sources are considered here: (1) semi-infinite volume source in the air; (2) infinite plane source in the ground; (3) semi-infinite volume source in the ground. The first source configuration models the gaseous radioactive release into the atmosphere at locations which are not too near to the release point, by assuming a homogeneous contamination of the air up to a height of 1000 m above a smooth air-ground interface. The second source simulates the deposition of radionuclides in the ground, by assuming an infinite plane source in the soil. The third source simulates the natural radioactivity in the ground (the dominant radionuclides of the ^{238}U series, the ^{232}Th series and ^{40}K) being homogeneously distributed to a depth of 1 m in the soil.

6.2.4 Methods of calculating protection quantities in computational models

Today the predominant method for assessment of absorbed doses in the body is the application of Monte Carlo methods to simulate the transport of radiation in the body. The organ and tissue doses are then estimated in the form of conversion coefficients giving organ doses per unit of a measurable quantity.

The Monte Carlo method is a computational model in which physical quantities are calculated by simulating the transport of particles. In the computer program, single particles are followed through their histories of inelastic and elastic scattering or absorption within the anthropomorphic model. Depending on their energy and on the material they are passing through, the particles interact differently and each mode of interaction has a certain probability of occurring, which can be selected by appropriate use of random numbers and probability distributions. Individual particles have different energies, directions and path lengths modelled randomly from probability distributions. By averaging over large numbers of random paths, good estimates of the quantities of interest can be made. Basic elements of Monte Carlo simulation include the choice of random number generator which provides the method of sampling the cross-section data and coordinate transformations from probability distributions. The mean absorbed dose in a defined volume of material is computed from the incident and emerging energies from the volume by dividing the energy imparted by the mass of the volume material.

Most codes dealing mainly with photon interaction assume that electrons generated through different interactions are absorbed “on the spot”. The energy transferred at a point of inelastic photon interaction is then modelled as being deposited at that point, without considering the energy transport by secondary charged particles (“kerma approximation”). This approach is valid as long as there is approximate secondary charged particle equilibrium, which can be supposed in most cases due to the macroscopic approach considering mean organ and tissue doses. This is acceptable for photon energies up to 3 MeV. For the skeleton, however, the boundary effects do have an impact on the tissue dose and corrections for secondary electron effects in the skeleton have to be applied. For neutrons up to 20 MeV the kerma approximation introduces no significant error due to the short range of the recoil protons and heavier charged particles.

For the estimation of absorbed doses distributions in the body, several transport codes are used and their description is beyond the scope of this book. General Monte Carlo codes are available, such as EGS4 [85Nel, 94Hir], ITS [92Hal] and MCNP4 [91Bri]. Various other research institutes have also developed their Monte Carlo codes like the GSF-National Research Center code [82Kra, 89Vei], PTB/PG [86Gro, 94Gro], etc.

The anthropomorphic models used for the collection of the data shown below were the mathematical Adam and Eva and the mathematical MIRD hermaphrodite for photons and neutrons; for electrons, the ICRU tissue sphere and slab as well as Adam and Eva were employed.

A joint task Group of ICRP and ICRU reviewed the conversion coefficients reported by different researchers. Conversion coefficients for external photon, neutron and electron exposures and the idealised geometries AP, PA, LLAT, RLAT and ROT were evaluated and compiled to be used as “reference data”; they can be found at the ICRP Report 74 [96ICR] and ICRU Report 57 [98ICR].

6.3 Conversion coefficients for photons

6.3.1 Occupational

This Section provides organ doses in the form of conversion coefficients, i.e. mean organ equivalent doses normalised to “air kerma free-in-air” which is a measurable quantity; the conversion coefficients are given in the unit $Sv·Gy^{-1}$. No location for a measurement of the normalisation quantity has to be specified since for the parallel and ideally isotropic geometries the photon fluence is invariant throughout the field.

The organ equivalent dose conversion coefficients were calculated for the male Adam and female Eva models [82Kra] separately. Average organ equivalent dose conversion coefficients were computed as the arithmetic mean of those for the male and female models. The gonad equivalent dose conversion coefficients are the arithmetic mean values of the respective coefficients for testes and ovaries.

For these calculations, the GSF Monte Carlo code was used which computes the dose deposited by photons from an external or internal source in various sections of a different media model of the body. The code is based on the fractional photon technique and uses the kerma approximation. The latter is valid only when charged particle equilibrium is established which can be supposed in most cases due to the moderate differences of the photon cross sections for the tissues in the human body and the macroscopic approach of energy deposition. There are two exceptions where boundary effects do have an impact on the tissue dose. One is the red bone marrow, where a moderate increase in energy deposited in the marrow cavities is expected from increased photoelectron emission from the surrounding bone. For photon exposures this effect was accounted for by applying appropriate correction factors [69Spi, 97Zan] to the energy deposited to the red bone marrow calculated using the kerma approximation. The other tissue where boundary effects could be of consequence is the bone surface, a very thin soft tissue layer enveloping the bones. Here secondary electron equilibrium is not valid for energies below approximately 300 keV as there the bone cross section values are considerably higher than those for soft tissues, resulting in an increased production of secondary electrons in the bones and, consequently, a dose enhancement at the interface between the bones and the adjacent soft tissues compared to the dose to tissue beyond the range of these secondary electrons. This enhanced dose to the tissue adjacent to bones is, however, not as high as the mean dose to the homogeneous mixture of skeletal tissues [68Dre]. Consequently this can be taken as a conservative estimate of the dose to the bone surface in this photon energy range. Above 300 keV, the cross sections of bone and soft tissue per mass density have a similar magnitude, and approximate secondary electron equilibrium is established.

To the calculated values of the conversion coefficients for monoenergetic photons, a fitting procedure using cubic spline functions was applied. With these fitting functions, values were also evaluated for 200 photon energies distributed equidistantly on a logarithmic scale between 10 or 15 keV and 10 MeV. Figures 6.2-6.8 show the conversion coefficients as a function of photon energy for 8 selected organs and tissues and for AP, PA, LLAT, RLAT, LAT, ROT and ISO geometries, respectively. These are the average values evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model. The complete sets of organ equivalent doses for the male, female and average can be found in Zankl et. al. [97Zan] shown graphically as well as in tabular form. The average values of the male and female models denoted as “adult” are also adopted as reference values for conversion coefficients and are presented in detail in ICRP Report 74 [96ICR] and ICRU Report 57 [98ICR] for those specific organs for which the ICRP recommends tissue weighting factors (see Chap. 4, Table 3).

The energy dependence of the conversion coefficients for single organs is determined by the photon interaction cross sections in tissues, the location of the organ in the body and the irradiation geometry. The cross sections decrease with increasing photon energy and the conversion coefficients correspondingly increase due to the increasing range of photons in the body. With further increasing energy and range of the photons, the conversion coefficients decrease. This leads to more or less pronounced peak in the energy range between 80-100 keV. The more pronounced peak of the conversion coefficients of skeleton is due to the large values of the ratio of the attenuation coefficients of bone and air respectively.

Table 6.1 shows the effective dose per unit air kerma as a function of energy for the six irradiation geometries, calculated for adults using the models Adam and Eva. The different forms of the energy dependence of the conversion coefficients for effective dose with irradiation geometry result from the different locations of the organs relative to the incoming photon beam and the value of their tissue weighting factors. As it can be seen from Table 6.1, the conversion coefficients of *E* for AP irradiation are always higher than the corresponding ones for other irradiation geometries. This is due to the fact that for AP photon incidence most organs with large tissue weighting factors are anteriorly located.

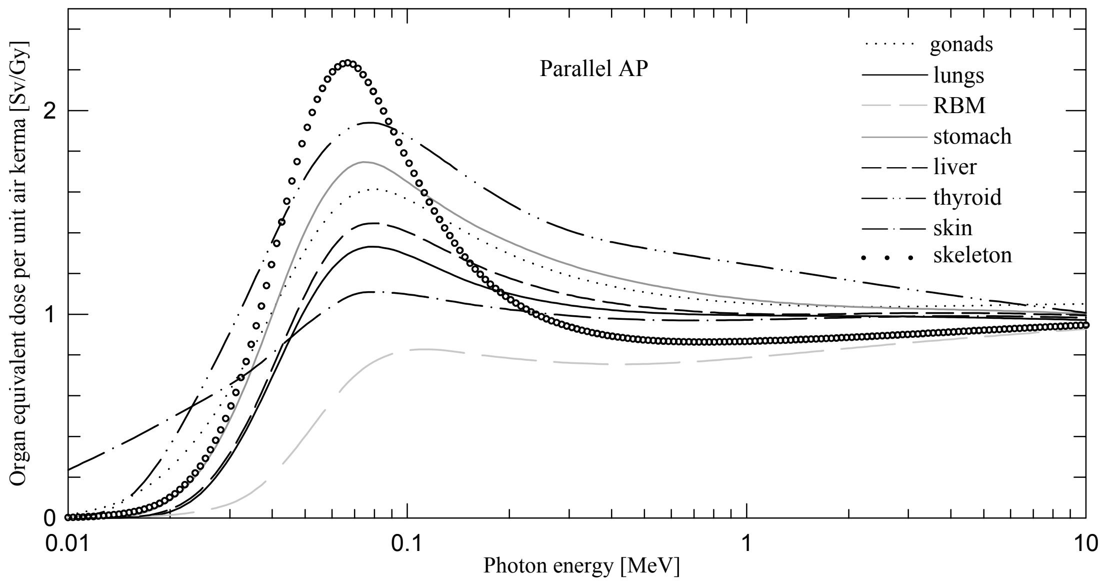

Fig. 6.2. Organ equivalent doses per unit air kerma free-in-air for selected organs in AP irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model;[97Zan].

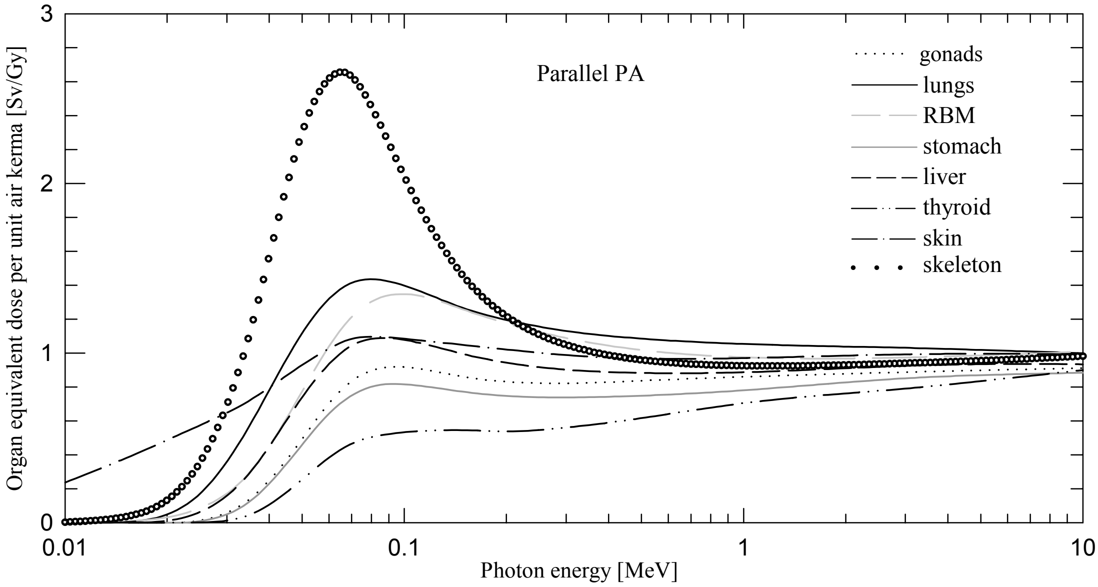

Fig. 6.3. Organ equivalent doses per unit air kerma free-in-air for selected organs in PA irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

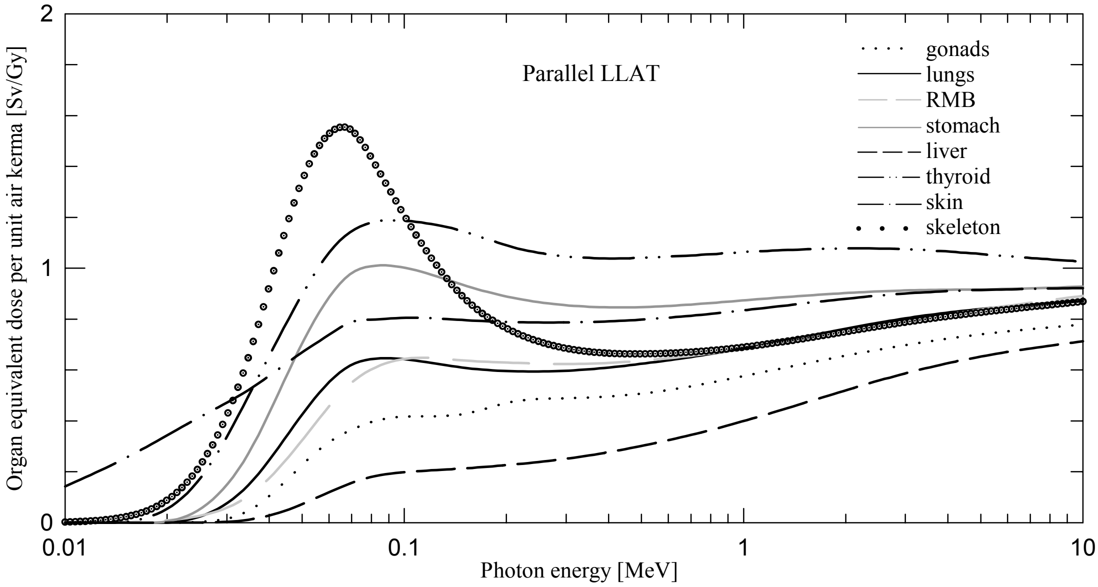

Fig. 6.4. Organ equivalent doses per unit air kerma free-in-air for selected organs in LLAT irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

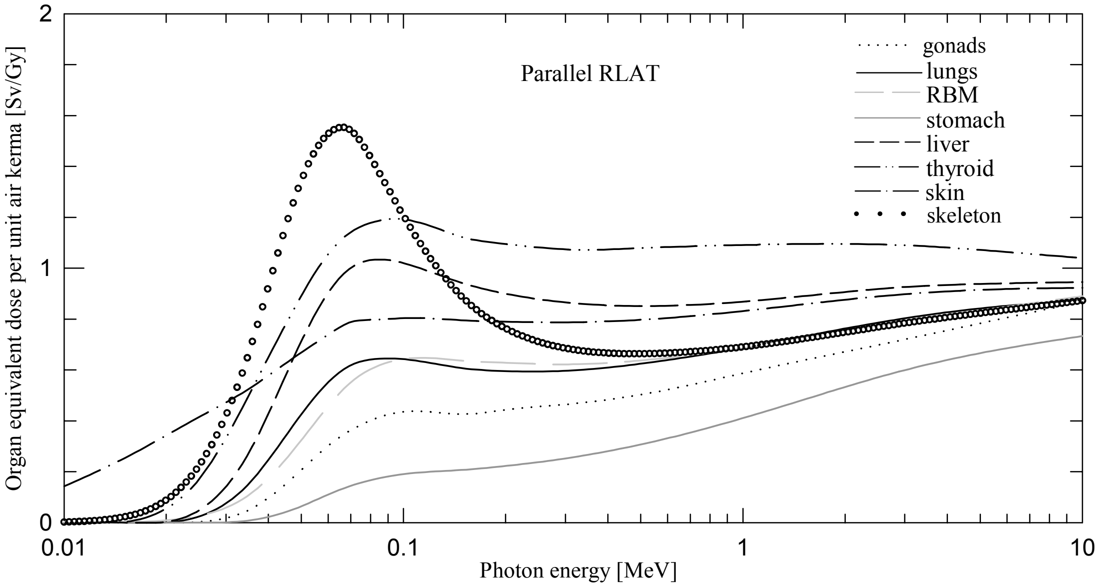

Fig. 6.5. Organ equivalent doses per unit air kerma free-in-air for selected organs in RLAT irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

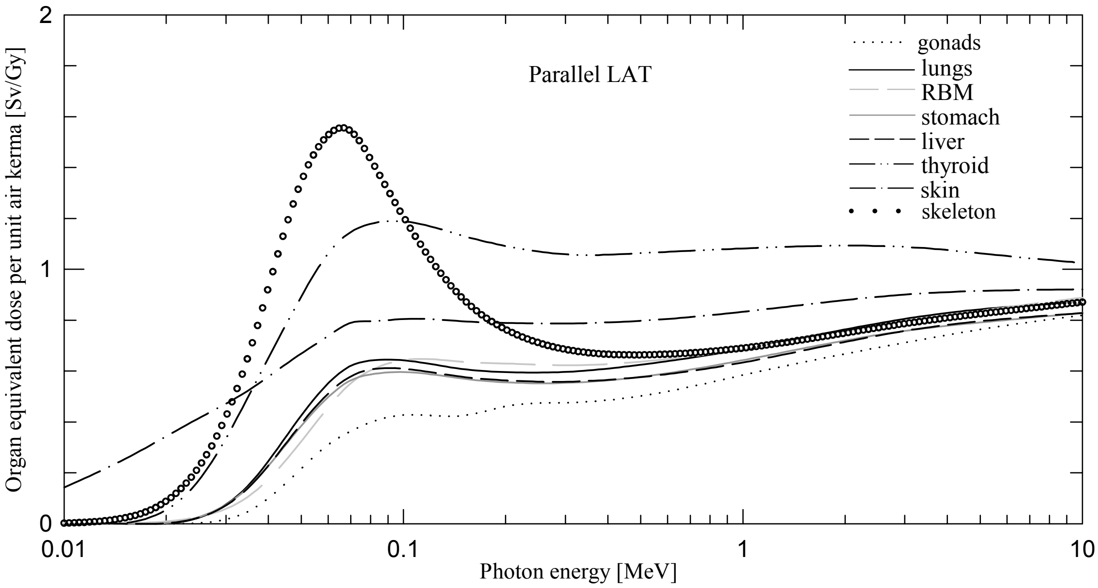

Fig. 6.6. Organ equivalent doses per unit air kerma free-in-air for selected organs in LAT irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

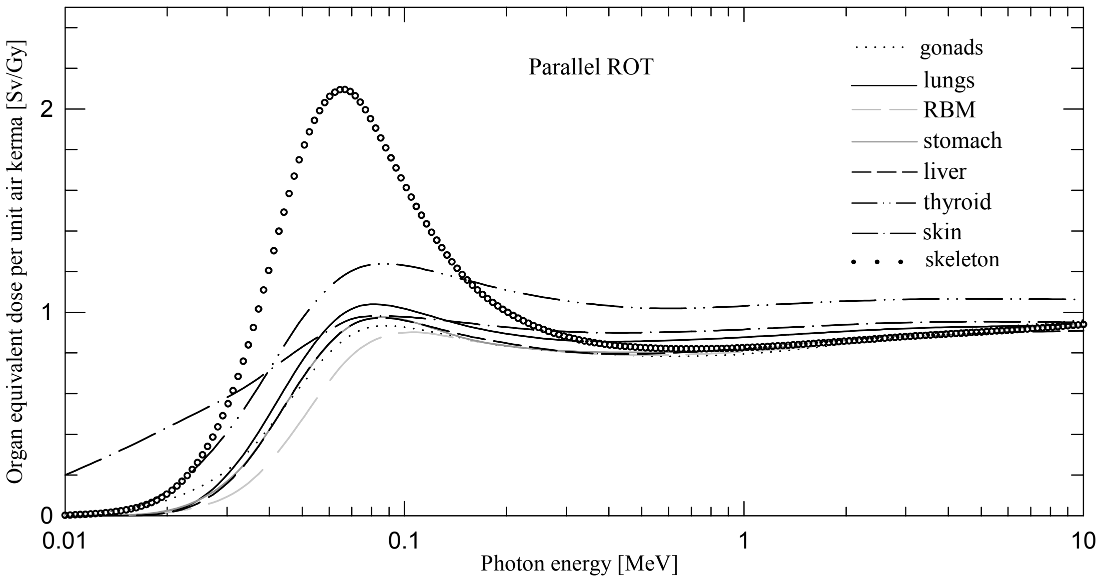

Fig. 6.7. Organ equivalent doses per unit air kerma free-in-air for selected organs in ROT irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

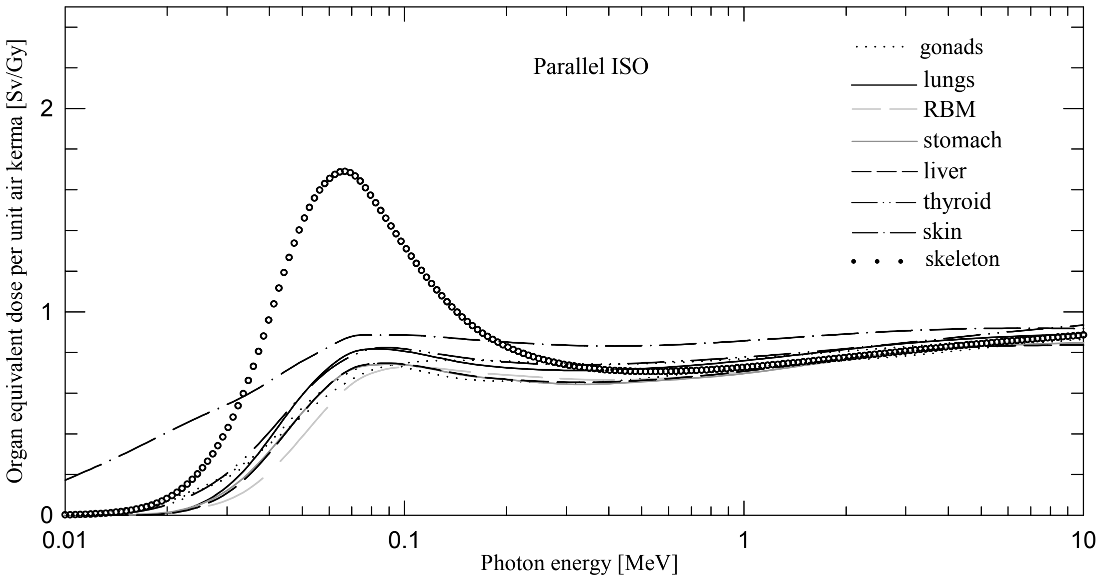

Fig. 6.8. Organ equivalent doses per unit air kerma free-in-air for selected organs in ISO irradiation as a function of photon energy, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

Table 6.1. Effective dose E per unit air kerma free-in-air K_a for monoenergetic photons and various irradiation geometries. Data are from Zankl et. al. [97Zan], calculated using the male (Adam) and female (Eva) model.

Photon energy	E/K_a [Sv·Gy^{-1}]					
[MeV]	AP	PA	LLAT	RLAT	ROT	ISO
0.010	0.00654	0.00248	0.00173	0.00172	0.00326	0.00271
0.015	0.0402	0.00590	0.00550	0.00551	0.0154	0.0123
0.020	0.122	0.0183	0.0156	0.0151	0.0463	0.0362
0.030	0.416	0.129	0.0907	0.0782	0.191	0.144
0.040	0.787	0.372	0.242	0.204	0.427	0.326
0.050	1.104	0.641	0.406	0.344	0.661	0.511
0.060	1.306	0.847	0.529	0.454	0.828	0.642
0.070	1.405	0.968	0.599	0.521	0.924	0.720
0.080	1.431	1.020	0.630	0.553	0.961	0.749
0.100	1.392	1.031	0.643	0.570	0.960	0.748
0.150	1.255	0.960	0.622	0.551	0.893	0.700
0.200	1.172	0.916	0.616	0.548	0.854	0.679
0.300	1.091	0.881	0.616	0.556	0.824	0.664
0.400	1.055	0.872	0.624	0.570	0.814	0.667
0.500	1.035	0.870	0.636	0.585	0.812	0.675
0.600	1.024	0.871	0.648	0.600	0.814	0.685
0.800	1.010	0.875	0.671	0.627	0.821	0.703
1.000	1.002	0.881	0.692	0.651	0.831	0.719
2.000	0.992	0.901	0.758	0.728	0.871	0.774
4.000	0.992	0.918	0.813	0.796	0.909	0.824
6.000	0.993	0.924	0.836	0.827	0.925	0.846
8.000	0.991	0.928	0.850	0.846	0.934	0.859
10.000	0.990	0.929	0.860	0.860	0.941	0.868

Figures 6.8 and 6.9 demonstrate the age dependence for effective dose, by showing the effective dose for adults as well as for 0-, 1-, 5-, 10-, and 15-year old children for AP and ROT geometry respectively. The data of this figure stem from Yamagushi [94Yam] who used hermaphrodite paediatric and adult mathematical models of different body sizes developed by Cristy [80Cri]. It can be seen that the smaller body size results in higher organ dose conversion coefficients, and consequently higher effective doses, particularly at low photon energies. The largest variation of effective dose with age was found for the LAT and ISO geometries. Similarly, Zankl et. al. [97Zan] have shown that the conversion coefficients for the female model Eva are approximately 2 % to 20 % higher than those for the male model, depending on photon energy, due to the slightly smaller body size of the female model. For AP irradiation, the lung dose conversion coefficients for the female model are between 5 % and 20 % lower than those for the male, as for this geometry the lungs of the female model are partially shielded by the breast. Furthermore, some differences were observed for the organ conversion coefficients calculated by different authors and are mainly due to the different human models used in the calculations and occur at low photon energies: the female model Eva, used for the calculations of Zankl et. al. has a smaller body size than the hermaphrodite model used by Yamaguchi, resulting in higher organ conversion coefficients particularly for low energies. Consequently, differences (up to 20 %) between the effective dose coefficients from adults were observed. For energies above 70 keV there was general agreement within the statistical uncertainties.

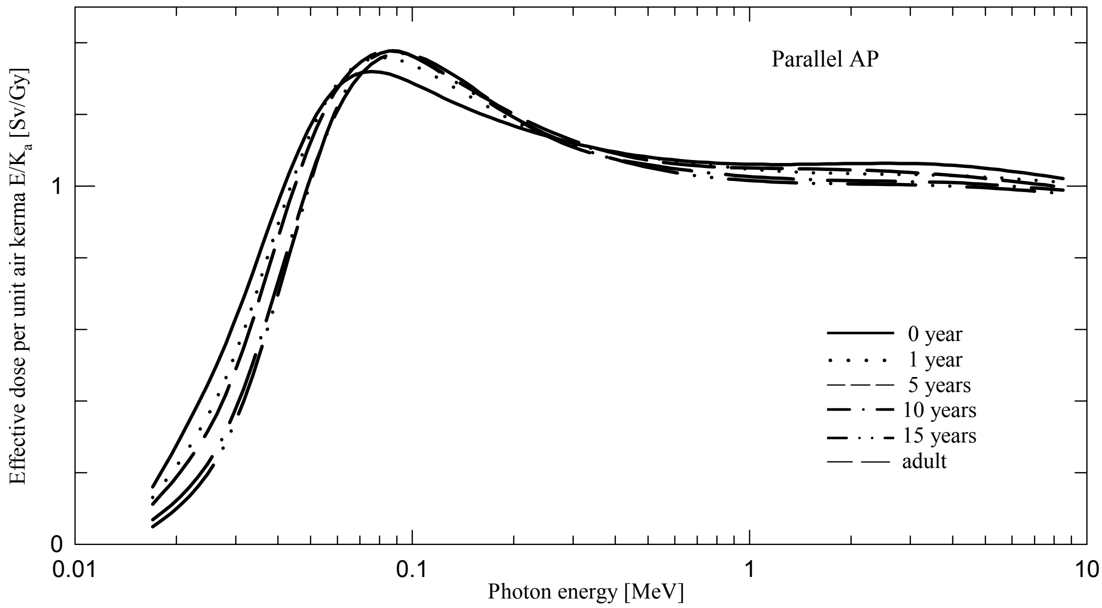

Fig. 6.9. Effective dose per unit air kerma free-in-air for AP irradiation geometry calculated for MIRD-type hermaphrodite phantoms of various ages; [94Yam].

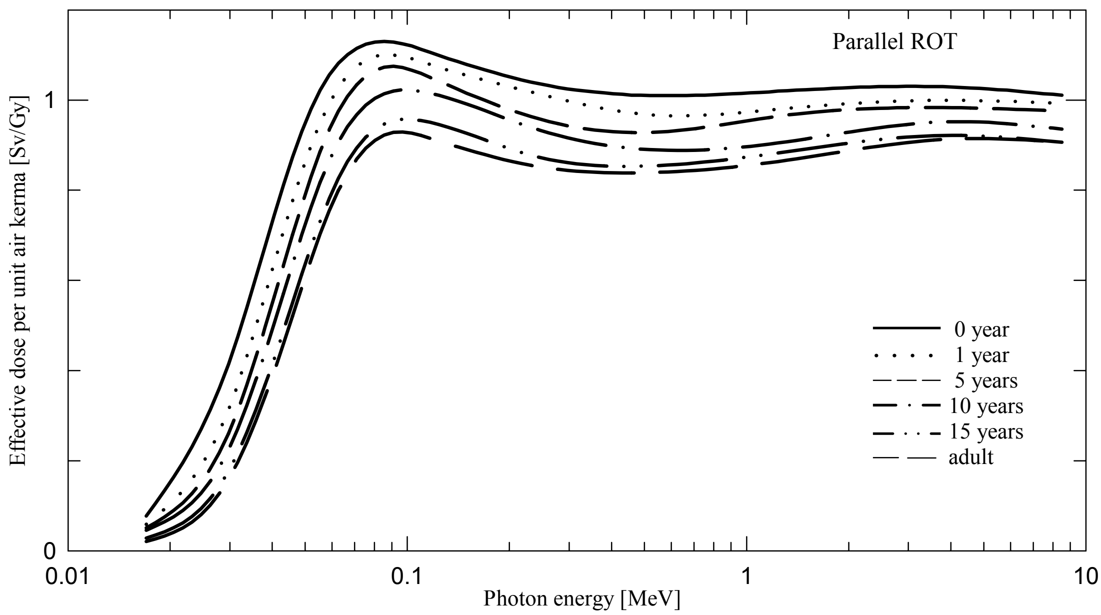

Fig. 6.10. Effective dose per unit air kerma free-in-air for ROT irradiation geometry calculated for MIRD-type hermaphrodite phantoms of various ages; [94Yam].

Conversion coefficients for the operational quantities ambient dose equivalent and directional dose equivalent are shown in Table 6.2. These are values recommended by the ICRP [92ICR1] and stem from calculations by several groups using Monte Carlo methods on the ICRU sphere assuming electronic equilibrium.

Table 6.2. Conversion coefficients for air kerma free-in-air K_a, directional dose equivalent $H'(0.07,0°)$, and ambient dose equivalent $H^*(10)$, per unit fluence of monoenergetic photons; [92ICR1].

Photon energy [MeV]	K_a/Φ [pGy cm^2]	$H'(0.07,0°)/\Phi$ [pSv cm^2]	$H^*(10)/\Phi$ [pSv cm^2]
0.010	7.60	7.20	0.061
0.015	3.21	3.19	0.83
0.020	1.73	1.81	1.05
0.030	0.739	0.90	0.81
0.040	0.438	0.62	0.64
0.050	0.328	0.50	0.55
0.060	0.292	[a]	0.51
0.080	0.308		0.53
0.100	0.372		0.61
0.150	0.600		0.89
0.200	0.856		1.20
0.300	1.38		1.80
0.400	1.89		2.38
0.500	2.38		2.93
0.600	2.84		3.44
0.800	3.69		4.38
1.0	4.47		5.20
1.5	6.12		6.90
2.0	7.51		8.60
3.0	9.89		11.1
4.0	12.0		13.4
5.0	13.9		15.5
6.0	15.8		17.6
8.0	19.5		21.6
10.0	23.2		25.6

[a] $H'(0.07,0°)$ is not accurately determined at energies above 60 keV since there is no electronic equilibrium.

Comparing tables 6.1 and 6.2, it can be seen that for photons with energies up to 10 MeV and irradiation geometries AP, PA and ROT, the operational quantity $H^*(10)$ always overestimates the protection quantity E, i.e. $E/H^*(10) < 1$.

6.3.2 Conversion coefficients for environmental gamma ray fields

6.3.2.1 Calculation of doses for monoenergetic photons

As already mentioned above, for simulating the exposure to environmental gamma-rays, the following three typical cases of environmental sources are considered to be representative: (a) semi-infinite volume source in the air; (b) infinite plane source in the ground; (c) semi-infinite volume source in the ground. The first source configuration models the gaseous radioactive release into the atmosphere at locations which are not too near to the release point, by assuming a homogeneous contamination of the air up to a height of 1000 m above a smooth air-ground interface. The second source simulates the deposition of radionuclides in the ground, by assuming an infinite plane source in the soil. The source is shielded by a soil slab of 0.5 g cm^{-2}, allowing for some surface roughness and initial migration into soil with precipitation. The third source simulates the natural radioactivity in the ground (e.g. radionuclides of the ^{238}U series, the ^{232}Th series and ^{40}K) being homogeneously distributed to a depth of 1 m in the soil.

In source (a), the dominant gamma rays come almost isotropically from the upper 2π directions, while only a small amount of scattered gamma-rays comes from the lower 2π directions. Source (c) shows the inverse tendency: the angular distribution is nearly uniform in the lower 2π directions with small components of scattered gamma-rays stemming from the upper 2π directions. In source (b), quite a large portion of the gamma-rays comes from horizontal directions. When the source distribution in the environment varies from the three typical source distributions, the angular and energy distributions also change.

To estimate the organ doses from environmental photon sources presented in this book, a three-step procedure [91Pet] was followed:

(1) Calculation of the gamma-ray transport in the environment (monoenergetic gamma-rays and natural radionuclides);
(2) Simulation of a secondary source around the phantom;
(3) Calculation of organ doses due to the secondary sources.

The result of this procedure, is a set of dose conversion coefficients for monoenergetic photons. Using those, and considering the energies and intensities of the radiations emitted during nuclear transformations of these nuclides, conversion coefficients for specific radionuclides can be computed to relate a measurable quantity i.e. activity concentration or air kerma to the non-measurable quantities of organ dose.

The photon transport in the environment was simulated with the Monte Carlo code YURI [85Sai], a code specially developed for environmental problems. Compton scattering, photoelectric absorption and pair production were considered as photon interaction processes. Air and ground were assumed to contact each other with an infinite plane. The cross Sections used were from Storm and Israel [70Sto]. Air was assumed to have a constant density of 1.2×10^{-3} g cm^{-3}, corresponding to a temperature of 20 ºC and an air pressure of 0.1 MPa and to consist of N_2, O_2 and Ar having weight fractions of 75.5 %, 23.2 % and 1.3 %, respectively. Soil was taken to consist of SiO_2, Al_2O_3, Fe_2O_3 and H_2O with weight fractions of 58.3 %, 16.7 %, 8.3 % and 16.7 %, respectively. A soil density of 1 g cm^{-3} has been assumed in the calculations, since this value represents reasonably well the upper 2 cm of soil. It should be noted that the environmental transport calculations were performed without the presence of the phantom; however, the perturbation caused by the human body was investigated and found to be insignificant.

From the transport calculations in the environment, double differential fluences, currents (i.e. fluences multiplied by the cosine of the angle of incidence) and air kerma values are obtained for points from 0 to 2 m above ground in steps of 20 cm. Table 6.3 shows calculated values of the air kerma rate free-in-air at 1 m height above the ground per unit activity concentration for a semi-infinite volume source in air and per unit activity per area for an infinite plane source in the ground; Table 6.4 shows the air kerma free-in-air at 1 m height above the ground per disintegration/kg for the semi-infinite volume source in the ground due to the natural radionuclides.

Table 6.3. next page

Table 6.4. Calculated air kerma at 1 m height above the ground per disintegration/kg for a semi-infinite volume source in the ground due to natural radionuclides; [95Sai].

Radionuclides	Air kerma per unit source intensity [Gy / (disintegration/kg)]
^{238}U series	1.29×10^{-13}
^{232}Th series	1.68×10^{-13}
^{40}K	1.16×10^{-14}

Table 6.3. Calculated air kerma rate at height 1 m above the ground per unit of activity concentration for a semi-infinite volume source in air and per unit of the activity per unit area for an infinite plane source in the ground; [95Sai].

	Volume source in air	Plane source in ground
Energy [MeV]	Air kerma rate per unit of activity concentration [(Gy s^{-1})/ (Bq m^{-3})]	Air kerma rate per unit of activity per unit area [(Gy s^{-1})/ (Bq m^{-2})]
0.015	1.47×10^{-15}	8.06×10^{-19}
0.020	1.71×10^{-15}	7.72×10^{-18}
0.030	2.12×10^{-15}	2.63×10^{-17}
0.040	2.40×10^{-15}	3.59×10^{-17}
0.050	2.81×10^{-15}	4.14×10^{-17}
0.060	3.31×10^{-15}	4.65×10^{-17}
0.070	3.79×10^{-15}	5.35×10^{-17}
0.080	4.36×10^{-15}	5.98×10^{-17}
0.100	5.55×10^{-15}	7.54×10^{-17}
0.150	8.68×10^{-15}	1.21×10^{-16}
0.200	1.20×10^{-14}	1.68×10^{-16}
0.300	1.87×10^{-14}	2.61×10^{-16}
0.500	3.21×10^{-14}	4.34×10^{-16}
0.700	4.56×10^{-14}	5.90×10^{-16}
1.000	6.58×10^{-14}	8.09×10^{-16}
1.500	9.08×10^{-14}	1.13×10^{-15}
2.000	1.32×10^{-13}	1.41×10^{-15}
3.000	1.96×10^{-13}	1.91×10^{-15}
6.000	3.85×10^{-13}	3.19×10^{-15}
10.000	6.26×10^{-13}	4.81×10^{-15}

These height-dependent double differential (with respect to angle of incidence and photon energy) gamma ray fields were then incorporated into the organ dose calculation with anthropomorphic models, by establishing a secondary cylindrical source around the model to simulate the gamma-ray fields after the results of the transport calculation in the environment (step 2 of the procedure mentioned above) [91Pet]. The anthropomorphical models are standing on the soil modelled as a planar air/ground interface. Scatter and absorption of the radiation in both air and ground was considered in the calculation. The Monte Carlo code used for the transport calculation in the body was the GSF code mentioned above. The interactions considered were photoelectric absorption, Compton scattering and pair production and the cross section data were taken from ORNL [83Rou]. Dose conversion coefficients for Adam and Eva (see previous Section) and several organs, including the critical ones, were estimated and can be found in Zankl et. al. [97Zan]. From the dose conversion coefficients of the sex-specific models Adam and Eva, conversion coefficients for an “adult” were derived as arithmetic average.

In Fig. 6.10 dose conversion coefficients are given for some selected organs for submersion in a radioactive cloud (volume source in air) and in Fig. 6.11 for surface contamination. The conversion coefficients are for an adult and are expressed as equivalent doses normalised to air kerma free-in-air at height 1 m above the ground in Sv Gy^{-1} as a function of photon energy. For the volume source in the ground, conversion coefficients for the photon energy distributions corresponding to the natural radionuclides of the decay series of ^{238}U, ^{232}Th and ^{40}K are tabulated in Table 6.5.

Table 6.5. Organ equivalent dose conversion coefficients for the natural radionuclides for an adult, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

Organ	Organ equivalent dose per unit air kerma free-in-air at 1 m above ground [Sv Gy^{-1}]		
	^{238}U series	^{232}Th series	^{40}K
Adrenals	0.589	0.617	0.634
Bladder	0.648	0.681	0.692
Brain	0.689	0.715	0.727
Colon	0.627	0.655	0.659
Eye lenses	0.872	0.876	0.947
Gonads	0.682	0.681	0.738
Kidneys	0.674	0.700	0.700
Liver	0.658	0.684	0.692
Lungs	0.709	0.732	0.740
Muscle	0.737	0.761	0.767
Oesophagus	0.608	0.635	0.638
Pancreas	0.600	0.627	0.662
Red bone marrow	0.656	0.680	0.687
Skeleton	0.770	0.792	0.764
Skin	0.849	0.863	0.861
Small intestine	0.620	0.651	0.652
Spleen	0.646	0.699	0.703
Stomach	0.660	0.671	0.684
Thymus	0.675	0.753	0.733
Thyroid	0.659	0.776	0.731
Effective dose	0.672	0.695	0.709

For the environmental irradiation geometries, the dependence of the organ equivalent dose conversion coefficients on photon energy is much more uniform than for the unidirectional geometries considered for occupational radiation exposures, and depends less on the position of the organ in the body. As the radiation comes from all directions, every organ is quasi deep-lying relative to at least a considerable part of the incoming photons.

The conversion coefficients for the female model were found to be up to 5 % higher than those for the male model, due to the slightly smaller body size of the female model. Considering the two different source types, it can be seen that the equivalent dose conversion coefficients for the volume source in air are generally lower than those for the plane source in the ground. This results from the different angular distribution of the radiation impinging on the body: the gamma-ray field from a source in the air is nearly isotropic with respect to directions from the upper hemisphere, while the incident directions of the gamma rays from a plane source have strong horizontal bias, and most photons come from horizontal directions. Since the human body standing vertically has a reduced shielding effect for photons coming from horizontal directions, this leads to the higher doses resulting from this geometry. However, in most cases, the differences in the conversion coefficients were found to be less than 20 %.

Saito et. al. [98Sai] investigated the variation of effective dose for environmental gamma-rays for source distributions other than these three typical ones and for a lying posture further to the standing one. The change of posture of a human body and the biases of environmental sources were found to affect the effective dose by some tens percent. A similar trend is anticipated for the individual organ doses. Therefore, it could be concluded that the conversion coefficients for the three typical environmental sources can be used as a reference set of values to derive the organ doses and effective doses of adults from air kerma or source activity obtained by measurement for a variety of environmental source configurations.

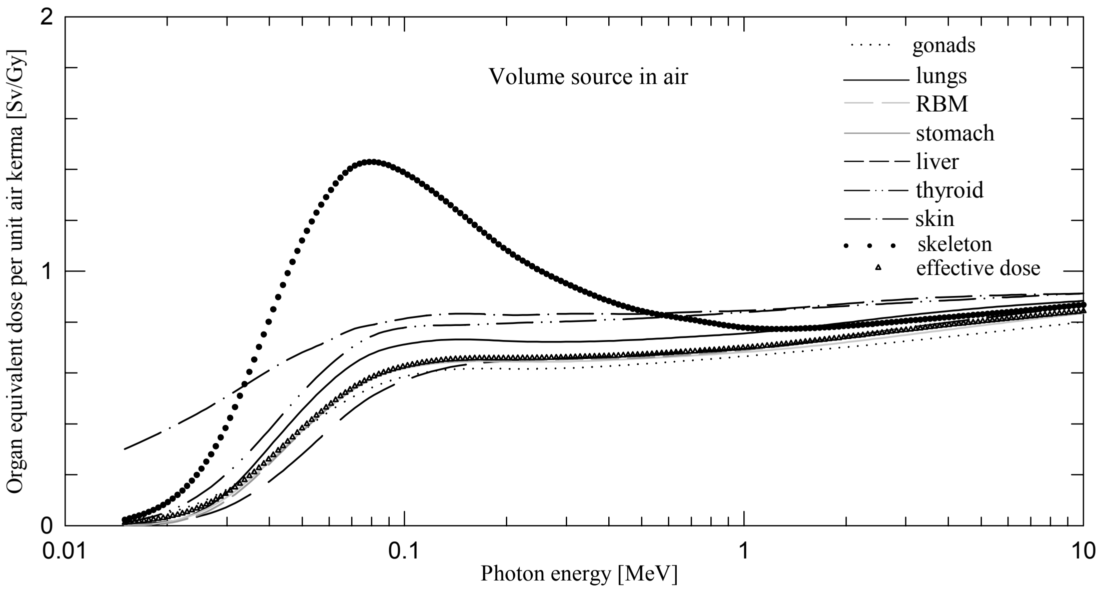

Fig. 6.11. Organ equivalent doses per unit air kerma at 1 m above the ground for some selected organs of an adult for a volume source in air, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

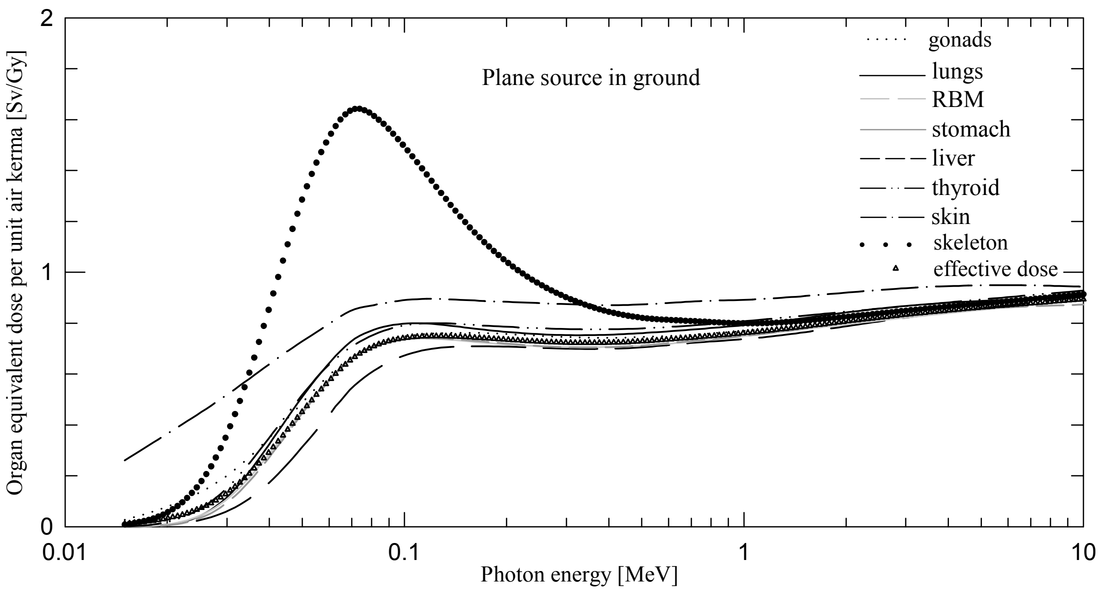

Fig. 6.12. Organ equivalent doses per unit air kerma at 1 m above the ground for some selected organs of an adult for plane source in ground, evaluated as the arithmetic mean of those for the male (Adam) and female (Eva) model; [97Zan].

6.3.2.2 Calculation of doses for radionuclides

Kerma rates in air and equivalent dose rates in organs for radionuclides are obtained from dose conversion coefficients for the monoenergetic sources $h_{T,i}$ by multiplication with the yield y_i^N (in number of photons Bq^{-1}) of photons with energy i per disintegration and summing over the photon energies of the emission spectrum of radionuclide N:

$$g^N = \sum_i y_i^N \cdot h_{T,i}$$

Kerma rates in air calculated with Monte Carlo methods in the environment due to monoenergetic photon sources distributed exponentially in the soil or homogeneously in the air are given in Tables 6.3 and 6.4 respectively. Radionuclide-specific results are given in Table 6.6.

Table 6.6. Kerma-rates in air at 1 m above ground per unit activity per unit area (nGy h^{-1} per kBq m^{-2}) and per activity concentration in air; [94ICR].

Radionuclide	Source in soil at a depth of 0.5 g cm^{-2} Kerma rate [(nGy h^{-1})/(kBq m^{-2})]	Volume source in air Kerma rate [(nGy h^{-1})/(kBq m^{-3})]
Be-7	1.67×10^{-1}	1.10×10^{-2}
Na-22	6.97×10^{0}	5.11×10^{-1}
Na-24	1.10×10^{1}	9.72×10^{-1}
K-40	4.62×10^{-1}	3.78×10^{-2}
K-42	8.53×10^{-1}	6.52×10^{-2}
Sc-46	6.31×10^{0}	4.75×10^{-1}
Cr-51	1.09×10^{-1}	7.06×10^{-3}
Mn-54	2.69×10^{0}	1.97×10^{1}
Mn-56	5.05×10^{0}	3.96×10^{-1}
Fe-59	3.64×10^{0}	2.81×10^{-1}
Co-56	9.86×10^{0}	8.39×10^{-1}
Co-57	3.88×10^{-1}	2.53×10^{-2}
Co-58	3.17×10^{0}	2.28×10^{-1}
Co-60	7.59×10^{0}	5.90×10^{-1}
Ni-65	1.65×10^{0}	1.31×10^{-1}
Zn-65	1.82×10^{0}	1.39×10^{-1}
Zn-69m	1.41×10^{0}	9.58×10^{-2}
Se-75	1.30×10^{0}	8.68×10^{-2}
Br-84	4.90×10^{0}	4.18×10^{-1}
Rb-86	2.94×10^{-1}	2.25×10^{-2}
Sr-92	4.01×10^{0}	3.14×10^{-1}
Y-90m	2.10×10^{0}	1.42×10^{-1}
Y-91	1.10×10^{-2}	8.50×10^{-4}
Y-91m	1.77×10^{0}	1.23×10^{-1}
Y-92	7.91×10^{-1}	5.94×10^{-2}
Y-93	2.69×10^{-1}	2.06×10^{-2}
Zr-95	2.40×10^{0}	1.73×10^{-1}
Zr-97	6.06×10^{-1}	4.14×10^{-2}
Nb-93m	1.29×10^{-2}	6.19×10^{-4}
Nb-95	2.49×10^{0}	1.80×10^{-1}
Nb-95m	2.40×10^{-1}	1.59×10^{-2}
Nb-97	2.21×10^{0}	1.52×10^{-1}
Mo-93	7.58×10^{-2}	3.54×10^{-3}
Mo-99	4.85×10^{-1}	3.43×10^{-2}
Tc-99m	3.93×10^{-1}	2.64×10^{-2}
Ru-103	1.64×10^{0}	1.08×10^{-1}
Ru-105	2.45×10^{0}	1.82×10^{1}
Rh-103m	8.82×10^{-2}	5.00×10^{4}
Rh-105	2.62×10^{-1}	1.73×10^{-2}
Rh-106	6.90×10^{-1}	4.75×10^{-2}
Ag-110m	8.76×10^{0}	6.14×10^{-1}
Ag-111	8.91×10^{-2}	5.90×10^{-3}
Sn-117m	5.52×10^{-1}	3.41×10^{-2}
Sn-126	1.92×10^{-1}	1.18×10^{-2}
Sb-124	5.67×10^{0}	4.25×10^{-1}
Sb-125	1.48×10^{0}	9.97×10^{2}
Sb-126	9.07×10^{0}	6.66×10^{1}
Sb-127	2.20×10^{0}	1.61×10^{-1}
Sb-128	1.01×10^{1}	7.20×10^{1}
Sb-129	4.58×10^{0}	3.36×10^{-1}
Sb-130	1.04×10^{1}	7.63×10^{-1}
Te-123m	4.96×10^{-1}	3.16×10^{-2}
Te-125m	1.87×10^{-1}	9.07×10^{-3}
Te-127	1.65×10^{-2}	1.11×10^{-3}
Te-127m	5.91×10^{-2}	2.78×10^{-3}
Te-129	2.07×10^{-1}	1.38×10^{-2}

Radionuclide	Source in soil at a depth of 0.5 g cm^{-2} Kerma rate [(nGy h^{-1})/(kBq m^{-2})]	Volume source in air Kerma rate [(nGy h^{-1})/(kBq m^{-3})]
Te-129m	1.65×10^{-1}	9.04×10^{3}
Te-131m	4.51×10^{0}	3.22×10^{-1}
Te-132	8.05×10^{-1}	5.15×10^{-2}
Te-133m	5.79×10^{0}	5.36×10^{-1}
Te-134	2.84×10^{0}	2.03×10^{-1}
I-129	1.14×10^{-1}	6.01×10^{-3}
I-130	7.05×10^{0}	4.93×10^{1}
I-131	1.29×10^{0}	8.68×10^{-2}
I-132	7.35×10^{0}	5.26×10^{-1}
I-133	2.01×10^{0}	1.40×10^{1}
I-134	8.26×10^{0}	6.05×10^{-1}
I-135	4.79×10^{0}	3.67×10^{-1}
Cs-134	5.09×10^{0}	3.64×10^{-1}
Cs-134m	1.08×10^{-1}	5.90×10^{-3}
Cs-136	6.75×10^{0}	5.08×10^{-1}
Cs-138	6.96×10^{0}	5.44×10^{-1}
Ba-137m	1.98×10^{0}	1.40×10^{-1}
Ba-139	1.45×10^{-1}	9.18×10^{-3}
Ba-140	6.21×10^{-1}	4.14×10^{-2}
La-140	6.93×10^{0}	5.44×10^{-1}
La-141	1.27×10^{-1}	9.97×10^{-3}
La-142	6.57×10^{0}	6.26×10^{-1}
Ce-141	2.44×10^{-1}	1.59×10^{-2}
Ce-143	9.28×10^{-1}	6.34×10^{-2}
Ce-144	6.37×10^{-2}	4.36×10^{-3}
Pr-145	8.32×10^{-2}	3.11×10^{-3}
Nd-147	4.71×10^{-1}	3.11×10^{-2}
Pm-148	1.78×10^{0}	1.35×10^{-1}
Pm-148m	6.55×10^{0}	4.64×10^{-1}
Pm-149	1.23×10^{-3}	2.36×10^{-3}
Pm-151	1.09×10^{0}	6.88×10^{-2}
Eu-152	3.53×10^{0}	1.82×10^{-1}
Eu-152m	9.47×10^{-1}	6.91×10^{-2}
Eu-154	3.85×10^{0}	2.89×10^{-1}
Eu-155	1.88×10^{-1}	1.22×10^{-2}
Eu-156	3.98×10^{0}	3.09×10^{-1}
Hf-181	1.79×10^{0}	1.25×10^{-1}
Ta-182	4.00×10^{0}	2.99×10^{-1}
W-187	1.70×10^{0}	1.09×10^{-1}
Pb-210	2.71×10^{-2}	1.51×10^{-3}
Pb-212	4.74×10^{-1}	3.24×10^{-2}
Bi-212	3.38×10^{-1}	4.36×10^{-2}
Ra-224	3.33×10^{-2}	2.17×10^{-3}
Ra-226	2.19×10^{-2}	1.46×10^{-3}
Ac-228	3.05×10^{0}	2.19×10^{-1}
Th-228	1.43×10^{-2}	8.75×10^{-4}
Th-231	1.31×10^{-1}	7.02×10^{-3}
Th-232	7.89×10^{-3}	4.54×10^{4}
Th-234	3.33×10^{-2}	2.07×10^{-3}
Pa-233	7.37×10^{-1}	4.54×10^{-2}
U-232	1.06×10^{-2}	7.24×10^{-4}
U-234	9.47×10^{-3}	5.80×10^{-4}
U-235	5.55×10^{-1}	3.34×10^{-2}
U-236	7.90×10^{-3}	5.44×10^{-4}
U-237	4.80×10^{-1}	3.11×10^{-2}
U-238	8.33×10^{-3}	6.88×10^{-4}
Np-237	1.42×10^{-1}	8.42×10^{-3}
Np-238	2.05×10^{0}	1.31×10^{-1}
Np-239	6.02×10^{-1}	3.78×10^{-2}
Pu-236	1.08×10^{-2}	7.06×10^{-4}
Pu-238	1.06×10^{-2}	6.19×10^{-4}
Pu-239	4.38×10^{-3}	2.41×10^{-4}
Pu-240	9.25×10^{-3}	5.83×10^{-4}
Pu-242	8.56×10^{-3}	5.04×10^{-4}
Am-241	1.12×10^{-1}	7.96×10^{-3}
Am-242	6.76×10^{-2}	4.39×10^{-3}
Am-242m	3.25×10^{-2}	1.61×10^{-3}
Am-243	1.81×10^{-1}	1.14×10^{-2}
Cm-242	9.38×10^{-3}	6.05×10^{-4}
Cm-243	4.47×10^{-1}	2.97×10^{-2}
Cm-244	8.87×10^{-3}	5.62×10^{-4}
Cm-245	3.10×10^{-1}	2.07×10^{-2}
Cm-247	1.03×10^{0}	7.16×10^{-2}

6.4 Conversion coefficients for neutrons

Significant radiation exposures to neutrons occur primarily at workplaces and not in the environment. In the natural environment neutrons are found mainly in secondary cosmic ray fields [00Pel, 02Roe]; accidental exposures to neutron emitting radionuclides in clouds or on the soil are extremely unlikely and therefore not considered here.

Neutron fields are in practice mixed radiation fields of wide neutron energy range, almost always associated with photons. To obtain the conversion coefficients for such fields, appropriate averaging of coefficients over the relevant spectra should be performed. The calculation of deposition of energy at any point in a body resulting from external exposure in mixed fields is a complex process of summation over all primary and secondary particle deposition.

Several authors calculated for incident neutrons the protection quantities organ absorbed dose and effective dose using anthropomorphic phantoms such as the hermaphrodite MIRD-5 phantom or the sex-specific MIRD-type phantoms Adam and Eva (see Sect. 6.2 and 6.3). For the operational quantities, the ICRU sphere and slab phantoms were used. Several Monte Carlo codes were applied such as the MCNP [91Bri], SAM-CE [79Lic], MORSE-CG [75Emm], the JAERI code [Yam93], the PTB-code [90Hol] etc. Extensive tables of organ dose conversion coefficients data are given in ICRP Report 74 [96ICR] and ICRU Report 57 [978ICR] derived as sets of "best estimates" of the data of various authors. Table 6.7 lists the effective dose per unit of neutron fluence for idealized whole-body irradiation geometries and for energies ranging from thermal up to 180 MeV. In the same table, the coefficients for ambient dose equivalent are also given.

Table 6.7. Effective dose per unit neutron fluence E/Φ for monoenergetic neutrons incident in various geometries on an adult anthropomorphic computational model. The last column of the table shows the coefficients for ambient dose equivalent; [978ICR].

Energy			E/Φ [pSv cm^2]				$H^*(10)/\Phi$
[MeV]	AP	PA	RLAT	LLAT	ROT	ISO	[pSv cm^2]
1.0×10^{-9}	5.24	3.52	1.36	1.68	2.99	2.99	6.60
1.0×10^{-8}	6.55	4.39	1.70	2.04	3.72	2.89	9.00
2.5×10^{-8}	7.60	5.16	1.99	2.31	4.40	3.30	10.6
1.0×10^{-7}	9.95	6.77	2.58	2.86	5.75	4.13	12.9
2.0×10^{-7}	11.2	7.63	2.92	3.21	6.43	4.59	13.5
5.0×10^{-7}	12.8	8.76	3.35	3.72	7.27	5.20	13.6
1.0×10^{-6}	13.8	9.55	3.67	4.12	7.84	5.63	13.3
2.0×10^{-6}	14.5	10.2	3.89	4.39	8.31	5.96	12.9
5.0×10^{-6}	15.0	10.7	4.08	4.66	8.72	6.28	12.0
1.0×10^{-5}	15.1	11.0	4.16	4.80	8.90	6.44	11.3
2.0×10^{-5}	15.1	11.1	4.20	4.89	8.92	6.51	10.6
5.0×10^{-5}	14.8	11.1	4.19	4.95	8.82	6.51	9.90
1.0×10^{-4}	14.6	11.0	4.15	4.95	8.69	6.45	9.40
2.0×10^{-4}	14.4	10.9	4.10	4.92	8.56	6.32	8.90
5.0×10^{-4}	14.2	10.7	4.03	4.86	8.40	6.14	8.30
1.0×10^{-3}	14.2	10.7	4.00	4.84	8.34	6.04	7.90
2.0×10^{-3}	14.4	10.8	4.00	4.87	8.39	6.05	7.70
5.0×10^{-3}	15.7	11.6	4.29	5.25	9.06	6.52	8.00
1.0×10^{-2}	18.3	13.5	5.02	6.14	10.6	7.70	10.5
2.0×10^{-2}	23.8	17.3	6.48	7.95	13.8	10.2	16.6
3.0×10^{-2}	29.0	21.0	7.93	9.74	16.9	12.7	23.7
5.0×10^{-2}	38.5	27.6	10.6	13.1	22.7	17.3	41.1
7.0×10^{-2}	47.2	33.5	13.1	16.1	27.8	21.5	60.0

Energy [MeV]	E/Φ [pSv cm^2] AP	PA	RLAT	LLAT	ROT	ISO	$H^*(10)/\Phi$ [pSv cm^2]
1.0×10^{-1}	59.8	41.3	16.4	20.1	34.8	27.2	88.0
1.5×10^{-1}	80.2	52.2	21.2	25.5	45.4	35.2	132
2.0×10^{-1}	99.0	61.5	25.6	30.3	54.8	42.4	170
3.0×10^{-1}	133	77.1	33.4	38.6	71.6	54.7	233
5.0×10^{-1}	188	103	46.8	53.2	99.4	75.0	322
7.0×10^{-1}	231	124	58.3	66.6	123	92.8	375
9.0×10^{-1}	267	144	69.1	79.6	144	108	400
1.0×10^{0}	282	154	74.5	86.0	154	116	416
1.2×10^{0}	310	175	85.8	99.8	173	130	425
2.0×10^{0}	383	247	129	153	234	178	420
3.0×10^{0}	432	308	171	195	283	220	412
4.0×10^{0}	458	345	198	224	315	250	408
5.0×10^{0}	474	366	217	244	335	272	405
6.0×10^{0}	483	380	232	261	348	282	400
7.0×10^{0}	490	391	244	274	358	290	405
8.0×10^{0}	494	399	253	285	366	297	409
9.0×10^{0}	497	406	261	294	373	303	420
1.0×10^{1}	499	412	268	302	378	309	440
1.2×10^{1}	499	422	278	315	385	322	480
1.4×10^{1}	496	429	286	324	390	333	520
1.5×10^{1}	494	431	290	328	391	338	540
1.6×10^{1}	491	433	293	331	393	342	555
1.8×10^{1}	486	435	299	335	394	345	570
2.0×10^{1}	480	436	305	338	395	343	600
3.0×10^{1}	458	437	324	na[a]	395	na[a]	515
5.0×10^{1}	437	444	358	na[a]	404	na[a]	400
7.5×10^{1}	429	459	397	na[a]	422	na[a]	300
1.0×10^{2}	429	477	433	na[a]	443	na[a]	285
1.3×10^{2}	432	495	467	na[a]	465	na[a]	260
1.5×10^{2}	438	514	501	na[a]	489	na[a]	245
1.8×10^{2}	445	535	542	na[a]	517	na[a]	250
2.0×10^{2}							260

[a] Not available

6.5 Conversion coefficients for electrons

6.5.1 Occupational exposure

Unshielded whole body irradiation by monoenergetic electrons does not represent a practical situation in occupational exposures and evaluated absorbed doses for electron beams are still sparse. However, irradiation of the skin, the lens of the eye and other superficial organs are of concern in radiological protection for electron energies below 10 MeV because the electron range is small, varying from 50 μm to about 5 cm for electron energies from 60 keV to 10 MeV. Table 6.8 shows some conversion coefficients for organ absorbed doses determined with the MCNP-4 code for the MIRD-type phantoms Adam and Eva, for monoenergetic electrons in the energy range of 100 keV to 10 MeV, incident in the AP geometry

(Schultz and Zoetelief, data from [96ICR]). ICRU Report 43 contains dose distributions in anthropomorphic phantoms resulting from irradiation by electrons of energies between 5 and 46 MeV [88ICR].

Various workers performed Monte Carlo calculations with different codes (EGS4 [85Nel], MCNP-4 [91Bri], MCNP-BO code [94Gua1, 94Gua2], PTB-BG code [86Gro] etc.) enabling them to derive fluence-to-dose-equivalent conversion coefficients for parallel electron beams of energies between 60 keV and 10 MeV. The conversion coefficients for $H'(0.07,\alpha)$, $H'(3,\alpha)$, $H_{p,slab}(0.07,\alpha)$, $H_{p,slab}(3,\alpha)$ and $H_{p,slab}(10,\alpha)$ were determined with the ICRU sphere or the 4-element ICRU tissue slab phantom, respectively. A compilation of data can be found in [96Cha], in ICRP 74 and ICRU 57 [96ICR, 98ICR]. By appropriately averaging of these data, reference fluence-to-dose-equivalent conversion coefficients were derived as a function of energy for normally incident electrons. Table 6.9 shows these data for depths of 0.07 mm and 3 mm.

Table 6.8. Organ absorbed dose per unit fluence D_T/Φ and effective dose per unit fluence E/Φ for monoenergetic electrons incident in the AP geometry on an adult anthropomorphic computational model (Schultz and Zoetelief, data from [96ICR]).

Energy [MeV]	0.1	0.4	0.6	1.0	1.5	2.0	4.0	10.0
	D_T/Φ and E/Φ [pGy cm²]							
Skin	8	98	171	164	158	153	150	165
Testes			0	1	14	37	214	345
Bone marrow			0	1	5	11	28	52
Stomach						0	3	184
Breast			0	14	43	75	200	325
Liver							0	97
Thyroid						0	121	297
Effective dose	0.1	1	1.5	2.7	5.9	11	44	131

Table 6.9. Reference conversion coefficients from fluence to directional dose equivalent for mono-energetic electrons and normal incidence

Energy [MeV]	$H'(0.07,0°)/\Phi$ [nSv cm²]	$H'(3,0°)/\Phi$ [nSv cm²]
0.07	0.221	
0.08	1.056	
0.09	1.527	
0.10	1.661	
0.1125	1.627	
0.125	1.513	
0.15	1.229	
0.20	0.834	
0.30	0.542	
0.40	0.455	
0.50	0.403	
0.60	0.366	
0.70	0.344	0.000
0.80	0.329	0.045

Energy [MeV]	$H'(0.07,0°)/\Phi$ [nSv cm²]	$H'(3,0°)/\Phi$ [nSv cm²]
1.00	0.312	0.301
1.25	0.296	0.486
1.50	0.287	0.524
1.75	0.282	0.512
2.00	0.279	0.481
2.50	0.278	0.417
3.00	0.276	0.373
3.50	0.274	0.351
4.00	0.272	0.334
5.00	0.271	0.317
6.00	0.271	0.309
7.00	0.271	0.306
8.00	0.271	0.305
10.0	0.275	0.303

6.5.2 Environmental exposure

Due to the short ranges of electrons emitted by radionuclides, electrons contribute only to the dose to skin. Skin dose coefficients for a series of monoenergetic electron sources were calculated by Eckerman and Ryman [93Eck1] using the code DOSFACTER of Kocher [88DOE]. The results are shown in Figs. 6.13 and 6.14 for submersion in contaminated air and for exposure to contaminated soil respectively. These data can be then convoluted to the spectra of the various radionuclides, using the energy and intensity of beta and electron emissions of radionuclides to obtain radionuclide specific conversion coefficients.

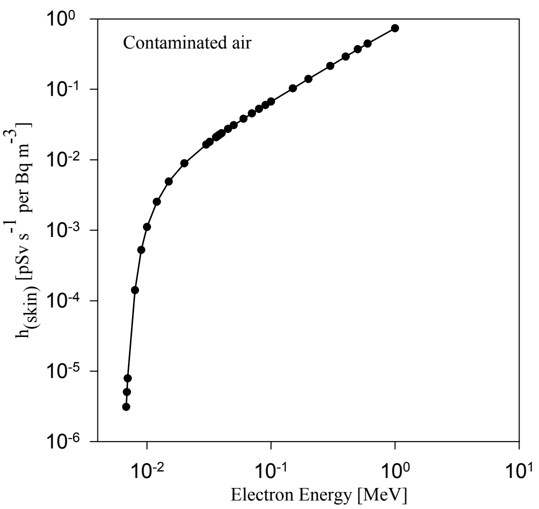

Fig. 6.13. Electron skin dose coefficient for submersion in air; [93Eck1].

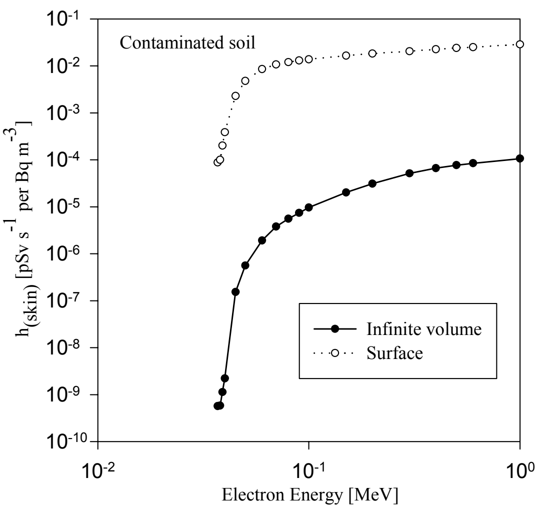

Fig. 6.14. Electron skin dose coefficient for exposure to contaminated soil on the surface and in the volume; [93Eck1].

6.6 Doses from external exposure of radionuclides in the environment

Only photons, including bremsstrahlung, and electrons emitted by the radionuclides are sufficiently penetrating to traverse the overlying tissues of the body and contribute to the dose to tissues and organs of the body. The energy spectra of emitted radiation are either discrete, as in the case of photons, or continuous, as in the case of beta particles and bremsstrahlung.

The dose coefficient H_T^S for tissue T for any exposure mode S can be expressed as

$$H_T^S = \sum_{j=e,\gamma} [\sum_i y_j(E_i) H_{T,j}^S(E_i) + \int_0^\infty y_j(E) H_{T,j}^S(E) \mathrm{d}E]$$

where $y_j(E_i)$ is the yield of radiations of type j and discrete energy E_i and $y_j(E)$ denotes the yield of radiations per nuclear transformation with continuous energy between E and E + dE. The other summation is over all electron and photon radiations. The contribution of the radiations to the dose in tissue or organ T is defined by the quantity H_T^S which is estimated by means of Monte Carlo calculations and is given as a function of energy for tissue and organ T for each exposure mode [93Eck1].

By using the dose conversion coefficients for monoenergetic sources of photon and electron radiation and by scaling them to the emissions of the radionuclides of interest, dose coefficients from radionuclides in the environment can be derived. The following tables contain data from the American Federal Guidance Report No. 12, based on Monte Carlo radiation transport calculations and data obtained from Eckerman [02Eck]. Tables 6.10 and 6.11 give the skin dose and effective dose coefficients for several radionuclides for exposure to contaminated ground surface to a depth of 5 cm and for air submersion respectively. The nuclear decay data used are from Eckerman et. al. [93Eck2] and are based on the ICRP Publication 38 [83ICR] on radionuclide transformations.

Table 6.10. Effective dose and skin dose coefficients for exposure to contaminated ground surface to a depth of 5 cm ; [93Eck1] and [02Eck].

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
He-3	0.00	0.00
Be-7	$1.04\cdot10^{-18}$	$8.55\cdot10^{-19}$
Be-10	$3.02\cdot10^{-20}$	$4.21\cdot10^{-21}$
C-11	$2.23\cdot10^{-17}$	$1.77\cdot10^{-17}$
N-13	$2.34\cdot10^{-17}$	$1.77\cdot10^{-17}$
C-14	$1.21\cdot10^{-22}$	$5.50\cdot10^{-23}$
O-15	$2.72\cdot10^{-17}$	$1.78\cdot10^{-17}$
F-18	$2.16\cdot10^{-17}$	$1.77\cdot10^{-17}$
Ne-19	$3.14\cdot10^{-17}$	$1.79\cdot10^{-17}$
Na-22	$4.48\cdot10^{-17}$	$3.76\cdot10^{-17}$
Na-24	$8.02\cdot10^{-17}$	$6.80\cdot10^{-17}$
Al-26	$5.52\cdot10^{-17}$	$4.54\cdot10^{-17}$
Al-28	$5.00\cdot10^{-17}$	$3.01\cdot10^{-17}$
Mg-28	$2.74\cdot10^{-17}$	$2.31\cdot10^{-17}$
P-30	$4.10\cdot10^{-17}$	$1.81\cdot10^{-17}$
Si-31	$3.59\cdot10^{-18}$	$7.88\cdot10^{-20}$
P-32	$5.18\cdot10^{-18}$	$9.05\cdot10^{-20}$
Si-32	$2.67\cdot10^{-22}$	$1.43\cdot10^{-22}$
P-33	$4.11\cdot10^{-22}$	$2.36\cdot10^{-22}$
S-35	$1.30\cdot10^{-22}$	$6.08\cdot10^{-23}$
Cl-36	$1.76\cdot10^{-19}$	$9.72\cdot10^{-21}$
Ar-37	0.00	0.00
Cl-38	$5.04\cdot10^{-17}$	$2.53\cdot10^{-17}$
K-38	$7.71\cdot10^{-17}$	$5.38\cdot10^{-17}$
Ar-39	$2.29\cdot10^{-20}$	$3.37\cdot10^{-21}$
Cl-39	$3.63\cdot10^{-17}$	$2.46\cdot10^{-17}$
K-40	$6.11\cdot10^{-18}$	$2.70\cdot10^{-18}$
Ar-41	$2.75\cdot10^{-17}$	$2.19\cdot10^{-17}$
Ca-41	0.00	0.00
K-42	$2.52\cdot10^{-17}$	$5.05\cdot10^{-18}$
K-43	$2.08\cdot10^{-17}$	$1.68\cdot10^{-17}$
Sc-43	$2.38\cdot10^{-17}$	$1.90\cdot10^{-17}$
K-44	$6.38\cdot10^{-17}$	$3.81\cdot10^{-17}$
Sc-44m	$5.84\cdot10^{-18}$	$4.79\cdot10^{-18}$
Sc-44	$4.76\cdot10^{-17}$	$3.68\cdot10^{-17}$
Ti-44	$1.90\cdot10^{-18}$	$1.47\cdot10^{-18}$
Ca-45	$4.30\cdot10^{-22}$	$2.50\cdot10^{-22}$
K-45	$4.66\cdot10^{-17}$	$3.14\cdot10^{-17}$
Ti-45	$1.94\cdot10^{-17}$	$1.51\cdot10^{-17}$
Sc-46	$4.09\cdot10^{-17}$	$3.45\cdot10^{-17}$
Ca-47	$2.27\cdot10^{-17}$	$1.81\cdot10^{-17}$
Sc-47	$2.13\cdot10^{-18}$	$1.74\cdot10^{-18}$
V-47	$2.80\cdot10^{-17}$	$1.74\cdot10^{-17}$
Cr-48	$8.80\cdot10^{-18}$	$7.19\cdot10^{-18}$
Sc-48	$6.79\cdot10^{-17}$	$5.73\cdot10^{-17}$
V-48	$5.92\cdot10^{-17}$	$4.99\cdot10^{-17}$
Ca-49	$6.47\cdot10^{-17}$	$5.08\cdot10^{-17}$
Cr-49	$2.55\cdot10^{-17}$	$1.80\cdot10^{-17}$
Sc-49	$7.49\cdot10^{-18}$	$1.47\cdot10^{-19}$
V-49	0.00	0.00
Cr-51	$6.64\cdot10^{-19}$	$5.43\cdot10^{-19}$
Mn-51	$3.05\cdot10^{-17}$	$1.74\cdot10^{-17}$
Fe-52	$1.56\cdot10^{-17}$	$1.26\cdot10^{-17}$
Mn-52m	$6.24\cdot10^{-17}$	$4.15\cdot10^{-17}$
Mn-52	$7.01\cdot10^{-17}$	$5.92\cdot10^{-17}$
Mn-53	0.00	0.00
Mn-54	$1.72\cdot10^{-17}$	$1.44\cdot10^{-17}$
Co-55	$4.33\cdot10^{-17}$	$3.44\cdot10^{-17}$
Fe-55	0.00	0.00
Co-56	$7.09\cdot10^{-17}$	$6.03\cdot10^{-17}$
Mn-56	$4.24\cdot10^{-17}$	$2.88\cdot10^{-17}$
Ni-56	$3.53\cdot10^{-17}$	$2.94\cdot10^{-17}$
Co-57	$2.21\cdot10^{-18}$	$1.81\cdot10^{-18}$
Ni-57	$3.85\cdot10^{-17}$	$3.26\cdot10^{-17}$
Co-58m	$4.58\cdot10^{-23}$	$9.55\cdot10^{-24}$
Co-58	$2.02\cdot10^{-17}$	$1.68\cdot10^{-17}$
Fe-59	$2.39\cdot10^{-17}$	$2.03\cdot10^{-17}$
Ni-59	0.00	0.00
Co-60m	$9.16\cdot10^{-20}$	$6.82\cdot10^{-20}$
Co-60	$5.02\cdot10^{-17}$	$4.27\cdot10^{-17}$
Cu-60	$8.68\cdot10^{-17}$	$6.62\cdot10^{-17}$
Fe-60	$1.08\cdot10^{-22}$	$4.60\cdot10^{-23}$
Co-61	$3.26\cdot10^{-18}$	$1.17\cdot10^{-18}$
Cu-61	$1.86\cdot10^{-17}$	$1.43\cdot10^{-17}$
Co-62m	$6.56\cdot10^{-17}$	$4.60\cdot10^{-17}$
Cu-62	$3.77\cdot10^{-17}$	$1.77\cdot10^{-17}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Zn-62	$9.03\cdot10^{-18}$	$7.41\cdot10^{-18}$
Ni-63	0.00	0.00
Zn-63	$3.27\cdot10^{-17}$	$1.92\cdot10^{-17}$
Cu-64	$4.00\cdot10^{-18}$	$3.28\cdot10^{-18}$
Ga-65	$3.21\cdot10^{-17}$	$2.02\cdot10^{-17}$
Ni-65	$1.62\cdot10^{-17}$	$9.42\cdot10^{-18}$
Zn-65	$1.18\cdot10^{-17}$	$9.96\cdot10^{-18}$
Cu-66	$1.40\cdot10^{-17}$	$1.67\cdot10^{-18}$
Ga-66	$6.18\cdot10^{-17}$	$4.13\cdot10^{-17}$
Ge-66	$1.42\cdot10^{-17}$	$1.15\cdot10^{-17}$
Ni-66	$3.11\cdot10^{-22}$	$1.73\cdot10^{-22}$
Cu-67	$2.24\cdot10^{-18}$	$1.82\cdot10^{-18}$
Ga-67	$3.01\cdot10^{-18}$	$2.45\cdot10^{-18}$
Ge-67	$4.62\cdot10^{-17}$	$2.44\cdot10^{-17}$
Ga-68	$2.65\cdot10^{-17}$	$1.66\cdot10^{-17}$
Ge-68	$4.59\cdot10^{-22}$	$6.94\cdot10^{-24}$
As-69	$3.76\cdot10^{-17}$	$1.78\cdot10^{-17}$
Ge-69	$1.87\cdot10^{-17}$	$1.50\cdot10^{-17}$
Zn-69m	$8.79\cdot10^{-18}$	$7.21\cdot10^{-18}$
Zn-69	$4.90\cdot10^{-19}$	$1.28\cdot10^{-20}$
As-70	$9.17\cdot10^{-17}$	$7.02\cdot10^{-17}$
Ga-70	$4.65\cdot10^{-18}$	$2.08\cdot10^{-19}$
Se-70	$2.34\cdot10^{-17}$	$1.70\cdot10^{-17}$
As-71	$1.19\cdot10^{-17}$	$9.70\cdot10^{-18}$
Ge-71	$4.65\cdot10^{-22}$	$7.02\cdot10^{-24}$
Zn-71m	$3.56\cdot10^{-17}$	$2.69\cdot10^{-17}$
As-72	$4.93\cdot10^{-17}$	$3.11\cdot10^{-17}$
Ga-72	$5.69\cdot10^{-17}$	$4.58\cdot10^{-17}$
Zn-72	$2.81\cdot10^{-18}$	$2.29\cdot10^{-18}$
As-73	$6.27\cdot10^{-20}$	$4.03\cdot10^{-20}$
Ga-73	$8.13\cdot10^{-18}$	$5.31\cdot10^{-18}$
Se-73m	$6.34\cdot10^{-18}$	$4.22\cdot10^{-18}$
Se-73	$2.42\cdot10^{-17}$	$1.84\cdot10^{-17}$
As-74	$1.68\cdot10^{-17}$	$1.31\cdot10^{-17}$
Br-74m	$1.00\cdot10^{-16}$	$6.92\cdot10^{-17}$
Br-74	$1.00\cdot10^{-16}$	$7.53\cdot10^{-17}$
Kr-74	$3.16\cdot10^{-17}$	$2.00\cdot10^{-17}$
Br-75	$2.93\cdot10^{-17}$	$2.10\cdot10^{-17}$
Ge-75	$2.11\cdot10^{-18}$	$6.11\cdot10^{-19}$
Se-75	$7.90\cdot10^{-18}$	$6.46\cdot10^{-18}$
As-76	$2.15\cdot10^{-17}$	$7.64\cdot10^{-18}$
Br-76	$6.09\cdot10^{-17}$	$4.46\cdot10^{-17}$
Kr-76	$8.86\cdot10^{-18}$	$7.23\cdot10^{-18}$
As-77	$2.64\cdot10^{-19}$	$1.54\cdot10^{-19}$
Br-77	$6.59\cdot10^{-18}$	$5.42\cdot10^{-18}$
Ge-77	$2.75\cdot10^{-17}$	$1.87\cdot10^{-17}$
Kr-77	$2.62\cdot10^{-17}$	$1.74\cdot10^{-17}$
Se-77m	$1.67\cdot10^{-18}$	$1.36\cdot10^{-18}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
As-78	$4.38\cdot10^{-17}$	$2.17\cdot10^{-17}$
Ge-78	$5.94\cdot10^{-18}$	$4.77\cdot10^{-18}$
Kr-79	$5.27\cdot10^{-18}$	$4.33\cdot10^{-18}$
Rb-79	$3.60\cdot10^{-17}$	$2.35\cdot10^{-17}$
Se-79	$1.61\cdot10^{-22}$	$7.61\cdot10^{-23}$
Br-80m	$1.20\cdot10^{-19}$	$4.75\cdot10^{-20}$
Br-80	$2.55\cdot10^{-18}$	$1.39\cdot10^{-18}$
Rb-80	$5.75\cdot10^{-17}$	$2.23\cdot10^{-17}$
Sr-80	$1.48\cdot10^{-20}$	$5.33\cdot10^{-22}$
Kr-81m	$2.61\cdot10^{-18}$	$2.12\cdot10^{-18}$
Kr-81	$1.24\cdot10^{-19}$	$9.48\cdot10^{-20}$
Rb-81m	$7.66\cdot10^{-20}$	$5.28\cdot10^{-20}$
Rb-81	$1.33\cdot10^{-17}$	$1.06\cdot10^{-17}$
Se-81m	$2.40\cdot10^{-19}$	$1.91\cdot10^{-19}$
Se-81	$4.15\cdot10^{-18}$	$2.29\cdot10^{-19}$
Sr-81	$4.04\cdot10^{-17}$	$2.40\cdot10^{-17}$
Br-82	$5.43\cdot10^{-17}$	$4.55\cdot10^{-17}$
Rb-82m	$5.99\cdot10^{-17}$	$5.00\cdot10^{-17}$
Rb-82	$4.23\cdot10^{-17}$	$1.93\cdot10^{-17}$
Sr-82	$1.45\cdot10^{-20}$	$5.24\cdot10^{-22}$
Br-83	$6.77\cdot10^{-19}$	$1.43\cdot10^{-19}$
Kr-83m	$3.47\cdot10^{-21}$	$1.35\cdot10^{-22}$
Rb-83	$1.05\cdot10^{-17}$	$8.61\cdot10^{-18}$
Se-83	$5.23\cdot10^{-17}$	$4.15\cdot10^{-17}$
Sr-83	$1.69\cdot10^{-17}$	$1.36\cdot10^{-17}$
Br-84	$5.04\cdot10^{-17}$	$2.99\cdot10^{-17}$
Rb-84	$1.91\cdot10^{-17}$	$1.58\cdot10^{-17}$
Kr-85m	$3.37\cdot10^{-18}$	$2.56\cdot10^{-18}$
Kr-85	$1.67\cdot10^{-19}$	$4.40\cdot10^{-20}$
Sr-85m	$4.51\cdot10^{-18}$	$3.68\cdot10^{-18}$
Sr-85	$1.06\cdot10^{-17}$	$8.73\cdot10^{-18}$
Rb-86	$7.19\cdot10^{-18}$	$1.71\cdot10^{-18}$
Y-86m	$4.53\cdot10^{-18}$	$3.69\cdot10^{-18}$
Y-86	$7.38\cdot10^{-17}$	$6.12\cdot10^{-17}$
Zr-86	$5.59\cdot10^{-18}$	$4.52\cdot10^{-18}$
Kr-87	$3.33\cdot10^{-17}$	$1.36\cdot10^{-17}$
Rb-87	$8.93\cdot10^{-22}$	$5.55\cdot10^{-22}$
Sr-87m	$6.73\cdot10^{-18}$	$5.51\cdot10^{-18}$
Y-87	$9.47\cdot10^{-18}$	$7.77\cdot10^{-18}$
Kr-88	$3.99\cdot10^{-17}$	$3.25\cdot10^{-17}$
Nb-88	$1.00\cdot10^{-16}$	$7.11\cdot10^{-17}$
Rb-88	$4.41\cdot10^{-17}$	$1.13\cdot10^{-17}$
Y-88	$5.27\cdot10^{-17}$	$4.53\cdot10^{-17}$
Zr-88	$8.32\cdot10^{-18}$	$6.80\cdot10^{-18}$
Nb-89b	$4.33\cdot10^{-17}$	$2.39\cdot10^{-17}$
Nb-89a	$4.89\cdot10^{-17}$	$3.35\cdot10^{-17}$
Rb-89	$5.26\cdot10^{-17}$	$3.52\cdot10^{-17}$
Sr-89	$3.69\cdot10^{-18}$	$6.67\cdot10^{-20}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Zr-89	$2.41\cdot10^{-17}$	$2.00\cdot10^{-17}$
Mo-90	$1.71\cdot10^{-17}$	$1.38\cdot10^{-17}$
Nb-90	$8.42\cdot10^{-17}$	$7.06\cdot10^{-17}$
Sr-90	$1.41\cdot10^{-20}$	$2.72\cdot10^{-21}$
Y-90m	$1.31\cdot10^{-17}$	$1.07\cdot10^{-17}$
Y-90	$9.85\cdot10^{-18}$	$1.74\cdot10^{-19}$
Sr-91	$1.98\cdot10^{-17}$	$1.21\cdot10^{-17}$
Y-91m	$1.12\cdot10^{-17}$	$9.19\cdot10^{-18}$
Y-91	$4.07\cdot10^{-18}$	$1.32\cdot10^{-19}$
Sr-92	$2.69\cdot10^{-17}$	$2.28\cdot10^{-17}$
Y-92	$2.53\cdot10^{-17}$	$4.71\cdot10^{-18}$
Mo-93m	$4.52\cdot10^{-17}$	$3.83\cdot10^{-17}$
Mo-93	$2.99\cdot10^{-20}$	$2.23\cdot10^{-21}$
Nb-93m	$5.26\cdot10^{-21}$	$3.94\cdot10^{-22}$
Tc-93m	$1.39\cdot10^{-17}$	$1.20\cdot10^{-17}$
Tc-93	$2.87\cdot10^{-17}$	$2.46\cdot10^{-17}$
Y-93	$1.64\cdot10^{-17}$	$1.78\cdot10^{-18}$
Zr-93	0.00	0.00
Nb-94	$3.26\cdot10^{-17}$	$2.72\cdot10^{-17}$
Ru-94	$1.09\cdot10^{-17}$	$9.01\cdot10^{-18}$
Tc-94m	$4.63\cdot10^{-17}$	$3.19\cdot10^{-17}$
Tc-94	$5.51\cdot10^{-17}$	$4.59\cdot10^{-17}$
Y-94	$4.70\cdot10^{-17}$	$1.95\cdot10^{-17}$
Nb-95m	$1.28\cdot10^{-18}$	$1.03\cdot10^{-18}$
Nb-95	$1.59\cdot10^{-17}$	$1.32\cdot10^{-17}$
Tc-95m	$1.38\cdot10^{-17}$	$1.14\cdot10^{-17}$
Tc-95	$1.63\cdot10^{-17}$	$1.36\cdot10^{-17}$
Y-95	$3.90\cdot10^{-17}$	$1.52\cdot10^{-17}$
Zr-95	$1.54\cdot10^{-17}$	$1.28\cdot10^{-17}$
Nb-96	$5.11\cdot10^{-17}$	$4.26\cdot10^{-17}$
Tc-96m	$9.38\cdot10^{-19}$	$7.71\cdot10^{-19}$
Tc-96	$5.16\cdot10^{-17}$	$4.30\cdot10^{-17}$
Nb-97m	$1.52\cdot10^{-17}$	$1.26\cdot10^{-17}$
Nb-97	$1.57\cdot10^{-17}$	$1.14\cdot10^{-17}$
Ru-97	$4.73\cdot10^{-18}$	$3.83\cdot10^{-18}$
Tc-97m	$3.51\cdot10^{-20}$	$7.18\cdot10^{-21}$
Tc-97	$3.44\cdot10^{-20}$	$3.02\cdot10^{-21}$
Zr-97	$9.34\cdot10^{-18}$	$3.17\cdot10^{-18}$
Nb-98	$5.85\cdot10^{-17}$	$4.18\cdot10^{-17}$
Tc-98	$2.95\cdot10^{-17}$	$2.45\cdot10^{-17}$
Mo-99	$4.45\cdot10^{-18}$	$2.58\cdot10^{-18}$
Rh-99m	$1.40\cdot10^{-17}$	$1.16\cdot10^{-17}$
Rh-99	$1.22\cdot10^{-17}$	$9.99\cdot10^{-18}$
Tc-99m	$2.38\cdot10^{-18}$	$1.95\cdot10^{-18}$
Tc-99	$7.94\cdot10^{-22}$	$4.94\cdot10^{-22}$
Pd-100	$1.71\cdot10^{-18}$	$1.29\cdot10^{-18}$
Rh-100	$5.49\cdot10^{-17}$	$4.64\cdot10^{-17}$
Mo-101	$3.16\cdot10^{-17}$	$2.33\cdot10^{-17}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Pd-101	$6.60\cdot10^{-18}$	$5.39\cdot10^{-18}$
Rh-101m	$6.22\cdot10^{-18}$	$5.05\cdot10^{-18}$
Rh-101	$5.09\cdot10^{-18}$	$4.12\cdot10^{-18}$
Tc-101	$9.09\cdot10^{-18}$	$5.78\cdot10^{-18}$
Ag-102	$7.72\cdot10^{-17}$	$5.73\cdot10^{-17}$
Rh-102m	$1.08\cdot10^{-17}$	$8.28\cdot10^{-18}$
Rh-102	$4.42\cdot10^{-17}$	$3.67\cdot10^{-17}$
Ag-103	$1.72\cdot10^{-17}$	$1.29\cdot10^{-17}$
Pd-103	$5.50\cdot10^{-20}$	$8.91\cdot10^{-21}$
Rh-103m	$6.22\cdot10^{-21}$	$9.09\cdot10^{-22}$
Ru-103	$9.87\cdot10^{-18}$	$8.12\cdot10^{-18}$
Ag-104m	$2.98\cdot10^{-17}$	$2.01\cdot10^{-17}$
Ag-104	$5.52\cdot10^{-17}$	$4.59\cdot10^{-17}$
Cd-104	$4.80\cdot10^{-18}$	$3.90\cdot10^{-18}$
Tc-104	$6.22\cdot10^{-17}$	$3.40\cdot10^{-17}$
Ag-105	$1.07\cdot10^{-17}$	$8.72\cdot10^{-18}$
Rh-105	$1.65\cdot10^{-18}$	$1.34\cdot10^{-18}$
Ru-105	$1.76\cdot10^{-17}$	$1.36\cdot10^{-17}$
Ag-106m	$5.77\cdot10^{-17}$	$4.83\cdot10^{-17}$
Ag-106	$1.93\cdot10^{-17}$	$1.23\cdot10^{-17}$
Rh-106m	$6.01\cdot10^{-17}$	$5.01\cdot10^{-17}$
Rh-106	$2.36\cdot10^{-17}$	$3.91\cdot10^{-18}$
Ru-106	0.00	0.00
Cd-107	$2.78\cdot10^{-19}$	$1.62\cdot10^{-19}$
Rh-107	$8.30\cdot10^{-18}$	$5.40\cdot10^{-18}$
Pd-107	0.00	0.00
Ag-108m	$3.38\cdot10^{-17}$	$2.79\cdot10^{-17}$
Ag-108	$4.49\cdot10^{-18}$	$3.77\cdot10^{-19}$
Ag-109m	$8.32\cdot10^{-20}$	$4.61\cdot10^{-20}$
Cd-109	$1.46\cdot10^{-19}$	$5.67\cdot10^{-20}$
In-109	$1.35\cdot10^{-17}$	$1.12\cdot10^{-17}$
Pd-109	$9.38\cdot10^{-19}$	$7.58\cdot10^{-20}$
Ag-110m	$5.64\cdot10^{-17}$	$4.73\cdot10^{-17}$
Ag-110	$1.52\cdot10^{-17}$	$7.96\cdot10^{-19}$
In-110b	$6.27\cdot10^{-17}$	$5.23\cdot10^{-17}$
In-110a	$3.85\cdot10^{-17}$	$2.67\cdot10^{-17}$
Sn-110	$6.03\cdot10^{-18}$	$4.87\cdot10^{-18}$
Ag-111	$1.36\cdot10^{-18}$	$4.71\cdot10^{-19}$
In-111	$7.98\cdot10^{-18}$	$6.45\cdot10^{-18}$
Sn-111	$1.17\cdot10^{-17}$	$8.58\cdot10^{-18}$
Ag-112	$3.22\cdot10^{-17}$	$1.16\cdot10^{-17}$
In-112	$6.56\cdot10^{-18}$	$4.56\cdot10^{-18}$
Cd-113m	$1.72\cdot10^{-20}$	$2.54\cdot10^{-21}$
Cd-113	$7.14\cdot10^{-22}$	$4.45\cdot10^{-22}$
In-113m	$5.34\cdot10^{-18}$	$4.36\cdot10^{-18}$
Sn-113	$1.81\cdot10^{-19}$	$9.77\cdot10^{-20}$
In-114m	$1.81\cdot10^{-18}$	$1.46\cdot10^{-18}$
In-114	$5.58\cdot10^{-20}$	$4.68\cdot10^{-20}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Ag-115	$2.62\cdot10^{-17}$	$1.21\cdot10^{-17}$
Cd-115m	$4.44\cdot10^{-18}$	$4.48\cdot10^{-19}$
Cd-115	$5.53\cdot10^{-18}$	$4.03\cdot10^{-18}$
In-115m	$3.28\cdot10^{-18}$	$2.65\cdot10^{-18}$
In-115	$3.09\cdot10^{-21}$	$1.52\cdot10^{-21}$
Sb-115	$2.04\cdot10^{-17}$	$1.56\cdot10^{-17}$
In-116m	$4.99\cdot10^{-17}$	$4.21\cdot10^{-17}$
Sb-116m	$6.38\cdot10^{-17}$	$5.33\cdot10^{-17}$
Sb-116	$4.72\cdot10^{-17}$	$3.67\cdot10^{-17}$
Te-116	$9.18\cdot10^{-19}$	$6.64\cdot10^{-19}$
Cd-117m	$4.07\cdot10^{-17}$	$3.45\cdot10^{-17}$
Cd-117	$2.48\cdot10^{-17}$	$1.86\cdot10^{-17}$
In-117m	$4.30\cdot10^{-18}$	$1.50\cdot10^{-18}$
In-117	$1.45\cdot10^{-17}$	$1.18\cdot10^{-17}$
Sb-117	$3.33\cdot10^{-18}$	$2.67\cdot10^{-18}$
Sn-117m	$2.83\cdot10^{-18}$	$2.26\cdot10^{-18}$
Sb-118m	$5.17\cdot10^{-17}$	$4.35\cdot10^{-17}$
In-119m	$1.21\cdot10^{-17}$	$3.38\cdot10^{-19}$
In-119	$2.00\cdot10^{-17}$	$1.33\cdot10^{-17}$
Sb-119	$1.08\cdot10^{-19}$	$2.41\cdot10^{-20}$
Sn-119m	$5.18\cdot10^{-20}$	$1.13\cdot10^{-20}$
I-120m	$1.24\cdot10^{-16}$	$9.05\cdot10^{-17}$
I-120	$7.52\cdot10^{-17}$	$4.65\cdot10^{-17}$
Sb-120b	$4.94\cdot10^{-17}$	$4.15\cdot10^{-17}$
Sb-120a	$1.16\cdot10^{-17}$	$7.69\cdot10^{-18}$
Xe-120	$8.29\cdot10^{-18}$	$6.72\cdot10^{-18}$
I-121	$8.62\cdot10^{-18}$	$6.84\cdot10^{-18}$
Sn-121m	$2.61\cdot10^{-20}$	$7.64\cdot10^{-21}$
Sn-121	$1.16\cdot10^{-21}$	$7.58\cdot10^{-22}$
Te-121m	$4.22\cdot10^{-18}$	$3.41\cdot10^{-18}$
Te-121	$1.18\cdot10^{-17}$	$9.68\cdot10^{-18}$
Xe-121	$4.22\cdot10^{-17}$	$3.04\cdot10^{-17}$
I-122	$3.36\cdot10^{-17}$	$1.66\cdot10^{-17}$
Sb-122	$1.29\cdot10^{-17}$	$7.70\cdot10^{-18}$
Xe-122	$1.07\cdot10^{-18}$	$8.05\cdot10^{-19}$
I-123	$3.04\cdot10^{-18}$	$2.41\cdot10^{-18}$
Sn-123m	$4.54\cdot10^{-18}$	$2.23\cdot10^{-18}$
Sn-123	$2.99\cdot10^{-18}$	$1.69\cdot10^{-19}$
Te-123m	$2.70\cdot10^{-18}$	$2.16\cdot10^{-18}$
Te-123	$9.89\cdot10^{-20}$	$2.49\cdot10^{-20}$
Xe-123	$1.35\cdot10^{-17}$	$1.04\cdot10^{-17}$
I-124	$2.38\cdot10^{-17}$	$1.86\cdot10^{-17}$
Sb-124n	$3.50\cdot10^{-22}$	$7.38\cdot10^{-23}$
Sb-124m	$7.65\cdot10^{-18}$	$6.10\cdot10^{-18}$
Sb-124	$3.89\cdot10^{-17}$	$3.10\cdot10^{-17}$
Cs-125	$1.70\cdot10^{-17}$	$1.15\cdot10^{-17}$
I-125	$2.24\cdot10^{-19}$	$6.36\cdot10^{-20}$
Sb-125	$8.82\cdot10^{-18}$	$7.21\cdot10^{-18}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Sn-125	$1.47\cdot10^{-17}$	$5.49\cdot10^{-18}$
Te-125m	$1.94\cdot10^{-19}$	$5.81\cdot10^{-20}$
Xe-125	$5.09\cdot10^{-18}$	$4.07\cdot10^{-18}$
Ba-126	$3.06\cdot10^{-18}$	$2.44\cdot10^{-18}$
Cs-126	$4.43\cdot10^{-17}$	$1.92\cdot10^{-17}$
I-126	$9.69\cdot10^{-18}$	$7.70\cdot10^{-18}$
Sb-126m	$3.68\cdot10^{-17}$	$2.69\cdot10^{-17}$
Sb-126	$6.02\cdot10^{-17}$	$4.90\cdot10^{-17}$
Sn-126	$7.67\cdot10^{-19}$	$5.82\cdot10^{-19}$
Cs-127	$8.44\cdot10^{-18}$	$6.85\cdot10^{-18}$
Sb-127	$1.50\cdot10^{-17}$	$1.19\cdot10^{-17}$
Sn-127	$4.28\cdot10^{-17}$	$3.26\cdot10^{-17}$
Te-127m	$6.64\cdot10^{-20}$	$2.06\cdot10^{-20}$
Te-127	$1.81\cdot10^{-19}$	$8.80\cdot10^{-20}$
Xe-127	$5.34\cdot10^{-18}$	$4.28\cdot10^{-18}$
Ba-128	$1.23\cdot10^{-18}$	$9.36\cdot10^{-19}$
Cs-128	$2.92\cdot10^{-17}$	$1.57\cdot10^{-17}$
I-128	$8.51\cdot10^{-18}$	$1.57\cdot10^{-18}$
Sb-128b	$6.64\cdot10^{-17}$	$5.35\cdot10^{-17}$
Sb-128a	$5.08\cdot10^{-17}$	$3.45\cdot10^{-17}$
Sn-128	$1.30\cdot10^{-17}$	$1.06\cdot10^{-17}$
Cs-129	$5.42\cdot10^{-18}$	$4.35\cdot10^{-18}$
I-129	$1.48\cdot10^{-19}$	$5.11\cdot10^{-20}$
Sb-129	$3.15\cdot10^{-17}$	$2.47\cdot10^{-17}$
Te-129m	$1.96\cdot10^{-18}$	$5.44\cdot10^{-19}$
Te-129	$3.95\cdot10^{-18}$	$1.00\cdot10^{-18}$
Xe-129m	$4.32\cdot10^{-19}$	$2.33\cdot10^{-19}$
Cs-130	$1.44\cdot10^{-17}$	$8.81\cdot10^{-18}$
I-130	$4.52\cdot10^{-17}$	$3.70\cdot10^{-17}$
Sb-130	$7.32\cdot10^{-17}$	$5.61\cdot10^{-17}$
Ba-131m	$1.16\cdot10^{-18}$	$9.03\cdot10^{-19}$
Ba-131	$9.05\cdot10^{-18}$	$7.35\cdot10^{-18}$
Cs-131	$1.31\cdot10^{-19}$	$4.20\cdot10^{-20}$
I-131	$8.03\cdot10^{-18}$	$6.56\cdot10^{-18}$
La-131	$1.49\cdot10^{-17}$	$1.11\cdot10^{-17}$
Sb-131	$4.15\cdot10^{-17}$	$3.18\cdot10^{-17}$
Te-131m	$2.95\cdot10^{-17}$	$2.43\cdot10^{-17}$
Te-131	$1.42\cdot10^{-17}$	$7.14\cdot10^{-18}$
Xe-131m	$1.58\cdot10^{-19}$	$8.13\cdot10^{-20}$
Cs-132	$1.44\cdot10^{-17}$	$1.19\cdot10^{-17}$
I-132m	$6.88\cdot10^{-18}$	$5.40\cdot10^{-18}$
I-132	$4.99\cdot10^{-17}$	$3.94\cdot10^{-17}$
La-132	$4.69\cdot10^{-17}$	$3.41\cdot10^{-17}$
Te-132	$4.43\cdot10^{-18}$	$3.54\cdot10^{-18}$
Ba-133m	$1.13\cdot10^{-18}$	$8.70\cdot10^{-19}$
Ba-133	$7.71\cdot10^{-18}$	$6.18\cdot10^{-18}$
I-133	$1.42\cdot10^{-17}$	$1.05\cdot10^{-17}$
Te-133m	$5.26\cdot10^{-17}$	$3.96\cdot10^{-17}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Te-133	$2.67 \cdot 10^{-17}$	$1.61 \cdot 10^{-17}$
Xe-133m	$5.84 \cdot 10^{-19}$	$4.26 \cdot 10^{-19}$
Xe-133	$5.59 \cdot 10^{-19}$	$4.00 \cdot 10^{-19}$
Ce-134	$1.72 \cdot 10^{-19}$	$6.73 \cdot 10^{-20}$
Cs-134m	$3.57 \cdot 10^{-19}$	$2.64 \cdot 10^{-19}$
Cs-134	$3.24 \cdot 10^{-17}$	$2.69 \cdot 10^{-17}$
I-134	$5.80 \cdot 10^{-17}$	$4.52 \cdot 10^{-17}$
La-134	$2.34 \cdot 10^{-17}$	$1.21 \cdot 10^{-17}$
Te-134	$1.84 \cdot 10^{-17}$	$1.50 \cdot 10^{-17}$
Ba-135m	$9.93 \cdot 10^{-19}$	$7.60 \cdot 10^{-19}$
Ce-135	$3.74 \cdot 10^{-17}$	$3.07 \cdot 10^{-17}$
Cs-135m	$3.30 \cdot 10^{-17}$	$2.74 \cdot 10^{-17}$
Cs-135	$2.87 \cdot 10^{-22}$	$1.55 \cdot 10^{-22}$
I-135	$3.27 \cdot 10^{-17}$	$2.68 \cdot 10^{-17}$
La-135	$3.76 \cdot 10^{-19}$	$2.37 \cdot 10^{-19}$
Xe-135m	$9.07 \cdot 10^{-18}$	$7.37 \cdot 10^{-18}$
Xe-135	$5.60 \cdot 10^{-18}$	$4.23 \cdot 10^{-18}$
Cs-136	$4.42 \cdot 10^{-17}$	$3.70 \cdot 10^{-17}$
Nd-136	$5.38 \cdot 10^{-18}$	$4.25 \cdot 10^{-18}$
Pr-136	$5.22 \cdot 10^{-17}$	$3.60 \cdot 10^{-17}$
Ba-137m	$1.27 \cdot 10^{-17}$	$1.03 \cdot 10^{-17}$
Ce-137m	$8.22 \cdot 10^{-19}$	$6.18 \cdot 10^{-19}$
Ce-137	$3.51 \cdot 10^{-19}$	$2.14 \cdot 10^{-19}$
Cs-137	$9.23 \cdot 10^{-20}$	$3.62 \cdot 10^{-21}$
La-137	$1.52 \cdot 10^{-19}$	$5.59 \cdot 10^{-20}$
Pr-137	$1.16 \cdot 10^{-17}$	$8.37 \cdot 10^{-18}$
Cs-138	$6.15 \cdot 10^{-17}$	$4.02 \cdot 10^{-17}$
La-138	$2.45 \cdot 10^{-17}$	$2.09 \cdot 10^{-17}$
Nd-138	$5.01 \cdot 10^{-19}$	$3.31 \cdot 10^{-19}$
Pr-138m	$5.20 \cdot 10^{-17}$	$4.23 \cdot 10^{-17}$
Pr-138	$3.32 \cdot 10^{-17}$	$1.43 \cdot 10^{-17}$
Xe-138	$2.81 \cdot 10^{-17}$	$1.90 \cdot 10^{-17}$
Ba-139	$9.72 \cdot 10^{-18}$	$8.29 \cdot 10^{-19}$
Ce-139	$2.78 \cdot 10^{-18}$	$2.19 \cdot 10^{-18}$
Nd-139m	$3.20 \cdot 10^{-17}$	$2.64 \cdot 10^{-17}$
Nd-139	$9.73 \cdot 10^{-18}$	$6.72 \cdot 10^{-18}$
Pr-139	$2.32 \cdot 10^{-18}$	$1.74 \cdot 10^{-18}$
Ba-140	$4.23 \cdot 10^{-18}$	$3.07 \cdot 10^{-18}$
La-140	$4.89 \cdot 10^{-17}$	$3.93 \cdot 10^{-17}$
Ba-141	$2.62 \cdot 10^{-17}$	$1.45 \cdot 10^{-17}$
Ce-141	$1.39 \cdot 10^{-18}$	$1.12 \cdot 10^{-18}$
La-141	$1.09 \cdot 10^{-17}$	$9.09 \cdot 10^{-19}$
Nd-141m	$1.61 \cdot 10^{-17}$	$1.31 \cdot 10^{-17}$
Nd-141	$1.18 \cdot 10^{-18}$	$8.98 \cdot 10^{-19}$
Pm-141	$2.29 \cdot 10^{-17}$	$1.28 \cdot 10^{-17}$
Sm-141m	$4.46 \cdot 10^{-17}$	$3.37 \cdot 10^{-17}$
Sm-141	$3.77 \cdot 10^{-17}$	$2.41 \cdot 10^{-17}$
Ba-142	$2.29 \cdot 10^{-17}$	$1.78 \cdot 10^{-17}$
La-142	$6.11 \cdot 10^{-17}$	$4.59 \cdot 10^{-17}$
Pm-142	$3.83 \cdot 10^{-17}$	$1.53 \cdot 10^{-17}$
Pr-142m	0.00	0.00
Pr-142	$8.94 \cdot 10^{-18}$	$1.12 \cdot 10^{-18}$
Sm-142	$1.67 \cdot 10^{-18}$	$1.23 \cdot 10^{-18}$
Ce-143	$6.97 \cdot 10^{-18}$	$4.50 \cdot 10^{-18}$
La-143	$1.94 \cdot 10^{-17}$	$1.92 \cdot 10^{-18}$
Pm-143	$6.17 \cdot 10^{-18}$	$5.04 \cdot 10^{-18}$
Pr-143	$5.06 \cdot 10^{-19}$	$1.28 \cdot 10^{-20}$
Ce-144	$3.33 \cdot 10^{-19}$	$2.61 \cdot 10^{-19}$
Pm-144	$3.23 \cdot 10^{-17}$	$2.67 \cdot 10^{-17}$
Pr-144m	$1.03 \cdot 10^{-19}$	$5.18 \cdot 10^{-20}$
Pr-144	$1.58 \cdot 10^{-17}$	$8.17 \cdot 10^{-19}$
Eu-145	$2.91 \cdot 10^{-17}$	$2.44 \cdot 10^{-17}$
Gd-145	$5.08 \cdot 10^{-17}$	$3.80 \cdot 10^{-17}$
Pm-145	$2.44 \cdot 10^{-19}$	$1.21 \cdot 10^{-19}$
Pr-145	$5.41 \cdot 10^{-18}$	$3.12 \cdot 10^{-19}$
Sm-145	$5.42 \cdot 10^{-19}$	$2.85 \cdot 10^{-19}$
Eu-146	$5.12 \cdot 10^{-17}$	$4.27 \cdot 10^{-17}$
Gd-146	$3.82 \cdot 10^{-18}$	$2.93 \cdot 10^{-18}$
Pm-146	$1.56 \cdot 10^{-17}$	$1.28 \cdot 10^{-17}$
Sm-146	0.00	0.00
Eu-147	$9.63 \cdot 10^{-18}$	$7.90 \cdot 10^{-18}$
Gd-147	$2.71 \cdot 10^{-17}$	$2.25 \cdot 10^{-17}$
Nd-147	$2.76 \cdot 10^{-18}$	$2.08 \cdot 10^{-18}$
Pm-147	$3.30 \cdot 10^{-22}$	$1.96 \cdot 10^{-22}$
Pr-147	$2.39 \cdot 10^{-17}$	$1.44 \cdot 10^{-17}$
Sm-147	0.00	0.00
Tb-147	$3.94 \cdot 10^{-17}$	$2.71 \cdot 10^{-17}$
Eu-148	$4.47 \cdot 10^{-17}$	$3.71 \cdot 10^{-17}$
Gd-148	0.00	0.00
Pm-148m	$4.17 \cdot 10^{-17}$	$3.45 \cdot 10^{-17}$
Pm-148	$1.81 \cdot 10^{-17}$	$9.94 \cdot 10^{-18}$
Eu-149	$9.06 \cdot 10^{-19}$	$6.59 \cdot 10^{-19}$
Gd-149	$8.14 \cdot 10^{-18}$	$6.59 \cdot 10^{-18}$
Nd-149	$9.74 \cdot 10^{-18}$	$6.34 \cdot 10^{-18}$
Pm-149	$1.15 \cdot 10^{-18}$	$2.02 \cdot 10^{-19}$
Tb-149	$3.38 \cdot 10^{-17}$	$2.72 \cdot 10^{-17}$
Eu-150b	$3.09 \cdot 10^{-17}$	$2.54 \cdot 10^{-17}$
Eu-150a	$1.61 \cdot 10^{-18}$	$7.76 \cdot 10^{-19}$
Pm-150	$3.58 \cdot 10^{-17}$	$2.45 \cdot 10^{-17}$
Tb-150	$4.10 \cdot 10^{-17}$	$2.87 \cdot 10^{-17}$
Gd-151	$8.52 \cdot 10^{-19}$	$6.08 \cdot 10^{-19}$
Nd-151	$2.29 \cdot 10^{-17}$	$1.55 \cdot 10^{-17}$
Pm-151	$6.95 \cdot 10^{-18}$	$5.30 \cdot 10^{-18}$
Sm-151	$2.46 \cdot 10^{-23}$	$3.62 \cdot 10^{-24}$
Tb-151	$1.79 \cdot 10^{-17}$	$1.46 \cdot 10^{-17}$
Eu-152m	$9.77 \cdot 10^{-18}$	$4.95 \cdot 10^{-18}$
Eu-152	$2.31 \cdot 10^{-17}$	$1.93 \cdot 10^{-17}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Gd-152	0.00	0.00
Gd-153	$1.33 \cdot 10^{-18}$	$9.54 \cdot 10^{-19}$
Sm-153	$9.29 \cdot 10^{-19}$	$6.08 \cdot 10^{-19}$
Tb-153	$4.03 \cdot 10^{-18}$	$3.20 \cdot 10^{-18}$
Eu-154	$2.58 \cdot 10^{-17}$	$2.10 \cdot 10^{-17}$
Tb-154	$4.51 \cdot 10^{-17}$	$3.88 \cdot 10^{-17}$
Dy-155	$1.14 \cdot 10^{-17}$	$9.39 \cdot 10^{-18}$
Eu-155	$9.06 \cdot 10^{-19}$	$7.06 \cdot 10^{-19}$
Ho-155	$9.53 \cdot 10^{-18}$	$6.25 \cdot 10^{-18}$
Sm-155	$4.93 \cdot 10^{-18}$	$1.48 \cdot 10^{-18}$
Tb-155	$2.16 \cdot 10^{-18}$	$1.65 \cdot 10^{-18}$
Eu-156	$2.93 \cdot 10^{-17}$	$2.25 \cdot 10^{-17}$
Sm-156	$2.28 \cdot 10^{-18}$	$1.80 \cdot 10^{-18}$
Tb-156m	$2.51 \cdot 10^{-19}$	$1.55 \cdot 10^{-19}$
Tb-156n	$3.96 \cdot 10^{-20}$	$2.63 \cdot 10^{-20}$
Tb-156	$3.64 \cdot 10^{-17}$	$3.05 \cdot 10^{-17}$
Dy-157	$7.05 \cdot 10^{-18}$	$5.68 \cdot 10^{-18}$
Eu-157	$6.10 \cdot 10^{-18}$	$4.02 \cdot 10^{-18}$
Ho-157	$9.49 \cdot 10^{-18}$	$7.58 \cdot 10^{-18}$
Tb-157	$2.23 \cdot 10^{-20}$	$1.22 \cdot 10^{-20}$
Eu-158	$3.11 \cdot 10^{-17}$	$1.81 \cdot 10^{-17}$
Tb-158	$1.59 \cdot 10^{-17}$	$1.32 \cdot 10^{-17}$
Dy-159	$4.09 \cdot 10^{-19}$	$2.35 \cdot 10^{-19}$
Gd-159	$1.38 \cdot 10^{-18}$	$7.53 \cdot 10^{-19}$
Ho-159	$6.51 \cdot 10^{-18}$	$5.19 \cdot 10^{-18}$
Tb-160	$2.29 \cdot 10^{-17}$	$1.91 \cdot 10^{-17}$
Er-161	$1.83 \cdot 10^{-17}$	$1.52 \cdot 10^{-17}$
Ho-161	$5.95 \cdot 10^{-19}$	$3.67 \cdot 10^{-19}$
Tb-161	$3.53 \cdot 10^{-19}$	$2.25 \cdot 10^{-19}$
Ho-162m	$1.11 \cdot 10^{-17}$	$9.19 \cdot 10^{-18}$
Ho-162	$2.98 \cdot 10^{-18}$	$2.34 \cdot 10^{-18}$
Tm-162	$3.86 \cdot 10^{-17}$	$2.96 \cdot 10^{-17}$
Yb-162	$2.18 \cdot 10^{-18}$	$1.69 \cdot 10^{-18}$
Ho-164m	$4.32 \cdot 10^{-19}$	$2.61 \cdot 10^{-19}$
Ho-164	$5.05 \cdot 10^{-19}$	$1.92 \cdot 10^{-19}$
Dy-165	$2.26 \cdot 10^{-18}$	$4.16 \cdot 10^{-19}$
Er-165	$3.62 \cdot 10^{-19}$	$2.20 \cdot 10^{-19}$
Dy-166	$4.94 \cdot 10^{-19}$	$3.49 \cdot 10^{-19}$
Ho-166m	$3.59 \cdot 10^{-17}$	$2.98 \cdot 10^{-17}$
Ho-166	$5.66 \cdot 10^{-18}$	$4.97 \cdot 10^{-19}$
Tm-166	$3.69 \cdot 10^{-17}$	$3.11 \cdot 10^{-17}$
Yb-166	$9.43 \cdot 10^{-19}$	$6.35 \cdot 10^{-19}$
Ho-167	$7.69 \cdot 10^{-18}$	$6.14 \cdot 10^{-18}$
Tm-167	$2.44 \cdot 10^{-18}$	$1.89 \cdot 10^{-18}$
Yb-167	$4.11 \cdot 10^{-18}$	$3.18 \cdot 10^{-18}$
Er-169	$8.53 \cdot 10^{-22}$	$5.43 \cdot 10^{-22}$
Lu-169	$2.03 \cdot 10^{-17}$	$1.70 \cdot 10^{-17}$
Yb-169	$5.02 \cdot 10^{-18}$	$3.89 \cdot 10^{-18}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Hf-170	$1.06 \cdot 10^{-17}$	$8.57 \cdot 10^{-18}$
Lu-170	$4.79 \cdot 10^{-17}$	$4.10 \cdot 10^{-17}$
Tm-170	$6.24 \cdot 10^{-19}$	$6.50 \cdot 10^{-20}$
Er-171	$8.55 \cdot 10^{-18}$	$6.21 \cdot 10^{-18}$
Lu-171	$1.36 \cdot 10^{-17}$	$1.12 \cdot 10^{-17}$
Tm-171	$7.02 \cdot 10^{-21}$	$4.75 \cdot 10^{-21}$
Er-172	$1.07 \cdot 10^{-17}$	$8.79 \cdot 10^{-18}$
Hf-172	$1.40 \cdot 10^{-18}$	$1.00 \cdot 10^{-18}$
Lu-172	$3.78 \cdot 10^{-17}$	$3.16 \cdot 10^{-17}$
Ta-172	$3.56 \cdot 10^{-17}$	$2.60 \cdot 10^{-17}$
Tm-172	$1.29 \cdot 10^{-17}$	$8.07 \cdot 10^{-18}$
Hf-173	$7.59 \cdot 10^{-18}$	$6.13 \cdot 10^{-18}$
Lu-173	$1.94 \cdot 10^{-18}$	$1.46 \cdot 10^{-18}$
Ta-173	$1.45 \cdot 10^{-17}$	$9.38 \cdot 10^{-18}$
Tm-173	$8.59 \cdot 10^{-18}$	$6.67 \cdot 10^{-18}$
Lu-174m	$7.57 \cdot 10^{-19}$	$5.42 \cdot 10^{-19}$
Lu-174	$2.06 \cdot 10^{-18}$	$1.65 \cdot 10^{-18}$
Ta-174	$1.54 \cdot 10^{-17}$	$1.02 \cdot 10^{-17}$
Hf-175	$7.25 \cdot 10^{-18}$	$5.85 \cdot 10^{-18}$
Ta-175	$1.80 \cdot 10^{-17}$	$1.51 \cdot 10^{-17}$
Tm-175	$2.39 \cdot 10^{-17}$	$1.81 \cdot 10^{-17}$
Yb-175	$8.07 \cdot 10^{-19}$	$6.57 \cdot 10^{-19}$
Lu-176m	$1.90 \cdot 10^{-18}$	$1.78 \cdot 10^{-19}$
Lu-176	$9.98 \cdot 10^{-18}$	$8.11 \cdot 10^{-18}$
Ta-176	$4.20 \cdot 10^{-17}$	$3.56 \cdot 10^{-17}$
W-176	$2.47 \cdot 10^{-18}$	$1.89 \cdot 10^{-18}$
Hf-177m	$4.56 \cdot 10^{-17}$	$3.71 \cdot 10^{-17}$
Lu-177m	$1.99 \cdot 10^{-17}$	$1.61 \cdot 10^{-17}$
Lu-177	$6.68 \cdot 10^{-19}$	$5.39 \cdot 10^{-19}$
Re-177	$1.47 \cdot 10^{-17}$	$9.90 \cdot 10^{-18}$
Ta-177	$8.91 \cdot 10^{-19}$	$6.60 \cdot 10^{-19}$
W-177	$1.76 \cdot 10^{-17}$	$1.44 \cdot 10^{-17}$
Yb-177	$5.60 \cdot 10^{-18}$	$3.14 \cdot 10^{-18}$
Hf-178m	$4.85 \cdot 10^{-17}$	$3.97 \cdot 10^{-17}$
Lu-178m	$2.42 \cdot 10^{-17}$	$1.84 \cdot 10^{-17}$
Lu-178	$9.38 \cdot 10^{-18}$	$2.42 \cdot 10^{-18}$
Re-178	$3.01 \cdot 10^{-17}$	$2.01 \cdot 10^{-17}$
Ta-178b	$2.03 \cdot 10^{-17}$	$1.64 \cdot 10^{-17}$
Ta-178a	$1.70 \cdot 10^{-18}$	$1.35 \cdot 10^{-18}$
W-178	$1.52 \cdot 10^{-19}$	$1.06 \cdot 10^{-19}$
Yb-178	$7.64 \cdot 10^{-19}$	$6.00 \cdot 10^{-19}$
Hf-179m	$1.81 \cdot 10^{-17}$	$1.47 \cdot 10^{-17}$
Lu-179	$2.64 \cdot 10^{-18}$	$5.48 \cdot 10^{-19}$
Ta-179	$3.56 \cdot 10^{-19}$	$2.45 \cdot 10^{-19}$
W-179	$6.13 \cdot 10^{-19}$	$4.06 \cdot 10^{-19}$
Hf-180m	$2.05 \cdot 10^{-17}$	$1.67 \cdot 10^{-17}$
Os-180	$8.23 \cdot 10^{-19}$	$6.04 \cdot 10^{-19}$
Re-180	$2.44 \cdot 10^{-17}$	$1.98 \cdot 10^{-17}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Ta-180m	$5.75 \cdot 10^{-19}$	$4.00 \cdot 10^{-19}$
Ta-180	$1.11 \cdot 10^{-17}$	$8.97 \cdot 10^{-18}$
Hf-181	$1.13 \cdot 10^{-17}$	$9.29 \cdot 10^{-18}$
Os-181	$2.43 \cdot 10^{-17}$	$2.02 \cdot 10^{-17}$
Re-181	$1.53 \cdot 10^{-17}$	$1.26 \cdot 10^{-17}$
W-181	$4.61 \cdot 10^{-19}$	$3.24 \cdot 10^{-19}$
Hf-182m	$1.89 \cdot 10^{-17}$	$1.55 \cdot 10^{-17}$
Hf-182	$4.91 \cdot 10^{-18}$	$4.00 \cdot 10^{-18}$
Ir-182	$3.97 \cdot 10^{-17}$	$2.29 \cdot 10^{-17}$
Os-182	$8.53 \cdot 10^{-18}$	$6.93 \cdot 10^{-18}$
Re-182b	$3.70 \cdot 10^{-17}$	$3.09 \cdot 10^{-17}$
Re-182a	$2.30 \cdot 10^{-17}$	$1.93 \cdot 10^{-17}$
Ta-182m	$4.49 \cdot 10^{-18}$	$3.59 \cdot 10^{-18}$
Ta-182	$2.57 \cdot 10^{-17}$	$2.16 \cdot 10^{-17}$
Hf-183	$1.70 \cdot 10^{-17}$	$1.27 \cdot 10^{-17}$
Ta-183	$5.44 \cdot 10^{-18}$	$4.35 \cdot 10^{-18}$
Hf-184	$5.34 \cdot 10^{-18}$	$3.90 \cdot 10^{-18}$
Ir-184	$4.03 \cdot 10^{-17}$	$3.20 \cdot 10^{-17}$
Re-184m	$7.48 \cdot 10^{-18}$	$6.13 \cdot 10^{-18}$
Re-184	$1.78 \cdot 10^{-17}$	$1.48 \cdot 10^{-17}$
Ta-184	$3.44 \cdot 10^{-17}$	$2.75 \cdot 10^{-17}$
Ir-185	$1.12 \cdot 10^{-17}$	$9.44 \cdot 10^{-18}$
Os-185	$1.46 \cdot 10^{-17}$	$1.20 \cdot 10^{-17}$
Ta-185	$8.03 \cdot 10^{-18}$	$2.89 \cdot 10^{-18}$
W-185	$2.34 \cdot 10^{-21}$	$1.66 \cdot 10^{-21}$
Ir-186a	$3.28 \cdot 10^{-17}$	$2.74 \cdot 10^{-17}$
Ir-186b	$2.08 \cdot 10^{-17}$	$1.61 \cdot 10^{-17}$
Pt-186	$1.50 \cdot 10^{-17}$	$1.24 \cdot 10^{-17}$
Re-186m	$1.69 \cdot 10^{-19}$	$1.15 \cdot 10^{-19}$
Re-186	$1.12 \cdot 10^{-18}$	$2.92 \cdot 10^{-19}$
Ta-186	$4.13 \cdot 10^{-17}$	$2.67 \cdot 10^{-17}$
Ir-187	$6.96 \cdot 10^{-18}$	$5.69 \cdot 10^{-18}$
Re-187	0.00	0.00
W-187	$1.03 \cdot 10^{-17}$	$8.05 \cdot 10^{-18}$
Ir-188	$3.07 \cdot 10^{-17}$	$2.62 \cdot 10^{-17}$
Pt-188	$3.57 \cdot 10^{-18}$	$2.85 \cdot 10^{-18}$
Re-188m	$1.04 \cdot 10^{-18}$	$7.83 \cdot 10^{-19}$
Re-188	$7.88 \cdot 10^{-18}$	$1.05 \cdot 10^{-18}$
W-188	$3.88 \cdot 10^{-20}$	$3.13 \cdot 10^{-20}$
Ir-189	$1.19 \cdot 10^{-18}$	$9.09 \cdot 10^{-19}$
Os-189m	$5.34 \cdot 10^{-22}$	$9.45 \cdot 10^{-24}$
Pt-189	$6.00 \cdot 10^{-18}$	$4.87 \cdot 10^{-18}$
Re-189	$1.89 \cdot 10^{-18}$	$1.10 \cdot 10^{-18}$
Ir-190n	$3.20 \cdot 10^{-17}$	$2.63 \cdot 10^{-17}$
Ir-190m	$5.86 \cdot 10^{-22}$	$1.10 \cdot 10^{-23}$
Ir-190	$2.95 \cdot 10^{-17}$	$2.42 \cdot 10^{-17}$
Os-190m	$3.32 \cdot 10^{-17}$	$2.73 \cdot 10^{-17}$
Ir-191m	$1.11 \cdot 10^{-18}$	$8.75 \cdot 10^{-19}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Os-191m	$9.26 \cdot 10^{-20}$	$6.74 \cdot 10^{-20}$
Os-191	$1.18 \cdot 10^{-18}$	$9.21 \cdot 10^{-19}$
Pt-191	$5.46 \cdot 10^{-18}$	$4.38 \cdot 10^{-18}$
Ir-192m	$3.16 \cdot 10^{-18}$	$2.58 \cdot 10^{-18}$
Ir-192	$1.72 \cdot 10^{-17}$	$1.41 \cdot 10^{-17}$
Au-193	$2.67 \cdot 10^{-18}$	$2.11 \cdot 10^{-18}$
Hg-193m	$2.09 \cdot 10^{-17}$	$1.73 \cdot 10^{-17}$
Hg-193	$3.47 \cdot 10^{-18}$	$2.72 \cdot 10^{-18}$
Os-193	$2.30 \cdot 10^{-18}$	$1.17 \cdot 10^{-18}$
Pt-193m	$1.42 \cdot 10^{-19}$	$1.06 \cdot 10^{-19}$
Pt-193	$1.66 \cdot 10^{-21}$	$3.38 \cdot 10^{-23}$
Au-194	$2.11 \cdot 10^{-17}$	$1.77 \cdot 10^{-17}$
Hg-194	$2.32 \cdot 10^{-21}$	$5.71 \cdot 10^{-23}$
Ir-194m	$4.90 \cdot 10^{-17}$	$4.03 \cdot 10^{-17}$
Ir-194	$9.47 \cdot 10^{-18}$	$1.68 \cdot 10^{-18}$
Os-194	$9.62 \cdot 10^{-21}$	$4.92 \cdot 10^{-21}$
Tl-194m	$5.06 \cdot 10^{-17}$	$3.96 \cdot 10^{-17}$
Tl-194	$1.59 \cdot 10^{-17}$	$1.30 \cdot 10^{-17}$
Au-195m	$4.03 \cdot 10^{-18}$	$3.27 \cdot 10^{-18}$
Au-195	$1.11 \cdot 10^{-18}$	$8.45 \cdot 10^{-19}$
Hg-195m	$4.05 \cdot 10^{-18}$	$3.29 \cdot 10^{-18}$
Hg-195	$3.69 \cdot 10^{-18}$	$3.00 \cdot 10^{-18}$
Ir-195m	$8.42 \cdot 10^{-18}$	$6.67 \cdot 10^{-18}$
Ir-195	$1.49 \cdot 10^{-18}$	$6.48 \cdot 10^{-19}$
Pb-195m	$3.37 \cdot 10^{-17}$	$2.70 \cdot 10^{-17}$
Pt-195m	$9.94 \cdot 10^{-19}$	$7.59 \cdot 10^{-19}$
Tl-195	$2.52 \cdot 10^{-17}$	$2.11 \cdot 10^{-17}$
Hg-197m	$1.58 \cdot 10^{-18}$	$1.27 \cdot 10^{-18}$
Hg-197	$9.19 \cdot 10^{-19}$	$7.00 \cdot 10^{-19}$
Pt-197m	$1.41 \cdot 10^{-18}$	$1.11 \cdot 10^{-18}$
Pt-197	$4.18 \cdot 10^{-19}$	$3.01 \cdot 10^{-19}$
Tl-197	$7.93 \cdot 10^{-18}$	$6.49 \cdot 10^{-18}$
Au-198m	$1.10 \cdot 10^{-17}$	$8.91 \cdot 10^{-18}$
Au-198	$9.07 \cdot 10^{-18}$	$7.01 \cdot 10^{-18}$
Pb-198	$8.60 \cdot 10^{-18}$	$7.00 \cdot 10^{-18}$
Tl-198m	$2.46 \cdot 10^{-17}$	$2.02 \cdot 10^{-17}$
Tl-198	$3.96 \cdot 10^{-17}$	$3.36 \cdot 10^{-17}$
Au-199	$1.67 \cdot 10^{-18}$	$1.35 \cdot 10^{-18}$
Hg-199m	$3.40 \cdot 10^{-18}$	$2.74 \cdot 10^{-18}$
Pb-199	$2.94 \cdot 10^{-17}$	$2.47 \cdot 10^{-17}$
Pt-199	$7.09 \cdot 10^{-18}$	$3.50 \cdot 10^{-18}$
Tl-199	$4.65 \cdot 10^{-18}$	$3.76 \cdot 10^{-18}$
Au-200m	$4.34 \cdot 10^{-17}$	$3.58 \cdot 10^{-17}$
Au-200	$1.23 \cdot 10^{-17}$	$4.77 \cdot 10^{-18}$
Bi-200	$5.03 \cdot 10^{-17}$	$4.07 \cdot 10^{-17}$
Pb-200	$3.64 \cdot 10^{-18}$	$2.93 \cdot 10^{-18}$
Pt-200	$1.02 \cdot 10^{-18}$	$7.90 \cdot 10^{-19}$
Tl-200	$2.64 \cdot 10^{-17}$	$2.21 \cdot 10^{-17}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Au-201	$2.62\cdot10^{-18}$	$9.30\cdot10^{-19}$
Bi-201	$2.76\cdot10^{-17}$	$2.25\cdot10^{-17}$
Pb-201	$1.53\cdot10^{-17}$	$1.26\cdot10^{-17}$
Tl-201	$1.37\cdot10^{-18}$	$1.07\cdot10^{-18}$
Bi-202	$5.56\cdot10^{-17}$	$4.61\cdot10^{-17}$
Pb-202m	$4.23\cdot10^{-17}$	$3.52\cdot10^{-17}$
Pb-202	$2.07\cdot10^{-21}$	$3.93\cdot10^{-23}$
Tl-202	$9.40\cdot10^{-18}$	$7.67\cdot10^{-18}$
Bi-203	$4.74\cdot10^{-17}$	$4.01\cdot10^{-17}$
Hg-203	$4.92\cdot10^{-18}$	$4.01\cdot10^{-18}$
Pb-203	$6.04\cdot10^{-18}$	$4.89\cdot10^{-18}$
Po-203	$3.37\cdot10^{-17}$	$2.77\cdot10^{-17}$
Tl-204	$1.92\cdot10^{-19}$	$1.77\cdot10^{-20}$
Bi-205	$3.34\cdot10^{-17}$	$2.83\cdot10^{-17}$
Pb-205	$2.24\cdot10^{-21}$	$4.39\cdot10^{-23}$
Po-205	$3.18\cdot10^{-17}$	$2.66\cdot10^{-17}$
Bi-206	$6.65\cdot10^{-17}$	$5.57\cdot10^{-17}$
Tl-206	$3.03\cdot10^{-18}$	$5.59\cdot10^{-20}$
At-207	$2.65\cdot10^{-17}$	$2.22\cdot10^{-17}$
Bi-207	$3.21\cdot10^{-17}$	$2.61\cdot10^{-17}$
Po-207	$2.70\cdot10^{-17}$	$2.25\cdot10^{-17}$
Tl-207	$2.48\cdot10^{-18}$	$8.28\cdot10^{-20}$
Tl-208	$6.74\cdot10^{-17}$	$5.58\cdot10^{-17}$
Pb-209	$3.80\cdot10^{-20}$	$3.19\cdot10^{-21}$
Tl-209	$4.51\cdot10^{-17}$	$3.43\cdot10^{-17}$
Bi-210m	$5.32\cdot10^{-18}$	$4.34\cdot10^{-18}$
Bi-210	$1.20\cdot10^{-18}$	$2.43\cdot10^{-20}$
Pb-210	$2.22\cdot10^{-20}$	$1.05\cdot10^{-20}$
Po-210	$1.77\cdot10^{-22}$	$1.47\cdot10^{-22}$
At-211	$5.73\cdot10^{-19}$	$4.51\cdot10^{-19}$
Bi-211	$9.71\cdot10^{-19}$	$7.93\cdot10^{-19}$
Pb-211	$3.08\cdot10^{-18}$	$9.07\cdot10^{-19}$
Po-211	$1.63\cdot10^{-19}$	$1.35\cdot10^{-19}$
Bi-212	$7.85\cdot10^{-18}$	$3.23\cdot10^{-18}$
Pb-212	$2.88\cdot10^{-18}$	$2.34\cdot10^{-18}$
Po-212	0.00	0.00
Bi-213	$4.53\cdot10^{-18}$	$2.32\cdot10^{-18}$
Po-213	0.00	0.00
Bi-214	$3.53\cdot10^{-17}$	$2.57\cdot10^{-17}$
Pb-214	$5.23\cdot10^{-18}$	$4.18\cdot10^{-18}$
Po-214	$1.73\cdot10^{-21}$	$1.44\cdot10^{-21}$
At-215	$4.07\cdot10^{-21}$	$3.33\cdot10^{-21}$
Po-215	$3.71\cdot10^{-21}$	$3.05\cdot10^{-21}$
At-216	$2.25\cdot10^{-20}$	$1.78\cdot10^{-20}$
Po-216	$3.51\cdot10^{-22}$	$2.92\cdot10^{-22}$
At-217	$6.40\cdot10^{-21}$	$5.26\cdot10^{-21}$
At-218	$4.28\cdot10^{-20}$	$2.50\cdot10^{-20}$
Po-218	$1.89\cdot10^{-22}$	$1.57\cdot10^{-22}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Rn-218	$1.59\cdot10^{-20}$	$1.31\cdot10^{-20}$
Fr-219	$7.25\cdot10^{-20}$	$5.94\cdot10^{-20}$
Rn-219	$1.17\cdot10^{-18}$	$9.56\cdot10^{-19}$
Fr-220	$2.00\cdot10^{-19}$	$1.61\cdot10^{-19}$
Rn-220	$8.12\cdot10^{-21}$	$6.68\cdot10^{-21}$
Fr-221	$6.22\cdot10^{-19}$	$5.06\cdot10^{-19}$
Fr-222	$6.16\cdot10^{-18}$	$1.08\cdot10^{-19}$
Ra-222	$1.93\cdot10^{-19}$	$1.58\cdot10^{-19}$
Rn-222	$8.40\cdot10^{-21}$	$6.91\cdot10^{-21}$
Ac-223	$8.91\cdot10^{-20}$	$7.01\cdot10^{-20}$
Fr-223	$1.69\cdot10^{-18}$	$6.90\cdot10^{-19}$
Ra-223	$2.50\cdot10^{-18}$	$2.03\cdot10^{-18}$
Ac-224	$3.64\cdot10^{-18}$	$2.95\cdot10^{-18}$
Ra-224	$2.03\cdot10^{-19}$	$1.66\cdot10^{-19}$
Ac-225	$2.86\cdot10^{-19}$	$2.28\cdot10^{-19}$
Ra-225	$9.80\cdot10^{-20}$	$4.58\cdot10^{-20}$
Ac-226	$3.00\cdot10^{-18}$	$2.07\cdot10^{-18}$
Ra-226	$1.32\cdot10^{-19}$	$1.07\cdot10^{-19}$
Th-226	$1.46\cdot10^{-19}$	$1.17\cdot10^{-19}$
Ac-227	$2.45\cdot10^{-21}$	$1.80\cdot10^{-21}$
Pa-227	$3.16\cdot10^{-19}$	$2.47\cdot10^{-19}$
Ra-227	$4.34\cdot10^{-18}$	$2.62\cdot10^{-18}$
Th-227	$2.09\cdot10^{-18}$	$1.69\cdot10^{-18}$
Ac-228	$2.15\cdot10^{-17}$	$1.65\cdot10^{-17}$
Pa-228	$2.28\cdot10^{-17}$	$1.90\cdot10^{-17}$
Ra-228	0.00	0.00
Th-228	$3.81\cdot10^{-20}$	$2.85\cdot10^{-20}$
Th-229	$1.49\cdot10^{-18}$	$1.18\cdot10^{-18}$
Pa-230	$1.30\cdot10^{-17}$	$1.09\cdot10^{-17}$
Th-230	$8.32\cdot10^{-21}$	$4.62\cdot10^{-21}$
U-230	$2.38\cdot10^{-20}$	$1.56\cdot10^{-20}$
Pa-231	$7.69\cdot10^{-19}$	$6.02\cdot10^{-19}$
Th-231	$2.15\cdot10^{-19}$	$1.41\cdot10^{-19}$
U-231	$1.13\cdot10^{-18}$	$8.79\cdot10^{-19}$
Np-232	$2.44\cdot10^{-17}$	$2.02\cdot10^{-17}$
Pa-232	$1.92\cdot10^{-17}$	$1.60\cdot10^{-17}$
Th-232	$5.04\cdot10^{-21}$	$2.05\cdot10^{-21}$
U-232	$8.66\cdot10^{-21}$	$3.38\cdot10^{-21}$
Np-233	$1.49\cdot10^{-18}$	$1.20\cdot10^{-18}$
Pa-233	$4.02\cdot10^{-18}$	$3.27\cdot10^{-18}$
U-233	$8.26\cdot10^{-21}$	$4.81\cdot10^{-21}$
Np-234	$2.85\cdot10^{-17}$	$2.41\cdot10^{-17}$
Pa-234m	$8.02\cdot10^{-18}$	$3.33\cdot10^{-19}$
Pa-234	$3.93\cdot10^{-17}$	$3.24\cdot10^{-17}$
Pu-234	$1.09\cdot10^{-18}$	$8.73\cdot10^{-19}$
Th-234	$1.24\cdot10^{-19}$	$9.49\cdot10^{-20}$
U-234	$5.61\cdot10^{-21}$	$1.55\cdot10^{-21}$
Np-235	$3.02\cdot10^{-20}$	$1.23\cdot10^{-20}$

Radionuclide	Skin dose [Sv/(Bq s m^{-2})]	Effective dose [Sv/(Bq s m^{-2})]
Pu-235	$1.52\cdot10^{-18}$	$1.22\cdot10^{-18}$
U-235	$3.01\cdot10^{-18}$	$2.45\cdot10^{-18}$
Np-236a	$2.12\cdot10^{-18}$	$1.69\cdot10^{-18}$
Np-236b	$8.38\cdot10^{-19}$	$6.72\cdot10^{-19}$
Pu-236	$6.04\cdot10^{-21}$	$8.63\cdot10^{-22}$
U-236	$4.46\cdot10^{-21}$	$8.36\cdot10^{-22}$
Am-237	$7.21\cdot10^{-18}$	$5.88\cdot10^{-18}$
Np-237	$4.03\cdot10^{-19}$	$2.96\cdot10^{-19}$
Pu-237	$7.74\cdot10^{-19}$	$6.12\cdot10^{-19}$
U-237	$2.37\cdot10^{-18}$	$1.88\cdot10^{-18}$
Am-238	$1.79\cdot10^{-17}$	$1.49\cdot10^{-17}$
Cm-238	$1.26\cdot10^{-18}$	$1.01\cdot10^{-18}$
Np-238	$1.19\cdot10^{-17}$	$9.41\cdot10^{-18}$
Pu-238	$5.03\cdot10^{-21}$	$5.78\cdot10^{-22}$
U-238	$3.54\cdot10^{-21}$	$4.20\cdot10^{-22}$
Am-239	$4.20\cdot10^{-18}$	$3.39\cdot10^{-18}$
Np-239	$3.17\cdot10^{-18}$	$2.57\cdot10^{-18}$
Pu-239	$2.87\cdot10^{-21}$	$1.01\cdot10^{-21}$
U-239	$2.10\cdot10^{-18}$	$6.37\cdot10^{-19}$
Am-240	$2.07\cdot10^{-17}$	$1.72\cdot10^{-17}$
Cm-240	$5.87\cdot10^{-21}$	$6.01\cdot10^{-22}$
Np-240m	$1.16\cdot10^{-17}$	$5.76\cdot10^{-18}$
Np-240	$2.69\cdot10^{-17}$	$2.21\cdot10^{-17}$
Pu-240	$4.83\cdot10^{-21}$	$5.66\cdot10^{-22}$
U-240	$2.64\cdot10^{-20}$	$5.79\cdot10^{-21}$
Am-241	$2.89\cdot10^{-19}$	$1.85\cdot10^{-19}$
Cm-241	$9.94\cdot10^{-18}$	$8.12\cdot10^{-18}$
Pu-241	$2.95\cdot10^{-23}$	$2.20\cdot10^{-23}$
Am-242m	$2.05\cdot10^{-20}$	$6.37\cdot10^{-21}$
Am-242	$2.69\cdot10^{-19}$	$1.88\cdot10^{-19}$
Cm-242	$5.42\cdot10^{-21}$	$6.38\cdot10^{-22}$
Pu-242	$4.03\cdot10^{-21}$	$4.94\cdot10^{-22}$
Am-243	$7.59\cdot10^{-19}$	$5.78\cdot10^{-19}$
Cm-243	$2.44\cdot10^{-18}$	$1.98\cdot10^{-18}$
Pu-243	$3.91\cdot10^{-19}$	$3.01\cdot10^{-19}$
Am-244m	$2.61\cdot10^{-18}$	$4.80\cdot10^{-20}$
Am-244	$1.65\cdot10^{-17}$	$1.35\cdot10^{-17}$
Cf-244	$6.02\cdot10^{-21}$	$6.80\cdot10^{-22}$
Cm-244	$4.89\cdot10^{-21}$	$4.79\cdot10^{-22}$
Pu-244	$3.27\cdot10^{-21}$	$2.92\cdot10^{-22}$
Am-245	$8.76\cdot10^{-19}$	$4.94\cdot10^{-19}$
Bk-245	$4.22\cdot10^{-18}$	$3.42\cdot10^{-18}$
Cm-245	$1.55\cdot10^{-18}$	$1.25\cdot10^{-18}$
Pu-245	$8.92\cdot10^{-18}$	$7.02\cdot10^{-18}$
Am-246m	$2.28\cdot10^{-17}$	$1.74\cdot10^{-17}$
Am-246	$1.50\cdot10^{-17}$	$1.15\cdot10^{-17}$
Bk-246	$1.92\cdot10^{-17}$	$1.59\cdot10^{-17}$
Cf-246	$4.40\cdot10^{-21}$	$7.06\cdot10^{-22}$
Cm-246	$4.38\cdot10^{-21}$	$4.43\cdot10^{-22}$
Pu-246	$2.46\cdot10^{-18}$	$1.96\cdot10^{-18}$
Bk-247	$1.88\cdot10^{-18}$	$1.52\cdot10^{-18}$
Cm-247	$6.61\cdot10^{-18}$	$5.41\cdot10^{-18}$
Cf-248	$4.11\cdot10^{-21}$	$4.69\cdot10^{-22}$
Cm-248	$3.34\cdot10^{-21}$	$3.35\cdot10^{-22}$
Bk-249	$4.80\cdot10^{-23}$	$1.86\cdot10^{-23}$
Cf-249	$6.95\cdot10^{-18}$	$5.68\cdot10^{-18}$
Cm-249	$7.31\cdot10^{-19}$	$3.39\cdot10^{-19}$
Bk-250	$1.86\cdot10^{-17}$	$1.52\cdot10^{-17}$
Cf-250	$3.91\cdot10^{-21}$	$4.45\cdot10^{-22}$
Cm-250	0.00	0.00
Es-250	$7.78\cdot10^{-18}$	$6.46\cdot10^{-18}$
Cf-251	$2.29\cdot10^{-18}$	$1.84\cdot10^{-18}$
Es-251	$1.64\cdot10^{-18}$	$1.32\cdot10^{-18}$
Cf-252	$4.03\cdot10^{-21}$	$6.60\cdot10^{-22}$
Fm-252	$3.93\cdot10^{-21}$	$5.05\cdot10^{-22}$
Cf-253	$5.66\cdot10^{-22}$	$3.04\cdot10^{-22}$
Es-253	$9.07\cdot10^{-21}$	$5.56\cdot10^{-21}$
Fm-253	$1.41\cdot10^{-18}$	$1.14\cdot10^{-18}$
Cf-254	$1.27\cdot10^{-23}$	$1.45\cdot10^{-24}$
Es-254m	$1.01\cdot10^{-17}$	$8.04\cdot10^{-18}$
Es-254	$1.01\cdot10^{-19}$	$4.54\cdot10^{-20}$
Fm-254	$4.63\cdot10^{-21}$	$9.12\cdot10^{-22}$
Fm-255	$6.14\cdot10^{-20}$	$2.36\cdot10^{-20}$
Fm-257	$1.89\cdot10^{-18}$	$1.52\cdot10^{-18}$
Md-257	$2.08\cdot10^{-18}$	$1.69\cdot10^{-18}$
Md-258	$2.83\cdot10^{-20}$	$9.02\cdot10^{-21}$

Table 6.11. Skin dose and effective dose coefficients for air submersion; [93Eck1].

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
He-3	0.00	0.00
Be-7	$2.74\cdot10^{-15}$	$2.19\cdot10^{-15}$
Be-10	$1.29\cdot10^{-14}$	$1.38\cdot10^{-16}$
C-11	$7.91\cdot10^{-14}$	$4.56\cdot10^{-14}$
N-13	$8.68\cdot10^{-14}$	$4.57\cdot10^{-14}$
C-14	$2.43\cdot10^{-16}$	$2.60\cdot10^{-18}$
O-15	$1.04\cdot10^{-13}$	$4.59\cdot10^{-14}$
F-18	$6.94\cdot10^{-14}$	$4.56\cdot10^{-14}$
Ne-19	$1.21\cdot10^{-13}$	$4.62\cdot10^{-14}$
Na-22	$1.33\cdot10^{-13}$	$1.02\cdot10^{-13}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Na-24	$2.75 \cdot 10^{-13}$	$2.08 \cdot 10^{-13}$
Al-26	$1.81 \cdot 10^{-13}$	$1.28 \cdot 10^{-13}$
Al-28	$1.88 \cdot 10^{-13}$	$8.87 \cdot 10^{-14}$
Mg-28	$8.33 \cdot 10^{-14}$	$6.38 \cdot 10^{-14}$
P-30	$1.56 \cdot 10^{-13}$	$4.68 \cdot 10^{-14}$
Si-31	$3.78 \cdot 10^{-14}$	$4.83 \cdot 10^{-16}$
P-32	$4.49 \cdot 10^{-14}$	$5.36 \cdot 10^{-16}$
Si-32	$8.27 \cdot 10^{-16}$	$8.68 \cdot 10^{-18}$
P-33	$1.38 \cdot 10^{-15}$	$1.45 \cdot 10^{-17}$
S-35	$2.92 \cdot 10^{-16}$	$3.11 \cdot 10^{-18}$
Cl-36	$1.47 \cdot 10^{-14}$	$1.66 \cdot 10^{-16}$
Ar-37	0.00	0.00
Cl-38	$1.94 \cdot 10^{-13}$	$7.58 \cdot 10^{-14}$
K-38	$2.66 \cdot 10^{-13}$	$1.56 \cdot 10^{-13}$
Ar-39	$1.07 \cdot 10^{-14}$	$1.15 \cdot 10^{-16}$
Cl-39	$1.36 \cdot 10^{-13}$	$6.90 \cdot 10^{-14}$
K-40	$4.20 \cdot 10^{-14}$	$7.92 \cdot 10^{-15}$
Ar-41	$1.01 \cdot 10^{-13}$	$6.14 \cdot 10^{-14}$
Ca-41	0.00	0.00
K-42	$1.15 \cdot 10^{-13}$	$1.48 \cdot 10^{-14}$
K-43	$7.11 \cdot 10^{-14}$	$4.35 \cdot 10^{-14}$
Sc-43	$7.91 \cdot 10^{-14}$	$4.88 \cdot 10^{-14}$
K-44	$2.35 \cdot 10^{-13}$	$1.14 \cdot 10^{-13}$
Sc-44m	$1.72 \cdot 10^{-14}$	$1.24 \cdot 10^{-14}$
Sc-44	$1.58 \cdot 10^{-13}$	$9.87 \cdot 10^{-14}$
Ti-44	$6.79 \cdot 10^{-15}$	$4.70 \cdot 10^{-15}$
Ca-45	$1.46 \cdot 10^{-15}$	$1.53 \cdot 10^{-17}$
K-45	$1.74 \cdot 10^{-13}$	$9.20 \cdot 10^{-14}$
Ti-45	$7.07 \cdot 10^{-14}$	$3.89 \cdot 10^{-14}$
Sc-46	$1.17 \cdot 10^{-13}$	$9.36 \cdot 10^{-14}$
Ca-47	$8.02 \cdot 10^{-14}$	$5.06 \cdot 10^{-14}$
Sc-47	$1.28 \cdot 10^{-14}$	$4.67 \cdot 10^{-15}$
V-47	$1.08 \cdot 10^{-13}$	$4.49 \cdot 10^{-14}$
Cr-48	$2.40 \cdot 10^{-14}$	$1.87 \cdot 10^{-14}$
Sc-48	$2.01 \cdot 10^{-13}$	$1.57 \cdot 10^{-13}$
V-48	$1.72 \cdot 10^{-13}$	$1.36 \cdot 10^{-13}$
Ca-49	$2.46 \cdot 10^{-13}$	$1.66 \cdot 10^{-13}$
Cr-49	$9.65 \cdot 10^{-14}$	$4.68 \cdot 10^{-14}$
Sc-49	$5.43 \cdot 10^{-14}$	$7.16 \cdot 10^{-16}$
V-49	0.00	0.00
Cr-51	$1.75 \cdot 10^{-15}$	$1.38 \cdot 10^{-15}$
Mn-51	$1.18 \cdot 10^{-13}$	$4.51 \cdot 10^{-14}$
Fe-52	$5.17 \cdot 10^{-14}$	$3.27 \cdot 10^{-14}$
Mn-52m	$2.13 \cdot 10^{-13}$	$1.13 \cdot 10^{-13}$
Mn-52	$1.99 \cdot 10^{-13}$	$1.62 \cdot 10^{-13}$
Mn-53	0.00	0.00
Mn-54	$4.67 \cdot 10^{-14}$	$3.83 \cdot 10^{-14}$
Co-55	$1.39 \cdot 10^{-13}$	$9.16 \cdot 10^{-14}$
Fe-55	0.00	0.00

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Co-56	$2.13 \cdot 10^{-13}$	$1.73 \cdot 10^{-13}$
Mn-56	$1.51 \cdot 10^{-13}$	$8.16 \cdot 10^{-14}$
Ni-56	$9.61 \cdot 10^{-14}$	$7.82 \cdot 10^{-14}$
Co-57	$6.63 \cdot 10^{-15}$	$4.97 \cdot 10^{-15}$
Ni-57	$1.17 \cdot 10^{-13}$	$9.12 \cdot 10^{-14}$
Co-58m	$3.05 \cdot 10^{-19}$	$6.06 \cdot 10^{-20}$
Co-58	$5.58 \cdot 10^{-14}$	$4.44 \cdot 10^{-14}$
Fe-59	$7.13 \cdot 10^{-14}$	$5.62 \cdot 10^{-14}$
Ni-59	0.00	0.00
Co-60m	$3.46 \cdot 10^{-16}$	$2.00 \cdot 10^{-16}$
Co-60	$1.45 \cdot 10^{-13}$	$1.19 \cdot 10^{-13}$
Cu-60	$2.82 \cdot 10^{-13}$	$1.87 \cdot 10^{-13}$
Fe-60	$1.64 \cdot 10^{-16}$	$1.79 \cdot 10^{-18}$
Co-61	$3.24 \cdot 10^{-14}$	$3.74 \cdot 10^{-15}$
Cu-61	$6.50 \cdot 10^{-14}$	$3.72 \cdot 10^{-14}$
Co-62m	$2.25 \cdot 10^{-13}$	$1.30 \cdot 10^{-13}$
Cu-62	$1.44 \cdot 10^{-13}$	$4.60 \cdot 10^{-14}$
Zn-62	$2.52 \cdot 10^{-14}$	$1.92 \cdot 10^{-14}$
Ni-63	0.00	0.00
Zn-63	$1.23 \cdot 10^{-13}$	$5.00 \cdot 10^{-14}$
Cu-64	$1.64 \cdot 10^{-14}$	$8.50 \cdot 10^{-15}$
Ga-65	$1.19 \cdot 10^{-13}$	$5.28 \cdot 10^{-14}$
Ni-65	$7.18 \cdot 10^{-14}$	$2.67 \cdot 10^{-14}$
Zn-65	$3.29 \cdot 10^{-14}$	$2.72 \cdot 10^{-14}$
Cu-66	$7.69 \cdot 10^{-14}$	$4.89 \cdot 10^{-15}$
Ga-66	$2.11 \cdot 10^{-13}$	$1.23 \cdot 10^{-13}$
Ge-66	$4.26 \cdot 10^{-14}$	$3.00 \cdot 10^{-14}$
Ni-66	$1.01 \cdot 10^{-15}$	$1.06 \cdot 10^{-17}$
Cu-67	$1.18 \cdot 10^{-14}$	$4.90 \cdot 10^{-15}$
Ga-67	$8.50 \cdot 10^{-15}$	$6.49 \cdot 10^{-15}$
Ge-67	$1.68 \cdot 10^{-13}$	$6.45 \cdot 10^{-14}$
Ga-68	$1.01 \cdot 10^{-13}$	$4.29 \cdot 10^{-14}$
Ge-68	$6.62 \cdot 10^{-18}$	$1.01 \cdot 10^{-19}$
As-69	$1.43 \cdot 10^{-13}$	$4.61 \cdot 10^{-14}$
Ge-69	$5.96 \cdot 10^{-14}$	$3.99 \cdot 10^{-14}$
Zn-69m	$2.44 \cdot 10^{-14}$	$1.84 \cdot 10^{-14}$
Zn-69	$1.81 \cdot 10^{-14}$	$1.99 \cdot 10^{-16}$
As-70	$2.89 \cdot 10^{-13}$	$1.92 \cdot 10^{-13}$
Ga-70	$4.17 \cdot 10^{-14}$	$8.40 \cdot 10^{-16}$
Se-70	$8.36 \cdot 10^{-14}$	$4.40 \cdot 10^{-14}$
As-71	$3.78 \cdot 10^{-14}$	$2.53 \cdot 10^{-14}$
Ge-71	$6.71 \cdot 10^{-18}$	$1.02 \cdot 10^{-19}$
Zn-71m	$1.21 \cdot 10^{-13}$	$6.99 \cdot 10^{-14}$
As-72	$1.70 \cdot 10^{-13}$	$8.26 \cdot 10^{-14}$
Ga-72	$1.86 \cdot 10^{-13}$	$1.31 \cdot 10^{-13}$
Zn-72	$1.00 \cdot 10^{-14}$	$6.17 \cdot 10^{-15}$
As-73	$2.78 \cdot 10^{-16}$	$1.55 \cdot 10^{-16}$
Ga-73	$4.37 \cdot 10^{-14}$	$1.39 \cdot 10^{-14}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Se-73m	$2.39\cdot10^{-14}$	$1.09\cdot10^{-14}$
Se-73	$8.31\cdot10^{-14}$	$4.78\cdot10^{-14}$
As-74	$5.80\cdot10^{-14}$	$3.40\cdot10^{-14}$
Br-74m	$3.31\cdot10^{-13}$	$1.96\cdot10^{-13}$
Br-74	$3.40\cdot10^{-13}$	$2.26\cdot10^{-13}$
Kr-74	$1.16\cdot10^{-13}$	$5.20\cdot10^{-14}$
Br-75	$1.01\cdot10^{-13}$	$5.43\cdot10^{-14}$
Ge-75	$2.71\cdot10^{-14}$	$1.78\cdot10^{-15}$
Se-75	$2.16\cdot10^{-14}$	$1.68\cdot10^{-14}$
As-76	$9.61\cdot10^{-14}$	$2.06\cdot10^{-14}$
Br-76	$1.97\cdot10^{-13}$	$1.26\cdot10^{-13}$
Kr-76	$2.37\cdot10^{-14}$	$1.86\cdot10^{-14}$
As-77	$1.20\cdot10^{-14}$	$5.09\cdot10^{-16}$
Br-77	$1.77\cdot10^{-14}$	$1.40\cdot10^{-14}$
Ge-77	$1.02\cdot10^{-13}$	$4.98\cdot10^{-14}$
Kr-77	$9.74\cdot10^{-14}$	$4.51\cdot10^{-14}$
Se-77m	$6.99\cdot10^{-15}$	$3.63\cdot10^{-15}$
As-78	$1.65\cdot10^{-13}$	$6.03\cdot10^{-14}$
Ge-78	$2.75\cdot10^{-14}$	$1.23\cdot10^{-14}$
Kr-79	$1.50\cdot10^{-14}$	$1.12\cdot10^{-14}$
Rb-79	$1.28\cdot10^{-13}$	$6.08\cdot10^{-14}$
Se-79	$3.71\cdot10^{-16}$	$3.94\cdot10^{-18}$
Br-80m	$7.13\cdot10^{-16}$	$2.37\cdot10^{-16}$
Br-80	$2.02\cdot10^{-14}$	$3.73\cdot10^{-15}$
Rb-80	$2.11\cdot10^{-13}$	$5.77\cdot10^{-14}$
Sr-80	$1.44\cdot10^{-16}$	$5.00\cdot10^{-18}$
Kr-81m	$9.42\cdot10^{-15}$	$5.56\cdot10^{-15}$
Kr-81	$4.04\cdot10^{-16}$	$2.44\cdot10^{-16}$
Rb-81m	$4.01\cdot10^{-16}$	$1.63\cdot10^{-16}$
Rb-81	$4.46\cdot10^{-14}$	$2.73\cdot10^{-14}$
Se-81m	$1.40\cdot10^{-15}$	$5.48\cdot10^{-16}$
Se-81	$3.94\cdot10^{-14}$	$8.69\cdot10^{-16}$
Sr-81	$1.44\cdot10^{-13}$	$6.24\cdot10^{-14}$
Br-82	$1.54\cdot10^{-13}$	$1.21\cdot10^{-13}$
Rb-82m	$1.68\cdot10^{-13}$	$1.34\cdot10^{-13}$
Rb-82	$1.58\cdot10^{-13}$	$5.01\cdot10^{-14}$
Sr-82	$1.42\cdot10^{-16}$	$4.92\cdot10^{-18}$
Br-83	$1.85\cdot10^{-14}$	$5.34\cdot10^{-16}$
Kr-83m	$3.56\cdot10^{-17}$	$1.20\cdot10^{-18}$
Rb-83	$2.77\cdot10^{-14}$	$2.21\cdot10^{-14}$
Se-83	$1.69\cdot10^{-13}$	$1.14\cdot10^{-13}$
Sr-83	$5.20\cdot10^{-14}$	$3.60\cdot10^{-14}$
Br-84	$1.88\cdot10^{-13}$	$9.02\cdot10^{-14}$
Rb-84	$5.71\cdot10^{-14}$	$4.18\cdot10^{-14}$
Kr-85m	$2.24\cdot10^{-14}$	$6.87\cdot10^{-15}$
Kr-85	$1.32\cdot10^{-14}$	$2.40\cdot10^{-16}$
Sr-85m	$1.23\cdot10^{-14}$	$9.48\cdot10^{-15}$
Sr-85	$2.83\cdot10^{-14}$	$2.24\cdot10^{-14}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Rb-86	$4.85\cdot10^{-14}$	$4.94\cdot10^{-15}$
Y-86m	$1.28\cdot10^{-14}$	$9.59\cdot10^{-15}$
Y-86	$2.17\cdot10^{-13}$	$1.69\cdot10^{-13}$
Zr-86	$1.56\cdot10^{-14}$	$1.17\cdot10^{-14}$
Kr-87	$1.37\cdot10^{-13}$	$3.97\cdot10^{-14}$
Rb-87	$3.15\cdot10^{-15}$	$3.30\cdot10^{-17}$
Sr-87m	$2.15\cdot10^{-14}$	$1.41\cdot10^{-14}$
Y-87	$2.51\cdot10^{-14}$	$1.99\cdot10^{-14}$
Kr-88	$1.35\cdot10^{-13}$	$9.71\cdot10^{-14}$
Nb-88	$3.12\cdot10^{-13}$	$1.89\cdot10^{-13}$
Rb-88	$1.83\cdot10^{-13}$	$3.33\cdot10^{-14}$
Y-88	$1.54\cdot10^{-13}$	$1.30\cdot10^{-13}$
Zr-88	$2.26\cdot10^{-14}$	$1.73\cdot10^{-14}$
Nb-89b	$1.56\cdot10^{-13}$	$6.62\cdot10^{-14}$
Nb-89a	$1.63\cdot10^{-13}$	$8.65\cdot10^{-14}$
Rb-89	$1.87\cdot10^{-13}$	$1.01\cdot10^{-13}$
Sr-89	$3.69\cdot10^{-14}$	$4.37\cdot10^{-16}$
Zr-89	$7.07\cdot10^{-14}$	$5.31\cdot10^{-14}$
Mo-90	$5.52\cdot10^{-14}$	$3.64\cdot10^{-14}$
Nb-90	$2.66\cdot10^{-13}$	$2.05\cdot10^{-13}$
Sr-90	$9.20\cdot10^{-15}$	$9.83\cdot10^{-17}$
Y-90m	$3.75\cdot10^{-14}$	$2.77\cdot10^{-14}$
Y-90	$6.24\cdot10^{-14}$	$7.92\cdot10^{-16}$
Sr-91	$8.14\cdot10^{-14}$	$3.27\cdot10^{-14}$
Y-91m	$3.11\cdot10^{-14}$	$2.37\cdot10^{-14}$
Y-91	$3.85\cdot10^{-14}$	$6.22\cdot10^{-16}$
Sr-92	$8.56\cdot10^{-14}$	$6.41\cdot10^{-14}$
Y-92	$1.14\cdot10^{-13}$	$1.32\cdot10^{-14}$
Mo-93m	$1.32\cdot10^{-13}$	$1.06\cdot10^{-13}$
Mo-93	$2.43\cdot10^{-16}$	$1.73\cdot10^{-17}$
Nb-93m	$4.28\cdot10^{-17}$	$3.05\cdot10^{-18}$
Tc-93m	$4.62\cdot10^{-14}$	$3.53\cdot10^{-14}$
Tc-93	$8.30\cdot10^{-14}$	$6.96\cdot10^{-14}$
Y-93	$8.50\cdot10^{-14}$	$5.28\cdot10^{-15}$
Zr-93	0.00	0.00
Nb-94	$9.52\cdot10^{-14}$	$7.20\cdot10^{-14}$
Ru-94	$2.95\cdot10^{-14}$	$2.36\cdot10^{-14}$
Tc-94m	$1.55\cdot10^{-13}$	$8.64\cdot10^{-14}$
Tc-94	$1.51\cdot10^{-13}$	$1.22\cdot10^{-13}$
Y-94	$1.80\cdot10^{-13}$	$5.39\cdot10^{-14}$
Nb-95m	$1.12\cdot10^{-14}$	$2.74\cdot10^{-15}$
Nb-95	$4.30\cdot10^{-14}$	$3.49\cdot10^{-14}$
Tc-95m	$3.76\cdot10^{-14}$	$2.99\cdot10^{-14}$
Tc-95	$4.42\cdot10^{-14}$	$3.58\cdot10^{-14}$
Y-95	$1.59\cdot10^{-13}$	$4.66\cdot10^{-14}$
Zr-95	$4.50\cdot10^{-14}$	$3.36\cdot10^{-14}$
Nb-96	$1.52\cdot10^{-13}$	$1.14\cdot10^{-13}$
Tc-96m	$2.68\cdot10^{-15}$	$2.09\cdot10^{-15}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Tc-96	$1.40·10^{-13}$	$1.14·10^{-13}$
Nb-97m	$4.16·10^{-14}$	$3.31·10^{-14}$
Nb-97	$6.51·10^{-14}$	$2.99·10^{-14}$
Ru-97	$1.32·10^{-14}$	$9.91·10^{-15}$
Tc-97m	$5.55·10^{-16}$	$3.72·10^{-17}$
Tc-97	$2.71·10^{-16}$	$2.26·10^{-17}$
Zr-97	$5.55·10^{-14}$	$8.90·10^{-15}$
Nb-98	$1.96·10^{-13}$	$1.14·10^{-13}$
Tc-98	$8.53·10^{-14}$	$6.41·10^{-14}$
Mo-99	$3.14·10^{-14}$	$6.99·10^{-15}$
Rh-99m	$3.94·10^{-14}$	$3.06·10^{-14}$
Rh-99	$3.42·10^{-14}$	$2.63·10^{-14}$
Tc-99m	$7.14·10^{-15}$	$5.25·10^{-15}$
Tc-99	$2.74·10^{-15}$	$2.87·10^{-17}$
Pd-100	$6.11·10^{-15}$	$3.98·10^{-15}$
Rh-100	$1.63·10^{-13}$	$1.33·10^{-13}$
Mo-101	$1.14·10^{-13}$	$6.48·10^{-14}$
Pd-101	$1.94·10^{-14}$	$1.42·10^{-14}$
Rh-101m	$1.71·10^{-14}$	$1.29·10^{-14}$
Rh-101	$1.49·10^{-14}$	$1.09·10^{-14}$
Tc-101	$4.77·10^{-14}$	$1.50·10^{-14}$
Ag-102	$2.45·10^{-13}$	$1.57·10^{-13}$
Rh-102m	$3.68·10^{-14}$	$2.15·10^{-14}$
Rh-102	$1.19·10^{-13}$	$9.68·10^{-14}$
Ag-103	$5.84·10^{-14}$	$3.43·10^{-14}$
Pd-103	$3.90·10^{-16}$	$5.32·10^{-17}$
Rh-103m	$4.49·10^{-17}$	$6.02·10^{-18}$
Ru-103	$2.77·10^{-14}$	$2.08·10^{-14}$
Ag-104m	$1.00·10^{-13}$	$5.48·10^{-14}$
Ag-104	$1.56·10^{-13}$	$1.23·10^{-13}$
Cd-104	$1.38·10^{-14}$	$1.04·10^{-14}$
Tc-104	$2.25·10^{-13}$	$9.61·10^{-14}$
Ag-105	$2.90·10^{-14}$	$2.26·10^{-14}$
Rh-105	$1.07·10^{-14}$	$3.47·10^{-15}$
Ru-105	$6.73·10^{-14}$	$3.56·10^{-14}$
Ag-106m	$1.58·10^{-13}$	$1.29·10^{-13}$
Ag-106	$7.27·10^{-14}$	$3.18·10^{-14}$
Rh-106m	$1.81·10^{-13}$	$1.35·10^{-13}$
Rh-106	$1.09·10^{-13}$	$1.06·10^{-14}$
Ru-106	0.00	0.00
Cd-107	$1.50·10^{-15}$	$5.11·10^{-16}$
Pd-107	0.00	0.00
Rh-107	$4.42·10^{-14}$	$1.41·10^{-14}$
Ag-108m	$9.05·10^{-14}$	$7.24·10^{-14}$
Ag-108	$4.00·10^{-14}$	$1.25·10^{-15}$
Ag-109m	$5.59·10^{-16}$	$1.59·10^{-16}$
Cd-109	$9.95·10^{-16}$	$2.28·10^{-16}$
In-109	$3.91·10^{-14}$	$2.98·10^{-14}$
Pd-109	$2.15·10^{-14}$	$4.20·10^{-16}$
Ag-110m	$1.57·10^{-13}$	$1.27·10^{-13}$
Ag-110	$8.22·10^{-14}$	$2.46·10^{-15}$
In-110b	$1.71·10^{-13}$	$1.39·10^{-13}$
In-110a	$1.29·10^{-13}$	$7.15·10^{-14}$
Sn-110	$1.66·10^{-14}$	$1.25·10^{-14}$
Ag-111	$2.19·10^{-14}$	$1.38·10^{-15}$
In-111	$2.29·10^{-14}$	$1.68·10^{-14}$
Sn-111	$4.22·10^{-14}$	$2.30·10^{-14}$
Ag-112	$1.33·10^{-13}$	$3.23·10^{-14}$
In-112	$2.88·10^{-14}$	$1.19·10^{-14}$
Cd-113m	$8.48·10^{-15}$	$9.06·10^{-17}$
Cd-113	$2.41·10^{-15}$	$2.53·10^{-17}$
In-113m	$2.18·10^{-14}$	$1.12·10^{-14}$
Sn-113	$8.20·10^{-16}$	$3.15·10^{-16}$
In-114m	$1.05·10^{-14}$	$3.89·10^{-15}$
In-114	$2.95·10^{-15}$	$1.59·10^{-16}$
Ag-115	$1.11·10^{-13}$	$3.46·10^{-14}$
Cd-115m	$3.99·10^{-14}$	$1.48·10^{-15}$
Cd-115	$2.97·10^{-14}$	$1.05·10^{-14}$
In-115m	$1.81·10^{-14}$	$6.86·10^{-15}$
In-115	$6.18·10^{-15}$	$6.55·10^{-17}$
Sb-115	$6.52·10^{-14}$	$4.02·10^{-14}$
In-116m	$1.58·10^{-13}$	$1.18·10^{-13}$
Sb-116m	$1.82·10^{-13}$	$1.45·10^{-13}$
Sb-116	$1.50·10^{-13}$	$1.02·10^{-13}$
Te-116	$3.37·10^{-15}$	$1.98·10^{-15}$
Cd-117m	$1.29·10^{-13}$	$9.89·10^{-14}$
Cd-117	$8.79·10^{-14}$	$5.14·10^{-14}$
In-117m	$3.17·10^{-14}$	$4.07·10^{-15}$
In-117	$5.16·10^{-14}$	$3.06·10^{-14}$
Sb-117	$1.03·10^{-14}$	$7.15·10^{-15}$
Sn-117m	$1.25·10^{-14}$	$6.11·10^{-15}$
Sb-118m	$1.46·10^{-13}$	$1.19·10^{-13}$
In-119m	$7.11·10^{-14}$	$1.26·10^{-15}$
In-119	$8.20·10^{-14}$	$3.53·10^{-14}$
Sb-119	$7.09·10^{-16}$	$1.50·10^{-16}$
Sn-119m	$3.42·10^{-16}$	$7.04·10^{-17}$
I-120m	$3.86·10^{-13}$	$2.49·10^{-13}$
I-120	$2.55·10^{-13}$	$1.31·10^{-13}$
Sb-120b	$1.39·10^{-13}$	$1.14·10^{-13}$
Sb-120a	$4.46·10^{-14}$	$2.00·10^{-14}$
Xe-120	$2.40·10^{-14}$	$1.79·10^{-14}$
I-121	$2.72·10^{-14}$	$1.78·10^{-14}$
Sn-121m	$1.07·10^{-15}$	$5.24·10^{-17}$
Sn-121	$3.71·10^{-15}$	$3.90·10^{-17}$
Te-121m	$1.23·10^{-14}$	$8.99·10^{-15}$
Te-121	$3.18·10^{-14}$	$2.50·10^{-14}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Xe-121	$1.40\cdot10^{-13}$	$8.62\cdot10^{-14}$
I-122	$1.25\cdot10^{-13}$	$4.31\cdot10^{-14}$
Sb-122	$6.03\cdot10^{-14}$	$2.02\cdot10^{-14}$
Xe-122	$3.36\cdot10^{-15}$	$2.19\cdot10^{-15}$
I-123	$9.40\cdot10^{-15}$	$6.49\cdot10^{-15}$
Sn-123m	$3.58\cdot10^{-14}$	$6.14\cdot10^{-15}$
Sn-123	$3.28\cdot10^{-14}$	$6.98\cdot10^{-16}$
Te-123m	$8.48\cdot10^{-15}$	$5.81\cdot10^{-15}$
Te-123	$6.32\cdot10^{-16}$	$1.51\cdot10^{-16}$
Xe-123	$4.52\cdot10^{-14}$	$2.82\cdot10^{-14}$
I-124	$7.39\cdot10^{-14}$	$5.04\cdot10^{-14}$
Sb-124n	$2.33\cdot10^{-18}$	$4.67\cdot10^{-19}$
Sb-124m	$2.46\cdot10^{-14}$	$1.58\cdot10^{-14}$
Sb-124	$1.26\cdot10^{-13}$	$8.62\cdot10^{-14}$
Cs-125	$5.97\cdot10^{-14}$	$3.01\cdot10^{-14}$
I-125	$1.39\cdot10^{-15}$	$3.73\cdot10^{-16}$
Sb-125	$2.65\cdot10^{-14}$	$1.87\cdot10^{-14}$
Sn-125	$7.13\cdot10^{-14}$	$1.54\cdot10^{-14}$
Te-125m	$1.94\cdot10^{-15}$	$3.35\cdot10^{-16}$
Xe-125	$1.50\cdot10^{-14}$	$1.08\cdot10^{-14}$
Ba-126	$9.26\cdot10^{-15}$	$6.41\cdot10^{-15}$
Cs-126	$1.62\cdot10^{-13}$	$4.96\cdot10^{-14}$
I-126	$3.37\cdot10^{-14}$	$2.01\cdot10^{-14}$
Sb-126m	$1.24\cdot10^{-13}$	$7.01\cdot10^{-14}$
Sb-126	$1.73\cdot10^{-13}$	$1.28\cdot10^{-13}$
Sn-126	$6.65\cdot10^{-15}$	$1.84\cdot10^{-15}$
Cs-127	$2.38\cdot10^{-14}$	$1.78\cdot10^{-14}$
Sb-127	$5.58\cdot10^{-14}$	$3.12\cdot10^{-14}$
Sn-127	$1.41\cdot10^{-13}$	$9.03\cdot10^{-14}$
Te-127m	$8.49\cdot10^{-16}$	$1.12\cdot10^{-16}$
Te-127	$1.14\cdot10^{-14}$	$3.34\cdot10^{-16}$
Xe-127	$1.57\cdot10^{-14}$	$1.12\cdot10^{-14}$
Ba-128	$3.85\cdot10^{-15}$	$2.54\cdot10^{-15}$
Cs-128	$1.07\cdot10^{-13}$	$4.06\cdot10^{-14}$
I-128	$5.38\cdot10^{-14}$	$4.33\cdot10^{-15}$
Sb-128b	$1.99\cdot10^{-13}$	$1.41\cdot10^{-13}$
Sb-128a	$1.73\cdot10^{-13}$	$9.08\cdot10^{-14}$
Sn-128	$4.50\cdot10^{-14}$	$2.77\cdot10^{-14}$
Cs-129	$1.52\cdot10^{-14}$	$1.13\cdot10^{-14}$
I-129	$1.10\cdot10^{-15}$	$2.81\cdot10^{-16}$
Sb-129	$1.05\cdot10^{-13}$	$6.71\cdot10^{-14}$
Te-129m	$1.49\cdot10^{-14}$	$1.56\cdot10^{-15}$
Te-129	$3.57\cdot10^{-14}$	$2.86\cdot10^{-15}$
Xe-129m	$8.29\cdot10^{-15}$	$9.14\cdot10^{-16}$
Cs-130	$5.48\cdot10^{-14}$	$2.30\cdot10^{-14}$
I-130	$1.36\cdot10^{-13}$	$9.67\cdot10^{-14}$
Sb-130	$2.29\cdot10^{-13}$	$1.50\cdot10^{-13}$
Ba-131m	$3.94\cdot10^{-15}$	$2.64\cdot10^{-15}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Ba-131	$2.55\cdot10^{-14}$	$1.92\cdot10^{-14}$
Cs-131	$7.84\cdot10^{-16}$	$2.38\cdot10^{-16}$
I-131	$2.98\cdot10^{-14}$	$1.69\cdot10^{-14}$
La-131	$4.87\cdot10^{-14}$	$2.91\cdot10^{-14}$
Sb-131	$1.40\cdot10^{-13}$	$8.84\cdot10^{-14}$
Te-131m	$8.85\cdot10^{-14}$	$6.55\cdot10^{-14}$
Te-131	$6.89\cdot10^{-14}$	$1.92\cdot10^{-14}$
Xe-131m	$4.82\cdot10^{-15}$	$3.49\cdot10^{-16}$
Cs-132	$3.92\cdot10^{-14}$	$3.11\cdot10^{-14}$
I-132m	$2.22\cdot10^{-14}$	$1.42\cdot10^{-14}$
I-132	$1.58\cdot10^{-13}$	$1.05\cdot10^{-13}$
La-132	$1.49\cdot10^{-13}$	$9.41\cdot10^{-14}$
Te-132	$1.39\cdot10^{-14}$	$9.32\cdot10^{-15}$
Ba-133m	$1.36\cdot10^{-14}$	$2.44\cdot10^{-15}$
Ba-133	$2.19\cdot10^{-14}$	$1.62\cdot10^{-14}$
I-133	$5.83\cdot10^{-14}$	$2.76\cdot10^{-14}$
Te-133m	$1.74\cdot10^{-13}$	$1.07\cdot10^{-13}$
Te-133	$1.06\cdot10^{-13}$	$4.34\cdot10^{-14}$
Xe-133m	$1.04\cdot10^{-14}$	$1.28\cdot10^{-15}$
Xe-133	$4.97\cdot10^{-15}$	$1.33\cdot10^{-15}$
Ce-134	$9.60\cdot10^{-16}$	$3.52\cdot10^{-16}$
Cs-134m	$2.88\cdot10^{-15}$	$7.95\cdot10^{-16}$
Cs-134	$9.45\cdot10^{-14}$	$7.06\cdot10^{-14}$
I-134	$1.87\cdot10^{-13}$	$1.22\cdot10^{-13}$
La-134	$8.88\cdot10^{-14}$	$3.15\cdot10^{-14}$
Te-134	$6.35\cdot10^{-14}$	$3.94\cdot10^{-14}$
Ba-135m	$1.30\cdot10^{-14}$	$2.16\cdot10^{-15}$
Ce-135	$1.10\cdot10^{-13}$	$7.93\cdot10^{-14}$
Cs-135m	$9.10\cdot10^{-14}$	$7.25\cdot10^{-14}$
Cs-135	$9.06\cdot10^{-16}$	$9.50\cdot10^{-18}$
I-135	$1.11\cdot10^{-13}$	$7.54\cdot10^{-14}$
La-135	$1.49\cdot10^{-15}$	$7.75\cdot10^{-16}$
Xe-135m	$2.97\cdot10^{-14}$	$1.90\cdot10^{-14}$
Xe-135	$3.12\cdot10^{-14}$	$1.10\cdot10^{-14}$
Cs-136	$1.25\cdot10^{-13}$	$9.94\cdot10^{-14}$
Nd-136	$1.71\cdot10^{-14}$	$1.15\cdot10^{-14}$
Pr-136	$1.69\cdot10^{-13}$	$9.72\cdot10^{-14}$
Ba-137m	$3.73\cdot10^{-14}$	$2.69\cdot10^{-14}$
Ce-137m	$1.20\cdot10^{-14}$	$1.83\cdot10^{-15}$
Ce-137	$1.45\cdot10^{-15}$	$7.30\cdot10^{-16}$
Cs-137	$8.63\cdot10^{-15}$	$9.28\cdot10^{-17}$
La-137	$8.68\cdot10^{-16}$	$3.00\cdot10^{-16}$
Pr-137	$4.01\cdot10^{-14}$	$2.20\cdot10^{-14}$
Cs-138	$2.17\cdot10^{-13}$	$1.15\cdot10^{-13}$
La-138	$7.09\cdot10^{-14}$	$5.84\cdot10^{-14}$
Nd-138	$1.92\cdot10^{-15}$	$1.07\cdot10^{-15}$
Pr-138m	$1.52\cdot10^{-13}$	$1.13\cdot10^{-13}$
Pr-138	$1.25\cdot10^{-13}$	$3.72\cdot10^{-14}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Xe-138	$1.07 \cdot 10^{-13}$	$5.48 \cdot 10^{-14}$
Ba-139	$6.16 \cdot 10^{-14}$	$2.54 \cdot 10^{-15}$
Ce-139	$8.94 \cdot 10^{-15}$	$5.97 \cdot 10^{-15}$
Nd-139m	$9.17 \cdot 10^{-14}$	$7.12 \cdot 10^{-14}$
Nd-139	$3.50 \cdot 10^{-14}$	$1.77 \cdot 10^{-14}$
Pr-139	$8.75 \cdot 10^{-15}$	$4.75 \cdot 10^{-15}$
Ba-140	$2.52 \cdot 10^{-14}$	$8.07 \cdot 10^{-15}$
La-140	$1.66 \cdot 10^{-13}$	$1.11 \cdot 10^{-13}$
Ba-141	$1.07 \cdot 10^{-13}$	$3.92 \cdot 10^{-14}$
Ce-141	$1.02 \cdot 10^{-14}$	$3.10 \cdot 10^{-15}$
La-141	$6.58 \cdot 10^{-14}$	$2.88 \cdot 10^{-15}$
Nd-141m	$4.67 \cdot 10^{-14}$	$3.45 \cdot 10^{-14}$
Nd-141	$4.24 \cdot 10^{-15}$	$2.59 \cdot 10^{-15}$
Pm-141	$8.42 \cdot 10^{-14}$	$3.39 \cdot 10^{-14}$
Sm-141m	$1.39 \cdot 10^{-13}$	$9.07 \cdot 10^{-14}$
Sm-141	$1.27 \cdot 10^{-13}$	$6.44 \cdot 10^{-14}$
Ba-142	$8.37 \cdot 10^{-14}$	$4.84 \cdot 10^{-14}$
La-142	$2.16 \cdot 10^{-13}$	$1.37 \cdot 10^{-13}$
Pm-142	$1.44 \cdot 10^{-13}$	$4.01 \cdot 10^{-14}$
Pr-142m	0.00	0.00
Pr-142	$5.67 \cdot 10^{-14}$	$3.50 \cdot 10^{-15}$
Sm-142	$6.44 \cdot 10^{-15}$	$3.43 \cdot 10^{-15}$
Ce-143	$3.96 \cdot 10^{-14}$	$1.21 \cdot 10^{-14}$
La-143	$9.64 \cdot 10^{-14}$	$5.78 \cdot 10^{-15}$
Pm-143	$1.72 \cdot 10^{-14}$	$1.35 \cdot 10^{-14}$
Pr-143	$1.76 \cdot 10^{-14}$	$1.94 \cdot 10^{-16}$
Ce-144	$2.93 \cdot 10^{-15}$	$7.63 \cdot 10^{-16}$
Pm-144	$8.71 \cdot 10^{-14}$	$6.95 \cdot 10^{-14}$
Pr-144m	$5.08 \cdot 10^{-16}$	$2.20 \cdot 10^{-16}$
Pr-144	$8.43 \cdot 10^{-14}$	$2.65 \cdot 10^{-15}$
Eu-145	$8.33 \cdot 10^{-14}$	$6.78 \cdot 10^{-14}$
Gd-145	$1.66 \cdot 10^{-13}$	$1.09 \cdot 10^{-13}$
Pm-145	$1.22 \cdot 10^{-15}$	$5.49 \cdot 10^{-16}$
Pr-145	$4.44 \cdot 10^{-14}$	$1.12 \cdot 10^{-15}$
Sm-145	$2.64 \cdot 10^{-15}$	$1.26 \cdot 10^{-15}$
Eu-146	$1.43 \cdot 10^{-13}$	$1.15 \cdot 10^{-13}$
Gd-146	$1.33 \cdot 10^{-14}$	$8.61 \cdot 10^{-15}$
Pm-146	$4.64 \cdot 10^{-14}$	$3.34 \cdot 10^{-14}$
Sm-146	0.00	0.00
Eu-147	$2.77 \cdot 10^{-14}$	$2.14 \cdot 10^{-14}$
Gd-147	$7.67 \cdot 10^{-14}$	$5.98 \cdot 10^{-14}$
Nd-147	$1.95 \cdot 10^{-14}$	$5.72 \cdot 10^{-15}$
Pm-147	$8.11 \cdot 10^{-16}$	$8.67 \cdot 10^{-18}$
Pr-147	$9.75 \cdot 10^{-14}$	$3.90 \cdot 10^{-14}$
Sm-147	0.00	0.00
Tb-147	$1.27 \cdot 10^{-13}$	$7.29 \cdot 10^{-14}$
Eu-148	$1.22 \cdot 10^{-13}$	$9.83 \cdot 10^{-14}$
Gd-148	0.00	0.00
Pm-148m	$1.18 \cdot 10^{-13}$	$9.01 \cdot 10^{-14}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Pm-148	$7.97 \cdot 10^{-14}$	$2.76 \cdot 10^{-14}$
Eu-149	$3.09 \cdot 10^{-15}$	$1.95 \cdot 10^{-15}$
Gd-149	$2.42 \cdot 10^{-14}$	$1.75 \cdot 10^{-14}$
Nd-149	$4.99 \cdot 10^{-14}$	$1.68 \cdot 10^{-14}$
Pm-149	$2.19 \cdot 10^{-14}$	$7.08 \cdot 10^{-16}$
Tb-149	$1.02 \cdot 10^{-13}$	$7.51 \cdot 10^{-14}$
Eu-150b	$8.50 \cdot 10^{-14}$	$6.64 \cdot 10^{-14}$
Eu-150a	$2.05 \cdot 10^{-14}$	$2.22 \cdot 10^{-15}$
Pm-150	$1.34 \cdot 10^{-13}$	$6.77 \cdot 10^{-14}$
Tb-150	$1.31 \cdot 10^{-13}$	$7.75 \cdot 10^{-14}$
Gd-151	$3.25 \cdot 10^{-15}$	$1.88 \cdot 10^{-15}$
Nd-151	$9.12 \cdot 10^{-14}$	$4.21 \cdot 10^{-14}$
Pm-151	$3.32 \cdot 10^{-14}$	$1.40 \cdot 10^{-14}$
Sm-151	$1.90 \cdot 10^{-19}$	$2.46 \cdot 10^{-20}$
Tb-151	$5.07 \cdot 10^{-14}$	$3.87 \cdot 10^{-14}$
Eu-152m	$4.85 \cdot 10^{-14}$	$1.36 \cdot 10^{-14}$
Eu-152	$6.90 \cdot 10^{-14}$	$5.28 \cdot 10^{-14}$
Gd-152	0.00	0.00
Gd-153	$5.00 \cdot 10^{-15}$	$3.11 \cdot 10^{-15}$
Sm-153	$1.45 \cdot 10^{-14}$	$2.04 \cdot 10^{-15}$
Tb-153	$1.23 \cdot 10^{-14}$	$8.86 \cdot 10^{-15}$
Eu-154	$8.29 \cdot 10^{-14}$	$5.75 \cdot 10^{-14}$
Tb-154	$1.38 \cdot 10^{-13}$	$1.14 \cdot 10^{-13}$
Dy-155	$3.27 \cdot 10^{-14}$	$2.56 \cdot 10^{-14}$
Eu-155	$3.39 \cdot 10^{-15}$	$2.14 \cdot 10^{-15}$
Ho-155	$3.46 \cdot 10^{-14}$	$1.65 \cdot 10^{-14}$
Sm-155	$4.01 \cdot 10^{-14}$	$4.43 \cdot 10^{-15}$
Tb-155	$7.29 \cdot 10^{-15}$	$4.84 \cdot 10^{-15}$
Eu-156	$9.98 \cdot 10^{-14}$	$6.38 \cdot 10^{-14}$
Sm-156	$1.46 \cdot 10^{-14}$	$4.93 \cdot 10^{-15}$
Tb-156m	$1.11 \cdot 10^{-15}$	$6.24 \cdot 10^{-16}$
Tb-156n	$3.56 \cdot 10^{-16}$	$9.73 \cdot 10^{-17}$
Tb-156	$1.04 \cdot 10^{-13}$	$8.34 \cdot 10^{-14}$
Dy-157	$1.94 \cdot 10^{-14}$	$1.48 \cdot 10^{-14}$
Eu-157	$3.57 \cdot 10^{-14}$	$1.09 \cdot 10^{-14}$
Ho-157	$2.90 \cdot 10^{-14}$	$2.04 \cdot 10^{-14}$
Tb-157	$1.06 \cdot 10^{-16}$	$5.34 \cdot 10^{-17}$
Eu-158	$1.21 \cdot 10^{-13}$	$5.00 \cdot 10^{-14}$
Tb-158	$4.70 \cdot 10^{-14}$	$3.58 \cdot 10^{-14}$
Dy-159	$1.89 \cdot 10^{-15}$	$9.93 \cdot 10^{-16}$
Gd-159	$1.91 \cdot 10^{-14}$	$2.16 \cdot 10^{-15}$
Ho-159	$1.98 \cdot 10^{-14}$	$1.43 \cdot 10^{-14}$
Tb-160	$7.34 \cdot 10^{-14}$	$5.19 \cdot 10^{-14}$
Er-161	$5.23 \cdot 10^{-14}$	$4.11 \cdot 10^{-14}$
Ho-161	$2.59 \cdot 10^{-15}$	$1.40 \cdot 10^{-15}$
Tb-161	$7.69 \cdot 10^{-15}$	$8.93 \cdot 10^{-16}$
Ho-162m	$3.22 \cdot 10^{-14}$	$2.54 \cdot 10^{-14}$
Ho-162	$1.01 \cdot 10^{-14}$	$6.70 \cdot 10^{-15}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Tm-162	$1.24 \cdot 10^{-13}$	$8.50 \cdot 10^{-14}$
Yb-162	$6.99 \cdot 10^{-15}$	$4.92 \cdot 10^{-15}$
Ho-164m	$1.93 \cdot 10^{-15}$	$1.06 \cdot 10^{-15}$
Ho-164	$8.33 \cdot 10^{-15}$	$8.03 \cdot 10^{-16}$
Dy-165	$2.82 \cdot 10^{-14}$	$1.35 \cdot 10^{-15}$
Er-165	$1.61 \cdot 10^{-15}$	$8.96 \cdot 10^{-16}$
Dy-166	$5.79 \cdot 10^{-15}$	$1.21 \cdot 10^{-15}$
Ho-166m	$9.90 \cdot 10^{-14}$	$7.84 \cdot 10^{-14}$
Ho-166	$4.46 \cdot 10^{-14}$	$1.72 \cdot 10^{-15}$
Tm-166	$1.08 \cdot 10^{-13}$	$8.78 \cdot 10^{-14}$
Yb-166	$3.88 \cdot 10^{-15}$	$2.35 \cdot 10^{-15}$
Ho-167	$2.95 \cdot 10^{-14}$	$1.59 \cdot 10^{-14}$
Tm-167	$1.17 \cdot 10^{-14}$	$5.39 \cdot 10^{-15}$
Yb-167	$1.38 \cdot 10^{-14}$	$9.48 \cdot 10^{-15}$
Er-169	$2.83 \cdot 10^{-15}$	$2.97 \cdot 10^{-17}$
Lu-169	$5.90 \cdot 10^{-14}$	$4.75 \cdot 10^{-14}$
Yb-169	$1.73 \cdot 10^{-14}$	$1.13 \cdot 10^{-14}$
Hf-170	$3.00 \cdot 10^{-14}$	$2.29 \cdot 10^{-14}$
Lu-170	$1.46 \cdot 10^{-13}$	$1.21 \cdot 10^{-13}$
Tm-170	$1.81 \cdot 10^{-14}$	$3.67 \cdot 10^{-16}$
Er-171	$4.22 \cdot 10^{-14}$	$1.64 \cdot 10^{-14}$
Lu-171	$3.80 \cdot 10^{-14}$	$3.00 \cdot 10^{-14}$
Tm-171	$3.17 \cdot 10^{-17}$	$1.77 \cdot 10^{-17}$
Er-172	$3.21 \cdot 10^{-14}$	$2.29 \cdot 10^{-14}$
Hf-172	$5.46 \cdot 10^{-15}$	$3.40 \cdot 10^{-15}$
Lu-172	$1.07 \cdot 10^{-13}$	$8.64 \cdot 10^{-14}$
Ta-172	$1.16 \cdot 10^{-13}$	$7.10 \cdot 10^{-14}$
Tm-172	$5.76 \cdot 10^{-14}$	$2.30 \cdot 10^{-14}$
Hf-173	$2.23 \cdot 10^{-14}$	$1.66 \cdot 10^{-14}$
Lu-173	$6.45 \cdot 10^{-15}$	$4.42 \cdot 10^{-15}$
Ta-173	$5.08 \cdot 10^{-14}$	$2.55 \cdot 10^{-14}$
Tm-173	$3.89 \cdot 10^{-14}$	$1.72 \cdot 10^{-14}$
Lu-174m	$2.89 \cdot 10^{-15}$	$1.84 \cdot 10^{-15}$
Lu-174	$6.53 \cdot 10^{-15}$	$4.94 \cdot 10^{-15}$
Ta-174	$5.36 \cdot 10^{-14}$	$2.75 \cdot 10^{-14}$
Hf-175	$2.15 \cdot 10^{-14}$	$1.54 \cdot 10^{-14}$
Ta-175	$5.32 \cdot 10^{-14}$	$4.24 \cdot 10^{-14}$
Tm-175	$9.10 \cdot 10^{-14}$	$4.81 \cdot 10^{-14}$
Yb-175	$6.93 \cdot 10^{-15}$	$1.75 \cdot 10^{-15}$
Lu-176m	$2.72 \cdot 10^{-14}$	$7.65 \cdot 10^{-16}$
Lu-176	$3.74 \cdot 10^{-14}$	$2.11 \cdot 10^{-14}$
Ta-176	$1.25 \cdot 10^{-13}$	$1.03 \cdot 10^{-13}$
W-176	$8.74 \cdot 10^{-15}$	$5.98 \cdot 10^{-15}$
Hf-177m	$1.39 \cdot 10^{-13}$	$9.67 \cdot 10^{-14}$
Lu-177m	$5.89 \cdot 10^{-14}$	$4.24 \cdot 10^{-14}$
Lu-177	$7.13 \cdot 10^{-15}$	$1.50 \cdot 10^{-15}$
Re-177	$5.17 \cdot 10^{-14}$	$2.76 \cdot 10^{-14}$
Ta-177	$3.36 \cdot 10^{-15}$	$2.15 \cdot 10^{-15}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
W-177	$5.11 \cdot 10^{-14}$	$3.91 \cdot 10^{-14}$
Yb-177	$3.60 \cdot 10^{-14}$	$8.82 \cdot 10^{-15}$
Hf-178m	$1.36 \cdot 10^{-13}$	$1.03 \cdot 10^{-13}$
Lu-178m	$9.06 \cdot 10^{-14}$	$4.80 \cdot 10^{-14}$
Lu-178	$5.68 \cdot 10^{-14}$	$7.12 \cdot 10^{-15}$
Re-178	$1.04 \cdot 10^{-13}$	$5.73 \cdot 10^{-14}$
Ta-178b	$5.87 \cdot 10^{-14}$	$4.32 \cdot 10^{-14}$
Ta-178a	$5.65 \cdot 10^{-15}$	$4.12 \cdot 10^{-15}$
W-178	$6.09 \cdot 10^{-16}$	$3.83 \cdot 10^{-16}$
Yb-178	$1.07 \cdot 10^{-14}$	$1.62 \cdot 10^{-15}$
Hf-179m	$5.26 \cdot 10^{-14}$	$3.84 \cdot 10^{-14}$
Lu-179	$2.99 \cdot 10^{-14}$	$1.66 \cdot 10^{-15}$
Ta-179	$1.45 \cdot 10^{-15}$	$9.00 \cdot 10^{-16}$
W-179	$2.58 \cdot 10^{-15}$	$1.50 \cdot 10^{-15}$
Hf-180m	$5.82 \cdot 10^{-14}$	$4.33 \cdot 10^{-14}$
Os-180	$3.19 \cdot 10^{-15}$	$1.96 \cdot 10^{-15}$
Re-180	$7.11 \cdot 10^{-14}$	$5.33 \cdot 10^{-14}$
Ta-180m	$3.67 \cdot 10^{-15}$	$1.43 \cdot 10^{-15}$
Ta-180	$3.26 \cdot 10^{-14}$	$2.35 \cdot 10^{-14}$
Hf-181	$3.62 \cdot 10^{-14}$	$2.42 \cdot 10^{-14}$
Os-181	$7.03 \cdot 10^{-14}$	$5.52 \cdot 10^{-14}$
Re-181	$4.76 \cdot 10^{-14}$	$3.37 \cdot 10^{-14}$
W-181	$1.84 \cdot 10^{-15}$	$1.16 \cdot 10^{-15}$
Hf-182m	$5.82 \cdot 10^{-14}$	$4.08 \cdot 10^{-14}$
Hf-182	$1.46 \cdot 10^{-14}$	$1.03 \cdot 10^{-14}$
Ir-182	$1.35 \cdot 10^{-13}$	$6.07 \cdot 10^{-14}$
Os-182	$2.46 \cdot 10^{-14}$	$1.83 \cdot 10^{-14}$
Re-182b	$1.08 \cdot 10^{-13}$	$8.49 \cdot 10^{-14}$
Re-182a	$6.71 \cdot 10^{-14}$	$5.39 \cdot 10^{-14}$
Ta-182m	$1.93 \cdot 10^{-14}$	$9.94 \cdot 10^{-15}$
Ta-182	$7.85 \cdot 10^{-14}$	$5.99 \cdot 10^{-14}$
Hf-183	$6.83 \cdot 10^{-14}$	$3.39 \cdot 10^{-14}$
Ta-183	$2.62 \cdot 10^{-14}$	$1.19 \cdot 10^{-14}$
Hf-184	$3.12 \cdot 10^{-14}$	$1.04 \cdot 10^{-14}$
Ir-184	$1.21 \cdot 10^{-13}$	$8.75 \cdot 10^{-14}$
Re-184m	$2.19 \cdot 10^{-14}$	$1.67 \cdot 10^{-14}$
Re-184	$5.00 \cdot 10^{-14}$	$3.99 \cdot 10^{-14}$
Ta-184	$1.16 \cdot 10^{-13}$	$7.25 \cdot 10^{-14}$
Ir-185	$3.52 \cdot 10^{-14}$	$2.74 \cdot 10^{-14}$
Os-185	$4.01 \cdot 10^{-14}$	$3.18 \cdot 10^{-14}$
Ta-185	$5.20 \cdot 10^{-14}$	$8.23 \cdot 10^{-15}$
W-185	$4.52 \cdot 10^{-15}$	$4.97 \cdot 10^{-17}$
Ir-186a	$9.55 \cdot 10^{-14}$	$7.51 \cdot 10^{-14}$
Ir-186b	$6.41 \cdot 10^{-14}$	$4.33 \cdot 10^{-14}$
Pt-186	$4.10 \cdot 10^{-14}$	$3.27 \cdot 10^{-14}$
Re-186m	$7.24 \cdot 10^{-16}$	$4.14 \cdot 10^{-16}$
Re-186	$2.03 \cdot 10^{-14}$	$9.97 \cdot 10^{-16}$
Ta-186	$1.49 \cdot 10^{-13}$	$7.02 \cdot 10^{-14}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Ir-187	$2.03 \cdot 10^{-14}$	$1.54 \cdot 10^{-14}$
Re-187	0.00	0.00
W-187	$4.09 \cdot 10^{-14}$	$2.13 \cdot 10^{-14}$
Ir-188	$9.18 \cdot 10^{-14}$	$7.52 \cdot 10^{-14}$
Pt-188	$1.18 \cdot 10^{-14}$	$7.90 \cdot 10^{-15}$
Re-188m	$3.91 \cdot 10^{-15}$	$2.56 \cdot 10^{-15}$
Re-188	$5.35 \cdot 10^{-14}$	$3.13 \cdot 10^{-15}$
W-188	$2.91 \cdot 10^{-15}$	$1.10 \cdot 10^{-16}$
Ir-189	$4.14 \cdot 10^{-15}$	$2.77 \cdot 10^{-15}$
Os-189m	$7.16 \cdot 10^{-18}$	$1.24 \cdot 10^{-19}$
Pt-189	$1.82 \cdot 10^{-14}$	$1.34 \cdot 10^{-14}$
Re-189	$2.15 \cdot 10^{-14}$	$3.08 \cdot 10^{-15}$
Ir-190n	$8.89 \cdot 10^{-14}$	$6.81 \cdot 10^{-14}$
Ir-190m	$7.52 \cdot 10^{-18}$	$1.38 \cdot 10^{-19}$
Ir-190	$8.24 \cdot 10^{-14}$	$6.32 \cdot 10^{-14}$
Os-190m	$9.12 \cdot 10^{-14}$	$7.03 \cdot 10^{-14}$
Ir-191m	$4.07 \cdot 10^{-15}$	$2.62 \cdot 10^{-15}$
Os-191m	$3.67 \cdot 10^{-16}$	$2.31 \cdot 10^{-16}$
Os-191	$4.35 \cdot 10^{-15}$	$2.78 \cdot 10^{-15}$
Pt-191	$1.71 \cdot 10^{-14}$	$1.21 \cdot 10^{-14}$
Ir-192m	$8.81 \cdot 10^{-15}$	$6.84 \cdot 10^{-15}$
Ir-192	$5.53 \cdot 10^{-14}$	$3.61 \cdot 10^{-14}$
Au-193	$9.16 \cdot 10^{-15}$	$6.03 \cdot 10^{-15}$
Hg-193m	$6.21 \cdot 10^{-14}$	$4.69 \cdot 10^{-14}$
Hg-193	$1.26 \cdot 10^{-14}$	$7.70 \cdot 10^{-15}$
Os-193	$2.44 \cdot 10^{-14}$	$3.29 \cdot 10^{-15}$
Pt-193m	$3.07 \cdot 10^{-15}$	$3.76 \cdot 10^{-16}$
Pt-193	$2.07 \cdot 10^{-17}$	$4.07 \cdot 10^{-19}$
Au-194	$6.19 \cdot 10^{-14}$	$4.94 \cdot 10^{-14}$
Hg-194	$2.65 \cdot 10^{-17}$	$6.23 \cdot 10^{-19}$
Ir-194m	$1.34 \cdot 10^{-13}$	$1.04 \cdot 10^{-13}$
Ir-194	$5.85 \cdot 10^{-14}$	$4.73 \cdot 10^{-15}$
Os-194	$5.22 \cdot 10^{-17}$	$2.17 \cdot 10^{-17}$
Tl-194m	$1.47 \cdot 10^{-13}$	$1.03 \cdot 10^{-13}$
Tl-194	$4.41 \cdot 10^{-14}$	$3.41 \cdot 10^{-14}$
Au-195m	$1.35 \cdot 10^{-14}$	$8.52 \cdot 10^{-15}$
Au-195	$4.12 \cdot 10^{-15}$	$2.73 \cdot 10^{-15}$
Hg-195m	$1.38 \cdot 10^{-14}$	$8.78 \cdot 10^{-15}$
Hg-195	$1.11 \cdot 10^{-14}$	$8.38 \cdot 10^{-15}$
Ir-195m	$3.53 \cdot 10^{-14}$	$1.78 \cdot 10^{-14}$
Ir-195	$2.19 \cdot 10^{-14}$	$2.17 \cdot 10^{-15}$
Pb-195m	$9.97 \cdot 10^{-14}$	$7.12 \cdot 10^{-14}$
Pt-195m	$5.92 \cdot 10^{-15}$	$2.44 \cdot 10^{-15}$
Tl-195	$7.52 \cdot 10^{-14}$	$5.94 \cdot 10^{-14}$
Hg-197m	$1.02 \cdot 10^{-14}$	$3.62 \cdot 10^{-15}$
Hg-197	$3.35 \cdot 10^{-15}$	$2.26 \cdot 10^{-15}$
Pt-197m	$1.86 \cdot 10^{-14}$	$3.25 \cdot 10^{-15}$
Pt-197	$1.06 \cdot 10^{-14}$	$9.73 \cdot 10^{-16}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Tl-197	$2.43 \cdot 10^{-14}$	$1.78 \cdot 10^{-14}$
Au-198m	$3.75 \cdot 10^{-14}$	$2.39 \cdot 10^{-14}$
Au-198	$4.08 \cdot 10^{-14}$	$1.81 \cdot 10^{-14}$
Pb-198	$2.66 \cdot 10^{-14}$	$1.86 \cdot 10^{-14}$
Tl-198m	$7.40 \cdot 10^{-14}$	$5.26 \cdot 10^{-14}$
Tl-198	$1.16 \cdot 10^{-13}$	$9.47 \cdot 10^{-14}$
Au-199	$8.23 \cdot 10^{-15}$	$3.67 \cdot 10^{-15}$
Hg-199m	$2.71 \cdot 10^{-14}$	$7.63 \cdot 10^{-15}$
Pb-199	$8.55 \cdot 10^{-14}$	$6.83 \cdot 10^{-14}$
Pt-199	$4.38 \cdot 10^{-14}$	$9.32 \cdot 10^{-15}$
Tl-199	$1.49 \cdot 10^{-14}$	$1.02 \cdot 10^{-14}$
Au-200m	$1.27 \cdot 10^{-13}$	$9.32 \cdot 10^{-14}$
Au-200	$6.36 \cdot 10^{-14}$	$1.32 \cdot 10^{-14}$
Bi-200	$1.43 \cdot 10^{-13}$	$1.08 \cdot 10^{-13}$
Pb-200	$1.31 \cdot 10^{-14}$	$8.17 \cdot 10^{-15}$
Pt-200	$1.13 \cdot 10^{-14}$	$2.33 \cdot 10^{-15}$
Tl-200	$7.50 \cdot 10^{-14}$	$5.98 \cdot 10^{-14}$
Au-201	$2.78 \cdot 10^{-14}$	$2.62 \cdot 10^{-15}$
Bi-201	$8.99 \cdot 10^{-14}$	$6.08 \cdot 10^{-14}$
Pb-201	$4.43 \cdot 10^{-14}$	$3.35 \cdot 10^{-14}$
Tl-201	$4.89 \cdot 10^{-15}$	$3.25 \cdot 10^{-15}$
Bi-202	$1.57 \cdot 10^{-13}$	$1.24 \cdot 10^{-13}$
Pb-202m	$1.17 \cdot 10^{-13}$	$9.29 \cdot 10^{-14}$
Pb-202	$2.72 \cdot 10^{-17}$	$4.96 \cdot 10^{-19}$
Tl-202	$2.63 \cdot 10^{-14}$	$2.00 \cdot 10^{-14}$
Bi-203	$1.39 \cdot 10^{-13}$	$1.13 \cdot 10^{-13}$
Hg-203	$1.56 \cdot 10^{-14}$	$1.04 \cdot 10^{-14}$
Pb-203	$1.87 \cdot 10^{-14}$	$1.30 \cdot 10^{-14}$
Po-203	$1.00 \cdot 10^{-13}$	$7.59 \cdot 10^{-14}$
Tl-204	$1.24 \cdot 10^{-14}$	$1.71 \cdot 10^{-16}$
Bi-205	$9.70 \cdot 10^{-14}$	$7.98 \cdot 10^{-14}$
Pb-205	$2.92 \cdot 10^{-17}$	$5.45 \cdot 10^{-19}$
Po-205	$9.10 \cdot 10^{-14}$	$7.29 \cdot 10^{-14}$
Bi-206	$1.90 \cdot 10^{-13}$	$1.51 \cdot 10^{-13}$
Tl-206	$3.36 \cdot 10^{-14}$	$3.95 \cdot 10^{-16}$
At-207	$7.76 \cdot 10^{-14}$	$6.09 \cdot 10^{-14}$
Bi-207	$9.31 \cdot 10^{-14}$	$7.04 \cdot 10^{-14}$
Po-207	$7.67 \cdot 10^{-14}$	$6.08 \cdot 10^{-14}$
Tl-207	$3.06 \cdot 10^{-14}$	$4.53 \cdot 10^{-16}$
Tl-208	$2.34 \cdot 10^{-13}$	$1.69 \cdot 10^{-13}$
Pb-209	$9.35 \cdot 10^{-15}$	$1.00 \cdot 10^{-16}$
Tl-209	$1.59 \cdot 10^{-13}$	$9.65 \cdot 10^{-14}$
Bi-210m	$1.63 \cdot 10^{-14}$	$1.12 \cdot 10^{-14}$
Bi-210	$2.30 \cdot 10^{-14}$	$2.58 \cdot 10^{-16}$
Pb-210	$1.28 \cdot 10^{-16}$	$4.48 \cdot 10^{-17}$
Po-210	$4.81 \cdot 10^{-19}$	$3.89 \cdot 10^{-19}$
At-211	$1.96 \cdot 10^{-15}$	$1.37 \cdot 10^{-15}$
Bi-211	$3.07 \cdot 10^{-15}$	$2.04 \cdot 10^{-15}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Pb-211	$3.06 \cdot 10^{-14}$	$2.59 \cdot 10^{-15}$
Po-211	$4.47 \cdot 10^{-16}$	$3.56 \cdot 10^{-16}$
Bi-212	$4.05 \cdot 10^{-14}$	$8.95 \cdot 10^{-15}$
Pb-212	$1.35 \cdot 10^{-14}$	$6.24 \cdot 10^{-15}$
Po-212	0.00	0.00
Bi-213	$3.39 \cdot 10^{-14}$	$6.16 \cdot 10^{-15}$
Po-213	0.00	0.00
Bi-214	$1.28 \cdot 10^{-13}$	$7.25 \cdot 10^{-14}$
Pb-214	$2.77 \cdot 10^{-14}$	$1.09 \cdot 10^{-14}$
Po-214	$4.71 \cdot 10^{-18}$	$3.81 \cdot 10^{-18}$
At-215	$1.12 \cdot 10^{-17}$	$8.51 \cdot 10^{-18}$
Po-215	$1.01 \cdot 10^{-17}$	$7.79 \cdot 10^{-18}$
At-216	$8.03 \cdot 10^{-17}$	$5.38 \cdot 10^{-17}$
Po-216	$9.57 \cdot 10^{-19}$	$7.75 \cdot 10^{-19}$
At-217	$1.86 \cdot 10^{-17}$	$1.37 \cdot 10^{-17}$
At-218	$2.12 \cdot 10^{-16}$	$9.71 \cdot 10^{-17}$
Po-218	$7.56 \cdot 10^{-19}$	$4.21 \cdot 10^{-19}$
Rn-218	$4.30 \cdot 10^{-17}$	$3.40 \cdot 10^{-17}$
Fr-219	$2.04 \cdot 10^{-16}$	$1.53 \cdot 10^{-16}$
Rn-219	$3.38 \cdot 10^{-15}$	$2.46 \cdot 10^{-15}$
Fr-220	$8.53 \cdot 10^{-16}$	$4.40 \cdot 10^{-16}$
Rn-220	$2.20 \cdot 10^{-17}$	$1.72 \cdot 10^{-17}$
Fr-221	$2.02 \cdot 10^{-15}$	$1.32 \cdot 10^{-15}$
Fr-222	$4.76 \cdot 10^{-14}$	$5.79 \cdot 10^{-16}$
Ra-222	$5.51 \cdot 10^{-16}$	$4.03 \cdot 10^{-16}$
Rn-222	$2.28 \cdot 10^{-17}$	$1.77 \cdot 10^{-17}$
Ac-223	$3.05 \cdot 10^{-16}$	$1.87 \cdot 10^{-16}$
Fr-223	$2.30 \cdot 10^{-14}$	$2.20 \cdot 10^{-15}$
Ra-223	$8.87 \cdot 10^{-15}$	$5.47 \cdot 10^{-15}$
Ac-224	$1.08 \cdot 10^{-14}$	$8.01 \cdot 10^{-15}$
Ra-224	$6.35 \cdot 10^{-16}$	$4.29 \cdot 10^{-16}$
Ac-225	$9.40 \cdot 10^{-16}$	$6.37 \cdot 10^{-16}$
Ra-225	$3.01 \cdot 10^{-15}$	$2.40 \cdot 10^{-16}$
Ac-226	$2.15 \cdot 10^{-14}$	$5.57 \cdot 10^{-15}$
Ra-226	$4.79 \cdot 10^{-16}$	$2.84 \cdot 10^{-16}$
Th-226	$6.37 \cdot 10^{-16}$	$3.21 \cdot 10^{-16}$
Ac-227	$1.10 \cdot 10^{-17}$	$5.12 \cdot 10^{-18}$
Pa-227	$1.08 \cdot 10^{-15}$	$7.38 \cdot 10^{-16}$
Ra-227	$3.19 \cdot 10^{-14}$	$7.01 \cdot 10^{-15}$
Th-227	$6.50 \cdot 10^{-15}$	$4.43 \cdot 10^{-15}$
Ac-228	$7.88 \cdot 10^{-14}$	$4.49 \cdot 10^{-14}$
Pa-228	$6.56 \cdot 10^{-14}$	$5.16 \cdot 10^{-14}$
Ra-228	0.00	0.00
Th-228	$1.50 \cdot 10^{-16}$	$8.10 \cdot 10^{-17}$
Th-229	$5.41 \cdot 10^{-15}$	$3.36 \cdot 10^{-15}$
Pa-230	$3.73 \cdot 10^{-14}$	$2.91 \cdot 10^{-14}$
Th-230	$4.51 \cdot 10^{-17}$	$1.48 \cdot 10^{-17}$
U-230	$1.07 \cdot 10^{-16}$	$4.56 \cdot 10^{-17}$
Pa-231	$2.44 \cdot 10^{-15}$	$1.57 \cdot 10^{-15}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Th-231	$2.52 \cdot 10^{-15}$	$4.58 \cdot 10^{-16}$
U-231	$3.82 \cdot 10^{-15}$	$2.56 \cdot 10^{-15}$
Np-232	$6.94 \cdot 10^{-14}$	$5.38 \cdot 10^{-14}$
Pa-232	$5.57 \cdot 10^{-14}$	$4.26 \cdot 10^{-14}$
Th-232	$3.44 \cdot 10^{-17}$	$7.24 \cdot 10^{-18}$
U-232	$5.92 \cdot 10^{-17}$	$1.17 \cdot 10^{-17}$
Np-233	$4.78 \cdot 10^{-15}$	$3.39 \cdot 10^{-15}$
Pa-233	$1.66 \cdot 10^{-14}$	$8.55 \cdot 10^{-15}$
U-233	$4.57 \cdot 10^{-17}$	$1.42 \cdot 10^{-17}$
Np-234	$8.41 \cdot 10^{-14}$	$6.83 \cdot 10^{-14}$
Pa-234m	$5.48 \cdot 10^{-14}$	$1.21 \cdot 10^{-15}$
Pa-234	$1.24 \cdot 10^{-13}$	$8.72 \cdot 10^{-14}$
Pu-234	$3.46 \cdot 10^{-15}$	$2.49 \cdot 10^{-15}$
Th-234	$7.50 \cdot 10^{-16}$	$2.94 \cdot 10^{-16}$
U-234	$4.25 \cdot 10^{-17}$	$6.11 \cdot 10^{-18}$
Np-235	$1.82 \cdot 10^{-16}$	$4.19 \cdot 10^{-17}$
Pu-235	$4.78 \cdot 10^{-15}$	$3.45 \cdot 10^{-15}$
U-235	$8.64 \cdot 10^{-15}$	$6.46 \cdot 10^{-15}$
Np-236a	$9.17 \cdot 10^{-15}$	$4.74 \cdot 10^{-15}$
Np-236b	$5.76 \cdot 10^{-15}$	$1.92 \cdot 10^{-15}$
Pu-236	$4.83 \cdot 10^{-17}$	$4.68 \cdot 10^{-18}$
U-236	$3.57 \cdot 10^{-17}$	$3.86 \cdot 10^{-18}$
Am-237	$2.14 \cdot 10^{-14}$	$1.55 \cdot 10^{-14}$
Np-237	$1.54 \cdot 10^{-15}$	$8.87 \cdot 10^{-16}$
Pu-237	$2.54 \cdot 10^{-15}$	$1.76 \cdot 10^{-15}$
U-237	$9.97 \cdot 10^{-15}$	$5.29 \cdot 10^{-15}$
Am-238	$5.09 \cdot 10^{-14}$	$4.04 \cdot 10^{-14}$
Cm-238	$3.94 \cdot 10^{-15}$	$2.85 \cdot 10^{-15}$
Np-238	$4.31 \cdot 10^{-14}$	$2.56 \cdot 10^{-14}$
Pu-238	$4.09 \cdot 10^{-17}$	$3.50 \cdot 10^{-18}$
U-238	$2.91 \cdot 10^{-17}$	$2.50 \cdot 10^{-18}$
Am-239	$1.56 \cdot 10^{-14}$	$9.26 \cdot 10^{-15}$
Np-239	$1.60 \cdot 10^{-14}$	$6.95 \cdot 10^{-15}$
Pu-239	$1.86 \cdot 10^{-17}$	$3.48 \cdot 10^{-18}$
U-239	$2.61 \cdot 10^{-14}$	$2.13 \cdot 10^{-15}$
Am-240	$5.79 \cdot 10^{-14}$	$4.67 \cdot 10^{-14}$
Cm-240	$4.68 \cdot 10^{-17}$	$4.17 \cdot 10^{-18}$
Np-240m	$5.93 \cdot 10^{-14}$	$1.55 \cdot 10^{-14}$
Np-240	$9.15 \cdot 10^{-14}$	$5.88 \cdot 10^{-14}$
Pu-240	$3.92 \cdot 10^{-17}$	$3.42 \cdot 10^{-18}$
U-240	$3.12 \cdot 10^{-15}$	$5.87 \cdot 10^{-17}$
Am-241	$1.28 \cdot 10^{-15}$	$6.74 \cdot 10^{-16}$
Cm-241	$3.14 \cdot 10^{-14}$	$2.11 \cdot 10^{-14}$
Pu-241	$1.17 \cdot 10^{-19}$	$6.33 \cdot 10^{-20}$
Am-242m	$1.36 \cdot 10^{-16}$	$2.49 \cdot 10^{-17}$
Am-242	$8.20 \cdot 10^{-15}$	$6.09 \cdot 10^{-16}$
Cm-242	$4.29 \cdot 10^{-17}$	$4.02 \cdot 10^{-18}$
Pu-242	$3.27 \cdot 10^{-17}$	$2.90 \cdot 10^{-18}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Am-243	$2.75 \cdot 10^{-15}$	$1.85 \cdot 10^{-15}$
Cm-243	$9.79 \cdot 10^{-15}$	$5.30 \cdot 10^{-15}$
Pu-243	$8.15 \cdot 10^{-15}$	$9.61 \cdot 10^{-16}$
Am-244m	$3.11 \cdot 10^{-14}$	$3.63 \cdot 10^{-16}$
Am-244	$5.25 \cdot 10^{-14}$	$3.59 \cdot 10^{-14}$
Cf-244	$4.65 \cdot 10^{-17}$	$4.74 \cdot 10^{-18}$
Cm-244	$3.91 \cdot 10^{-17}$	$3.40 \cdot 10^{-18}$
Pu-244	$2.69 \cdot 10^{-17}$	$2.08 \cdot 10^{-18}$
Am-245	$1.62 \cdot 10^{-14}$	$1.45 \cdot 10^{-15}$
Bk-245	$1.58 \cdot 10^{-14}$	$9.26 \cdot 10^{-15}$
Cm-245	$5.36 \cdot 10^{-15}$	$3.49 \cdot 10^{-15}$
Pu-245	$4.00 \cdot 10^{-14}$	$1.86 \cdot 10^{-14}$
Am-246m	$8.56 \cdot 10^{-14}$	$4.74 \cdot 10^{-14}$
Am-246	$6.42 \cdot 10^{-14}$	$3.06 \cdot 10^{-14}$
Bk-246	$5.31 \cdot 10^{-14}$	$4.27 \cdot 10^{-14}$
Cf-246	$3.35 \cdot 10^{-17}$	$3.92 \cdot 10^{-18}$
Cm-246	$3.49 \cdot 10^{-17}$	$3.10 \cdot 10^{-18}$
Pu-246	$8.82 \cdot 10^{-15}$	$5.35 \cdot 10^{-15}$
Bk-247	$7.43 \cdot 10^{-15}$	$4.20 \cdot 10^{-15}$
Cm-247	$1.79 \cdot 10^{-14}$	$1.38 \cdot 10^{-14}$
Cf-248	$3.17 \cdot 10^{-17}$	$3.25 \cdot 10^{-18}$
Cm-248	$2.67 \cdot 10^{-17}$	$2.35 \cdot 10^{-18}$

Radionuclide	Skin Dose [Sv/(Bq s m^{-2})]	Effective Dose [Sv/(Bq s m^{-2})]
Bk-249	$4.07 \cdot 10^{-17}$	$4.68 \cdot 10^{-19}$
Cf-249	$1.91 \cdot 10^{-14}$	$1.45 \cdot 10^{-14}$
Cm-249	$1.59 \cdot 10^{-14}$	$1.02 \cdot 10^{-15}$
Bk-250	$6.43 \cdot 10^{-14}$	$4.12 \cdot 10^{-14}$
Cf-250	$3.02 \cdot 10^{-17}$	$3.09 \cdot 10^{-18}$
Cm-250	0.00	0.00
Es-250	$2.21 \cdot 10^{-14}$	$1.76 \cdot 10^{-14}$
Cf-251	$1.12 \cdot 10^{-14}$	$5.01 \cdot 10^{-15}$
Es-251	$5.35 \cdot 10^{-15}$	$3.65 \cdot 10^{-15}$
Cf-252	$3.08 \cdot 10^{-17}$	$3.63 \cdot 10^{-18}$
Fm-252	$2.95 \cdot 10^{-17}$	$3.45 \cdot 10^{-18}$
Cf-253	$1.66 \cdot 10^{-15}$	$1.75 \cdot 10^{-17}$
Es-253	$4.55 \cdot 10^{-17}$	$1.60 \cdot 10^{-17}$
Fm-253	$4.55 \cdot 10^{-15}$	$3.12 \cdot 10^{-15}$
Cf-254	$9.83 \cdot 10^{-20}$	$1.01 \cdot 10^{-20}$
Es-254m	$3.76 \cdot 10^{-14}$	$2.11 \cdot 10^{-14}$
Es-254	$5.65 \cdot 10^{-16}$	$1.57 \cdot 10^{-16}$
Fm-254	$3.43 \cdot 10^{-17}$	$4.76 \cdot 10^{-18}$
Fm-255	$3.95 \cdot 10^{-16}$	$8.82 \cdot 10^{-17}$
Fm-257	$7.18 \cdot 10^{-15}$	$4.15 \cdot 10^{-15}$
Md-257	$6.20 \cdot 10^{-15}$	$4.52 \cdot 10^{-15}$
Md-258	$1.82 \cdot 10^{-16}$	$3.89 \cdot 10^{-17}$

6.7 References

68Dre Drexler, G.: Proceedings of the Symposium on Microdosimetry, Ispra (Italy), 13-15 November 1967. European Communities, Brussels. Report No. EUR 3747 d-f-e, 1968, p. 433.

69Sny Snyder, W.S., Ford, M.R., Warner, G.G., Fisher jr., H.L.: Medical Internal Radiation Dose Committee (MIRD) Pamphlet No. 5, Supplement No. 3: J. Nucl. Med. **10** (1969).

69Spi Spiers, F.W.: Delayed effects of bone-seeking radionuclides, Mays, C.W., Jee, W.S.S., Lloyd, R.D., Stover, B.J., Dougherty, J.H., Taylor, G. (eds.), Salt Lake City: University of Utah Press, 1969, p. 95.

70Sto Storm, E., Israel, H.I.: Nucl. Data Tables A **7** (1970) 565.

75Emm Emmett, M.B.: Oak Ridge National Laboratory Report No ORNL4972. Oak Ridge, TN, 1975.

75ICR International Commission on Radiological Protection: ICRP Publication 23. Oxford, UK: Pergamon Press, 1975.

77ICR International Commission on Radiological Protection: ICRP Publication 26. Oxford, UK: Pergamon Press, 1977.

78Sny Snyder, W.S., Ford, M.R., Warner, G.G., Fisher jr., H.L.: Medical Internal Radiation Dose Committee (MIRD) Pamphlet No. 5, New York: The Society of Nuclear Medicine, 1978.

79Lic Lichtenstein, H., Cohen, M.O., Steinber, H.A., Trubetzkoys, E.S., Beer, M.: Computer code manual of the electric power research institutes (MAGI) EPRI-CCM-8. Palo Alto, California: Mathematical application group Inc., 1979.

80Cri Cristy, M.: Oak Ridge National Laboratory Report No. ORNL/NUREG/TM-367. Oak Ridge, TN, 1980.

82Kra Kramer, R., Zankl, M., Williams, G., Drexler, G.: GSF-Report S-885. Neuherberg, Germany: GSF-National Research Center for Environment and Health, 1982.

83ICR International Commission on Radiological Protection: ICRP Publication 38. Oxford, UK: Pergamon Press, 1983.

83Rou Roussin, R.W., Knight, J.R., Hubbell, J.H., Howerton, R.J.: Report No. ORNL-RSIC-46 (ENDF-335), Oak Ridge, TN: Radiation Shielding Information Center, Oak Ridge National Laboratory, 1983.

85ICR International Commission on Radiation Units and Measurements: ICRU Report 39. Bethesda, MD: ICRU Publications, 1985.

85Nel Nelson, W.R., Hirayama, H., Rogers, D.W.O.: SLAC-265-UC-32. Stanford, CA: Stanford Linear Accelerator Center, 1985.

85Sai Saito, K., Moriuchi, S.: Radiat. Prot. Dosim. **12** (1985) 21.

86Gro Grosswendt, B, Roos, M.: Medizin Physik (1986) 265.

88DOE Department of Energy DOE/EH-0070 DOE, Washington DC: Department of Energy, 1988.

88ICR International Commission on Radiation Units and Measurements: ICRU Report 43. Bethesda, MD: ICRU Publications, 1988.

88Zan Zankl, M., Veit, R., Williams, G., Schneider, K., Fendel, H., Petoussi, N., Drexler, G.: Radiat. Environ. Biophys. **27** (1988) 153.

89Vei Veit, R., Zankl, M., Petoussi, N., Mannweiler, E., Williams, G., Drexler, G.: GSF-Report 3/89. Neuherberg, Germany: GSF - National Research Center for Environment and Health, 1989.

90Hol Hollnagel, R.A.: Radiat Prot. Dosim. **30** (1990) 149.

90Sai Saito, K., Petoussi, N., Zankl, M., Veit, R., Jacob, P., Drexler, G.: GSF-Report 2/90. Neuherberg, Germany: GSF-National Research Center for Environment and Health, 1990.

91Bri Briesmeister, J.F.: Los Alamos National Laboratory Report LA-12625-M. Los Alamos, New Mexico, 1977.

91Gro Grosswendt, B.: Radiat Prot. Dosim. **35** (1991) 221.

91ICR International Commission on Radiological Protection: ICRP Publication 60. Oxford, UK: Pergamon Press, 1991.

91Pet Petoussi, N., Jacob, P., Zankl, M., Saito, K.: Radiat. Prot. Dosim. **37** (1991) 31.

92Hal Halbleib, J.A., Kensek R.P., Mehlhorn, T.A., Valdez, G.D., Seltzer, S.M., Berger, M.J.: Report No SAND-1634 / UC-405. Albuquerque, New Mexico and Livermore, California: SANDIA National Laboratories, 1992.

92ICR1 International Commission on Radiation Units and Measurements: ICRU Report 47. Bethesda, MD: ICRU Publications, 1992.

92ICR2 International Commission on Radiation Units and Measurements: ICRU Report 48. Bethesda, MD: ICRU Publications, 1992.

92Zan Zankl, M., Petoussi, N., Drexler, G.: Health Phys. **62** (1992) 395.

93Eck1 Eckerman, K.F., Ryman, J.C.: Federal Guidance Report No. 12. Oak Ridge, TN: Oak Ridge National Laboratory, 1993.

93Eck2 Eckerman, K.F., Westfall, R.J., Ryman, J.C., Cristy, M.: Oak Ridge National Laboratory Report No ORNL/TM-12350. Oak Ridge, TN: Oak Ridge National Laboratory, 1993.

93Gro Grosswendt, B.: PTB-Report Dos-22, Braunschweig: Physikalisch-Technische Bundesanstalt, 1993.

93ICR International Commission on Radiation Units and Measurements: ICRU Report 51. Bethesda, MD: ICRU Publications, 1993.

93Yam Yamaguchi, Y.: Radioisotopes **42** (1993) 35.

94Gro Grosswendt, B.: Radiat Prot. Dosim. **54** (1994) 85.

94Gua1 Guaraldi , R., Padoani, F.: ENEA Report RT/ERG/94/17, 1994.

94Gua2 Guaraldi , R., Padoani, F.: ENEA Report RT/ERG/94/21, 1994.

94Hir Hirayama, H.: Radiat. Prot. Dosim. **51** (1994) 107.

94ICR International Commission on Radiation Units and Measurements: ICRU Report 53. Bethesda, MD: ICRU Publications, 1994.

94Yam Yamaguchi, Y.: Radiat. Prot. Dosim. **55** (1994) 123.

94Zub Zubal, I.G., Harrell, C.R., Smith, E.O., Rattner, Z., Gindi, G., Hoffer, P.B.: Med. Phys. **21** (1994) 299.

95ISO International Organization for Standardization: ISO FDIS 4037-3, 1995.

95Sai Saito, K., Jacob, P.: Radiat. Prot. Dosim. **58** (1) (1995) 29.

95Til Till, E., Zankl, M., Drexler G.: GSF-Report 27/95. Neuherberg, Germany: GSF-National Research Center for Environment and Health, 1995.

96Cha Chartier, J.-L., Grosswendt, B., Gualdrini, G.F., Hirayama, H., Ma, C.-M., Padoani, F., Petoussi, N., Seltzer, S.M., Terrisol, M.: Radiat. Prot. Dosim. **63** (1996) 7.

96Dim Dimbylow, P.J.: Proc. Voxel phantom development 6-7 July 1996, Dimbylow, P.J. (ed.), Chilton, UK: National Radiological Protection Board, 1996, p. 1.

96ICR International Commission on Radiological Protection: ICRP Publication 74. Oxford, UK: Pergamon Press, 1996.

97Zan Zankl, M., Drexler, G., Petoussi-Henss, N., Saito, K.: GSF-Report 8/97. Neuherberg, Germany: GSF - National Research Center for Environment and Health, 1997.

98Cla Clark, M.J., Chartier, J.-L., Siebert, B.R.L., Zankl, M.: Radiat. Prot. Dosim. **78** (1998) 91.

98ICR International Commission on Radiation Units and Measurements: ICRU Report 57. Bethesda, MD: ICRU Publications, 1998.

98Sai Saito, K., Petoussi-Henss, N., Zankl, M.: Health Phys. **74** (6) (1998) 698.

99Sta Stabin, M.G., Tagesson, M., Thomas, S.R., Ljungberg, M., Strand, S.E.: Appl. Radiat. Isot. **50** (1999) 73.

99Zan Zankl, M.: Health Phys. **76** (1999) 162.

00Pel Pellicioni, M.: Radiat. Prot. Dosim. **88** (2002) 279.

00Xu Xu, X.G, Chao, T. C., Bozkurt A.: Health Phys. **78** (2000) 476.
01Zan Zankl, M., Wittmann, A.: Radiat. Environ. Biophys. **40** (2001) 153.
02Eck Eckerman, K.F. Private communication, 2002.
02Pet Petoussi-Henss, N., Zankl, M., Fill, U., Regulla, D.: Phys. Med. Biol. **47** (2002) 89.
02Roe Roesler, S., Heinrich, W., Schraube, H.: Radiat. Prot. Dosim. **98** (2002) 367.