Age-dependent inhalation doses to members of the public from indoor short-lived radon progeny

K. Brudecki[a,*], W. B. Li[a,*], O. Meisenberg[b], J. Tschiersch[b], C. Hoeschen[a], U. Oeh[a]

[a]Helmholtz Zentrum München, German Research Center for Environmental Health, Research Unit Medical Radiation Physics and Diagnostics, Ingolstädter Landstr. 1, D-85764 Neuherberg, Germany

[b]Helmholtz Zentrum München, German Research Center for Environmental Health, Institute of Radiation Protection, Ingolstädter Landstr. 1, D-85764 Neuherberg, Germany

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Age-dependent inhalation doses to radon progeny

*__Corresponding authors:__

K. Brudecki and W.B. Li

Research Unit Medical Radiation Physics and Diagnostics

Helmholtz Zentrum München, German Research Center for Environmental Health

Ingolstädter Landstr. 1, D-85764 Neuherberg, Germany.

kamil.brudecki@helmholtz-muenchen.de and wli@helmholtz-muenchen.de

Tel: 0049 89 3187 3314, Fax: 0049 89 3187 2517

Abstract

The main contribution of radiation dose to the human lungs originates from exposure to the short-lived radon decay products. In the present work, the inhalation doses from indoor short-lived radon decay products, i.e. ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po to different age groups of members of the public were calculated. In the calculations, the age-dependent systemic biokinetic models of polonium, bismuth and lead published by the International Commission on Radiological Protection (ICRP) were adopted. In addition, the ICRP human respiratory tract model and the human alimentary tract model were applied in the determination of the deposition fractions in different regions of the lungs and the absorption fraction of radon progeny in the alimentary tract during inhalation and exhalation. Based on equivalent dose and effective dose of each progeny calculated, the dose conversion coefficient was estimated, taking into account the unattached fraction, attached aerosols in the nucleation, accumulation and coarse modes and the potential alpha energy concentration fraction in indoor air. For each progeny, the equivalent doses to ET airways and the lungs are greater than to other organs. The contribution of the progeny ^{214}Po to the effective dose is much smaller comparing to other short-lived radon progeny and can be neglected in the dose assessment. In most cases, 90% of the effective dose from short-lived radon progeny arises from ^{214}Pb and ^{214}Bi, the rest from ^{218}Po. The dose conversion coefficients obtained in the present study are 17 and 18 mSv WLM^{-1} for adult female and male, respectively, comparing to the values ranged from 6 mSv WLM^{-1} to 20 mSv WLM^{-1} calculated by other investigators. The dose coefficients of each radon progeny calculated in the present study can be used to estimate the radiation doses for the population, especially for small children and women, in specific regions exposed to radon progeny by measuring their concentrations, aerosol sizes and unattached fractions.

1. Introduction

Radon (^{222}Rn) is a radioactive noble gas; it is a decay product of ^{226}Ra in the ^{238}U decay chain. Radon gas can leave earth crust by convection or diffusion and migrate to the atmosphere. The decay products of ^{222}Rn are radioactive isotopes of polonium, bismuth and lead. These daughters are isotopes of heavy metals and can easily be attached to aerosols in the atmosphere (Fig. 1). Radon progeny can be divided into two groups: the short-lived with half time below 30 min., say ^{218}Po (3.05 min), ^{214}Pb (26.8 min), ^{214}Bi (19.9 min) and ^{214}Po (164.3 s); and the long-lived, like ^{210}Pb (22.3 years), ^{210}Po (5.01 days) and ^{210}Po (138.8 days). The decay chain ends on the stable isotope ^{206}Pb (Firestone 1996). This study concerns about the short-lived radon progeny.

Radon and its decay products are responsible for more than half of natural radiation effective dose (average annual dose 1.3 mSv due to radon and its progeny comparing to natural annual radiation dose 2.4 mSv) (UNSCEAR 2000). ^{222}Rn is a recognized course of lung cancer to underground miners and residential public and has been proved to be the second cause of lung cancer after smoking (WHO 2009). Three pooling studies on indoor radon and lung cancer in Europe, North America and Asia provide a strong evidence that radon causes a substantial number of lung cancers in the general population. Studies reported increased risks of lung cancer of 8%, 11% and 13% per 100 Bq m^{-3} increase in measured radon concentration in Europe, North America and Asia, respectively (Darby et al 2005, 2006, Krewski et al 2005, 2006, Lubin et al 2004). While considering the year-to-year random variation of radon concentrations at home, data from Europe (Darby et al 2005, 2006), China (Lubin et al 2005), and the United States (Zhang et al 2007) suggested that the risk estimate based on long-term average concentrations should be doubled in contrast to that based on short-term measured concentrations. Therefore, a joint risk estimate from the three pooling studies, based on long term radon concentrations, would be around 20% per 100 Bq m^{-3} (WHO 2009). According to the statement on radon published by the International Commission on Radiological Protection (ICRP) (ICRP 2010), the dose conversion coefficient may be increased by a factor of two comparing to the current recommended values by ICRP (1993b) if applying the current ICRP biokinetic and dosimetric models. The calculated inhalation dose for adults exposed to radon progeny using ICRP biokinetic and dosimetric models demonstrated this phenomenon (Al-Jundi et al. 2011).

In the present study, a general method was developed for calculations of dose coefficients and dose conversion coefficient of short-lived radon progeny including four radon progeny, i.e. ^{210}Po, ^{214}Pb, ^{214}Bi and ^{214}Po. An assessment of the contribution of radon progeny to radiation doses in the lungs and in other organs for members of public of six different age groups was performed, for age groups of 15 years old and adults, inhalation doses for female and male were individually calculated. The age-dependent systemic biokinetic models of Po, Bi and Pb (ICRP 1980; 1993; 1995) published by the ICRP were adopted and combined with the ICRP human respiratory tract model (HRTM) (ICRP 1994) and the human alimentary tract model (HATM) (ICRP 2006) for determination of the deposition fractions of progeny in different regions in the lungs and the absorption fraction of progeny in the alimentary tract after inhalation and exhalation. Based on the organ equivalent dose and the effective dose of each progeny calculated, the dose conversion coefficient was estimated, taking into account the unattached fraction, attached aerosols in the nucleation, accumulation and coarse modes and the potential alpha energy concentration (PAEC) fraction. These dose coefficients and the dose conversion coefficients for radon progeny are appropriate to the risk assessment of radon exposure of members of the public, especially for the children, who live in areas with high radon concentrations.

2. Materials and methods

In this section, the general method of dose calculation of radon progeny is introduced. First, deposition fractions of progeny and aerosols in different lung regions were evaluated; second, a complete biokinetic model for modeling the translocation of deposited materials inside the human body after inhalation was constructed; third, the ICRP dosimetric model was applied to estimate the equivalent dose and effective dose; at last the dose conversion coefficient was calculated.

2.1 Deposition of radon progeny in human respiratory tract

The human respiratory tract model (HRTM) published by the ICRP (ICRP 1994) was applied in this study. In the HRTM, the human respiratory tract was mathematically divided into four anatomic regions as filters of inhaled materials: extrathoracic region (denoted as ET) including anterior nose, posterior nasal passages, larynx, pharynx and mouth; bronchial region (denoted as BB); bronchiolar region (denoted as bb) and alveolar-interstitial region (denoted as AI). The deposition fractions of radon progeny attached to aerosols in the respiratory tract depend on aerosols sizes and human physiological parameters like age, sex and life style. To cover the particle sizes of radon progeny in indoor air, deposition fractions of three activity median aerodynamic diameters (AMAD) of attached aerosols, 50 nm, 230 nm and 2500 nm and one activity median thermodynamic diameter (AMTD) of 1 nm representing the unattached aerosol were calculated by interpolation of the published deposition fraction values in the ICRP Publication 66 (1994). These activity sizes are assumed lognormal distributed with a geometric standard deviation (σ_g) 1.0 for AMTD of 1 nm and σ_g =1.45, 2.26 and 2.49 for AMAD of 50 nm, 230 nm and 2500 nm, respectively. Furthermore, the age-dependent of aerosol depositions in different regions of the lungs were implemented into the modeling of the six age groups and two sex for 15 years old and adults: 3 months infant (3 mo), 1 year old (1 y), 5 years old (5 y), 10 years old (10 y), 15 years old male (15 y ♂), 15 years old female (15 y ♀), adults male (Adult ♂) and adults female (Adult ♀). Fractions of the four modes of aerosol activity sizes 1 nm, 50 nm, 230 nm and 2500 nm in indoor air were defined as 0.1, 0.135, 0.747 and 0.018, respectively (Marsh et al. 2002).

Generally the fractional depositions in regions of the respiratory tract were estimated on the base of ICRP references values for six age groups and two sex and three exercise levels (sitting, sleeping, light excises) of human activity in indoor as a function of aerosol size. A logarithmic interpolation of deposition fractions was performed over the age groups using a six degree polynomial function. The typical indoor time budget distribution of different activities for the human being is supposed as 71% and 29% for sleeping and light exercise respectively for three month infant and 55%, 15%, and 30% for sleeping, sitting, and light exercise, respectively for all other age groups (Table A4 in ICRP 2002). The average breathing rate for adult male at home is 0.78 m^3 h^{-1} and the breathing rates for other age groups are following: 0.11 m^3 h^{-1} for 3 months infant; 0.22 m^3 h^{-1} for 1 year old; 0.35 m^3 h^{-1} for 5 years old; 0.56 m^3 h^{-1} for 10 years old; 0.64 m^3 h^{-1} for 15 years old female, 0.72 m^3 h^{-1} for 15 years old male and 0.61 m^3 h^{-1} for adult female, respectively.

2.2 Biokinetic models

To model the biokinetics of inhaled radionuclides in human lungs and retention in other organs and tissues, the systemic models (ICRP 1989), the respiratory tract model, HRTM (ICRP 1994a) and alimentary tract model, HATM (ICRP 2006) were coupled into one general compartmental model (Fig. 2). This model has been successfully applied in the estimation of the inhalation doses of thoron progeny for the public population of different age and sex (Li et al. 2008a, Bi et al. 2010) and for adults exposed to radon progeny (Al-Jundi et al. 2011). This general inhalation biokinetic model was also used to predict the retention and excretion after inhaled aerosols of depleted uranium (Li et al. 2008b).

Regarding to radon progeny, model transfer rates between organs or tissues are available for the HRTM, the HATM and systemic models (ICRP 1980, 1989, 1993, 1994, 1995, 2006), except that the procedure of absorption into blood from the respiratory tract is substituted by a simplified compartmental model proposed by Marsh and Birchall (1999), based on the earlier published data sets by Booker et al (1969), Hursh et al (1969), and Hursh and Mercer (1970). It is assumed that Pb is absorbed into blood with a half-life of 10 h and Bi with a half-life of 13 h no matter what kind of attachment forms they hold. These values are in the range of the absorption half-life values of 18 h estimated by Pillai et al (1994) and 8 h estimated by Jacobi (1964).

In the biokinetic modeling, two aspects are relative complicated to be implemented, namely, age-dependent transfer rates and the treatment of decay products of radon progeny. For simplicity a linear interpolation of age-independent transfer rates in the systemic models is applied. The age-dependent transfer rates change over time for inhalation starting at different age groups proposed by Li et al. (2005) for uranium age-dependent biokinetic model was adopted in the present modeling for Pb, for modeling of Po and Bi, the starting of intake at age adult is defined at 20 years old instead of 25 years old.

For treatment of decay products, the biokinetics of the decay daughters are assumed to behave independently as they are produced in the human body. The independent biokinetic models published by ICRP Publication 71 (ICRP 1995) were used in the present work. For the "other" tissue consideration in the decay chain member, the first approach suggested by the ICRP was applied in the present study (ICRP 1995). In the biokinetic models it is convenient to consider a set of organs and tissues, so called "other" tissues, which are not explicitly noted as tissues of deposition and in general with anatomical identity among decay chain member.

The number of nuclear transformations for each chain member is calculated using its independent biokinetic descriptions. Nuclear transformations within the member's "other" tissues are partitioned, by mass fraction among the source regions of the chain not present in the member's kinetics. Also, source regions present in the kinetics of the member but not in the kinetics of the parent of the chain, here ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po, should receive a portion of the transformations calculated in the member's "other". The number of transformation in "other" is reduced by the number allocated to the specific source regions, thus conserving transformations.

The complete dynamic transfer process of the inhaled radon progeny in the lungs and between the organs can be described by a system of first-order linear differential equations. The number of each nuclide in an individual tissue and organ at any time elapsed from the intake can be calculated by a numerical method. The time-integrated activity, $\tilde{A}$ (formerly defined as number of nuclear transformations, U_S) from any radon progeny in each organ was calculated by integrating the radioactivity in the organ over 70 years for children and over 50 years for adults. The system of first-order differential equations was solved by using commercial software package SAAM II (Barrett et al. 1998) (The Epsilon Group VA, USA).

2.3 Equivalent dose and effective dose

Equivalent doses were calculated with the time-integrated activity, $\tilde{A}$ of the deposited radon progeny in so-called source organs and the radiation-weighted S_w factors (formerly defined as specific effective energy, SEE). The committed equivalent dose in each target organ T from radiations emitted in a source organ S is determined by the product of two factors: (1) the time-integrated activity, $\tilde{A}$ of the radionuclide in source region S over a period of integration τ after intake of the radionuclide; (2) the radiation-weighted S_w factors, that is, the energy absorbed per unit mass in target organ T, multiplied the radiation-weighting factor, for each radiation emitted per transformation in source region S. The equivalent dose $H(r_S,T_D)$ in target organ T at age t of an individual intake over the dose-integration period T_D is given as equation (1) (ICRP 1989; Bolch et al. 2009).

$$H(r_T,T_D)=\sum_{r_S}\int_0^{T_D} A(r_S,t)\ S_w(r_T \leftarrow r_S,t)\ dt \tag{1}$$

where: $A(r_S,t)$ is the activity in sources region in source region r_S at time t;

$S_w(r_T \leftarrow r_S,t)$ is the radiation-weighted S;

$S_w(r_T \leftarrow r_S,t)=\sum_R w_R S(r_T \leftarrow r_S,E_R,t)$.

The value of radiation-weighted S_w factors (formerly as known SEE) was calculated by using the SEECAL program (Oak Ridge National Laboratory, Oak Ridge, TN, USA), in which each type of radiation is weighted by a given radiation weighting factor, w_R, which accounts for the different biological effectiveness in inducing late effects. Therefore the effective dose E can be calculated by equation (2) as a sum of the product of the equivalent doses, H_T for each systematic organ and tissue weighting factor, w_T:

$$E=\sum_T w_T H_T \tag{2}$$

Since $A(r_S,t)$ and S_w of the respiratory tract are calculated in separate anatomical regions, the assigned fractions for target cells in different regions are assumed to be 0.001, 0.998 and 0.001 for ET_1, ET_2 and LN_{ET} in the ET area, and 0.1665, 0.1665, 0.333, 0.333 and 0.001 for BB_{bas}, BB_{sec}, bb, AI and LN_{TH} in lungs, respectively (ICRP 1994).

As the new ICRP recommendation (2007) suggested, the effective dose, E, for adults should be calculated by averaging the effective doses of female and male as equation (3):

$$E = \sum_T w_T \left(\frac{H_T^{Male} + H_T^{Female}}{2} \right) \quad (3)$$

where H_T^{Female} and H_T^{Male} are equivalent doses for adult female and adult male, respectively. In the present work, the effective doses for 15 years old and adult are calculated using the female and male equivalent doses.

2.4 Dose conversion factor

The effective dose arising from the inhalation of short-lived radon progeny are expressed normally in terms of dose conversion coefficient and is calculated by Equation (3) as effective dose per unit potential alpha exposure in unit of Sv per J h m^{-3} or in unit of Sv per WLM (1 WLM=3.54×10^{-3} J h m^{-3}. One WLM equals about 6.37×10^{5} Bq h m^{-3} of equilibrium equivalent concentration (EEC) of ^{222}Rn):

$$E \ \ (Sv \ \ per \ \ WLM) = \sum_{i=1}^{3}\sum_{j=1}^{4} C_{j,i} \ \ B \ \ t \ \ f_{pj} \ \ E_{j,i} \quad (4)$$

The index i corresponds to inhaled radon progeny; i =1, 2, and 3, for the ^{218}Po, ^{214}Pb and ^{214}Bi respectively. Index j corresponds to the aerosol mode of the activity size distribution; j=1, 2, 3 and 4 for the unattached, nucleation, accumulation and coarse modes respectively. The symbol $C_{j,i}$ is the activity concentration of the decay product i and activity size distribution j corresponding to a radon progeny mixture of 1 WL (Table 1), B is the average breathing rate for each age group, t is taken as the exposure period of 170 h, f_{pj} is fraction of the PAEC associated with mode j and $E_{j,i}$ is the effective dose coefficient for decay product i with an activity size distribution for mode j.

3. Results and discussion

Equivalent dose and effective dose of short-lived radon progeny, ^{210}Po, ^{214}Pb, ^{214}Bi, ^{214}Po in unattached mode (1 nm) and attached modes (50 nm, 230 nm and 2500 nm) for members of the public of eight age groups were presented in Tables A1-A16 in the Appendix. The dose coefficients of the short-lived radon progeny with “mixed” activity diameters were presented in Tables 2-4. For each radon progeny equivalent doses to ET airways and the lungs were greater than other organs. For progeny in activity sizes of 1 nm, 50 nm and 230 nm, the equivalent doses to ET airways are usually lower than the lungs, whereas for progeny in size of 2500 nm, it varies inversely. Bone surfaces and kidneys can be classified as more sensitivity organs due to high organ equivalent doses received. The highest effective dose of short-lived radon progeny was found at unattached mode of 1 nm, the lowest effective dose was found at attached mode of 230 nm.

For each short-lived radon progeny and attached aerosol sizes, the effective doses were greatest for infant and decrease with the increase of ages (Fig. 3). In each short-lived radon progeny it can be observed that the highest effective dose is at unattached mode of 1 nm and the lowest at attached aerosol 230 nm.

For adults the lung equivalent dose to ^{218}Po reached 9.8×10^{-8} Sv Bq^{-1} for the unattached mode and it was 2.2 to 5.6 times larger than attached modes. Lung equivalent dose of ^{214}Pb was estimated as 5.2×10^{-7} Sv Bq^{-1} for 1 nm, 2.1×10^{-7} Sv Bq^{-1} for 50 nm, 8.5×10^{-8} Sv Bq^{-1} for 230 nm and 1.1×10^{-7} Sv Bq^{-1} for 2500 nm, respectively. Lung equivalent dose of ^{214}Bi declined from 4.3×10^{-7} Sv Bq^{-1} to 6.7×10^{-8} Sv Bq^{-1} in the order of 1 nm, 50 nm, 2500 nm and 230 nm. Depending on the activity size of radon progeny the lung equivalent dose for infants were in the range 6.4×10^{-8} Sv Bq^{-1} - 4.6×10^{-7} Sv Bq^{-1} for ^{218}Po, 3.3×10^{-7} Sv Bq^{-1} - 2.6×10^{-6} Sv Bq^{-1} for ^{214}Pb, 2.7×10^{-7} Sv Bq^{-1} - 2.3×10^{-6} Sv Bq^{-1} for ^{214}Bi and 4×10^{-14} Sv Bq^{-1} - 3.5×10^{-13} Sv Bq^{-1} for ^{214}Po, respectively.

In the present study, effective dose was separately calculated for male and female of age groups of 15 years old youth and adults. The new ICRP dosimetric model calculates an average effective dose between the female and the male. Table 6 shows a comparison between these two methods. As can be seen in the age group of 15 years old children there is no differences, however for adults differences the effective dose are quite large, for example ^{218}Po effective dose in 230nm mode for male reaches 2.1×10^{-9} Sv Bq^{-1} meanwhile for female reaches 2.9×10^{-9} Sv Bq^{-1}. However, the contribution of effective dose of ^{218}Po to the dose conversion factor is small and therefore a minor effect to the DCF.

Dose coefficients of radon progeny calculated in the present study are compared to the values calculated by Kendall and Smith (2002, 2005) in Table 7. The differences between the two calculations were found in the range from 0% to 32% with an average value of 16%. Kendall and Smith calculated dose coefficients only for two aerosol size modes, 0.6 nm AMTD and 200 nm AMAD; in addition, the transfer rate from lung to blood is different from the present study.

The contributions of each short-lived radon progeny to the effective dose for each age group and aerosol activity size are presented in Table 8. The contribution to effective dose from ^{214}Po is very small than other short-lived radon progeny and can be neglected in the dose assessment. The main dose contributions, say 90%, to the effective dose were attributed to the progeny ^{214}Pb and ^{214}Bi; and other 10% to the progeny ^{218}Po. For the unattached progeny ^{218}Po the contribution to the effective dose is about 7% to 9%, the rest is almost evenly contributed from ^{214}Pb and ^{214}Bi, almost the same situation we can observed in case 230nm size mode. For attached nucleation mode of 50 nm, the ratio of contributions to the effective dose was 1:5:4 for ^{218}Po, ^{214}Pb and ^{214}Bi. In case of activity size of 2500 nm, the contribution of ^{214}Pb to effective dose increases from 37% to 43% as the age increasing, while contribution of ^{214}Bi decreases a bit from 57% to 50%.

The dose conversion factor (DCF) of radon progeny estimated in the present study were 20 mSv WLM^{-1} for 3 months infants, 21 mSv WLM^{-1} for 1 year old, 18 mSv WLM^{-1} for 5 years old, 20 mSv WLM^{-1} for 10 years old, 18 mSv WLM^{-1} for 15 years old male, 16 mSv WLM^{-1} for 15 years old female, 18 mSv WLM^{-1} for adults male and 17 mSv WLM^{-1} for adults female, respectively.

The DCF for adults calculated by other investigations were presented in Table 9 for comparison. Depending on the different models and exposure conditions, the DCF values were ranged from 6 mSv WLM^{-1} to 20 mSv WLM^{-1} (Jacobi and Eisfeld 1980; ICRP 1987; ICRP 1993b; Birchall and James 1994; Marsh and Birchall 2000; Porstendörfer 2001; Yu et al. 2001a; Yu et al. 2001b; Marsh et al. 2002; James et al. 2004; Marsh et al. 2005; Mohamed 2005; Lau et al. 2006; Nikezic et al. 2006; UNSCEAR 2008; Marsh et al. 2010; Al Jundi et al. 2011).

This present calculation was performed independently and it follows the ICRP biokinetic models and dosimetric model and represents the state of the art of radon dose calculation. The DCF value of 18 mSv WLM^{-1} is close to the result 20 mSv WLM^{-1} of James et al. (2004) and the value of 15 mSv WLM^{-1} reported by Marsh and Birchall (2000), Marsh et al. (2002), Mohamed (2005), Lau et al. (2006), Nikezic et al. (2006) and Al Jundi et al. (2011). The lower value of 6 mSv WLM^{-1} reported by ICRP (1987) and UNSCEAR (2008) was based on the calculation of Jacobi and Eisfeld (1980) and it is known that the authors neglected the contribution from the unattached progeny. Therefore the present study supports a DCF at the higher end of the range of values as most of the recent investigations.

4. Conclusion

In the present work, the age-dependent inhalation doses to members of the public exposed to indoor short-lived radon decay products, ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po were calculated. The equivalent doses to ET airways and the lungs were greater than that to other organs. The contribution to effective dose from ^{214}Po is very small comparing to other short-lived radon progeny and can be neglected in the dose assessment. About 90% of effective dose from short-lived radon progeny is attributed to ^{214}Pb and ^{214}Bi, the other 10% to ^{218}Po. The dose conversion coefficient per unit exposure of radon progeny calculated in the present study was 18 mSv WLM^{-1} which was in the range of 6 to 20 mSv WLM^{-1} calculated by other investigators. The dose coefficients and dose conversion coefficient calculated can be used to estimate the radiation doses of population, especially for small children and women, in specific regions exposed to radon progeny by measuring their concentration, aerosol size and unattached fraction.

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Appendix A. Age-dependent dose coefficients for members of the public exposed to short-lived radon progeny

In this appendix, the age-dependent dose coefficients (Sv Bq^{-1}) for members of the public exposed to short-lived radon progeny, i.e. ^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po as unattached mode (1 nm) and as attached aerosols in the nucleation (50 nm), accumulation (230 nm) and coarse (2500 nm) modes were presented in Tables A1-A16.

Appendix B. Calculation of the radon dose conversion factor (DCF) from individual dose coefficients of progeny

In the calculation of dose conversion coefficients, the following steps were performed:

1. The dose coefficient per potential alpha energy was firstly calculated;
2. The contribution of each progeny in each state to the potential alpha energy was calculated, according to the ratios of concentrations of the nuclides and the size modes;
3. The dose contribution per exposure of each progeny in each state was calculated;
4. Summing up all the contributions.

Furthermore, the ratio of the activity concentrations in the air is assumed as following (cf. table 1):

^{218}Po : ^{214}Pb : ^{214}Bi =: 1 : 0.1 : 0 (unattached)

^{218}Po : ^{214}Pb : ^{214}Bi =: 1 : 0.75 : 0.6 (attached)

The ratio of the four activity size modes (unattached to coarse) is assumed as following:

1 nm : 50 nm : 230 nm :2500 nm = 0.1 : 0.135 : 0.747 : 0.018

The dose coefficients (Sv Bq^{-1}) are summarized in following table:

Size (nm)	^{218}Po	^{214}Pb	^{214}Bi
1	1.2×10^{-8}	6.3×10^{-8}	6.5×10^{-8}
50	5.5×10^{-9}	2.6×10^{-8}	2.0×10^{-8}
230	2.1×10^{-9}	1.0×10^{-8}	9.9×10^{-9}
2500	3.1×10^{-9}	1.8×10^{-8}	2.0×10^{-8}

For a convenient application in practical, the dose conversion coefficients of radon progeny are calculated in the units of Sv (J m^{-3} h)$^{-1}$ and Sv WLM^{-1}:

$$1\ \text{WL} = 2.08\times10^{-5}\ \text{J m}^{-3}$$

$$1\ \text{WLM} = 2.08\times10^{-5}\ \text{J m}^{-3}\times170\ \text{h} = 3.54\times10^{-3}\ \text{J m}^{-3}\ \text{h}$$

DCF in Sv (J m^{-3} h)$^{-1}$

1. DC_{ij} in Sv J^{-1}:

	^{218}Po	^{214}Pb	^{214}Bi
1	20.3	22.0	30.6
50	9.3	9.1	9.4
230	3.6	3.5	4.7
2500	5.2	6.3	9.4

2. Contribution of the nuclides to a concentration of 1 J m^{-3}: C_{ij} in J m^{-3}

	^{218}Po	^{214}Pb	^{214}Bi	Sum
1	0.0674	0.0326	0	0.1
50	0.0199	0.0722	0.0429	0.135
320	0.110	0.400	0.238	0.747
2500	0.00265	0.00963	0.00572	0.018

3. Contribution to dose from each nuclide in each state:
$DC_{ij} \times C_{ij}$ gives Sv per m^3 of inhaled air
$DC_{ij} \times C_{ij} \times B$ gives Sv per h of exposure at a concentration of 1 J m^{-3}

d_{ij} in Sv h^{-1}:

	^{218}Po	^{214}Pb	^{214}Bi
1	1.07	0.560	0
50	0.144	0.512	0.315
320	0.305	1.09	0.863
2500	0.0108	0.0472	0.0420

4. Total dose for an exposure of 1 J m^{-3} h is calculated as:

DCF in Sv WLM^{-1}

1. DC_{ij} in Sv (WL m^{3})$^{-1}$:

	^{218}Po	^{214}Pb	^{214}Bi
1	4.22×10^{-4}	4.58×10^{-4}	6.36×10^{-4}
50	1.93×10^{-4}	1.89×10^{-4}	1.96×10^{-4}
230	7.49×10^{-5}	7.28×10^{-5}	9.78×10^{-5}
2500	1.08×10^{-4}	1.31×10^{-4}	1.96×10^{-4}

2. Contribution of the nuclides to an exposure of 1 WL: C_{ij} in WL

	^{218}Po	^{214}Pb	^{214}Bi	sum
1	0.0674	0.0326	0	0.1
50	0.0199	0.0722	0.0429	0.135
320	0.110	0.400	0.238	0.747
2500	0.00265	0.00963	0.00572	0.018

3. Contribution to dose from each nuclide in each state:
$DC_{ij} \times C_{ij}$ gives Sv per m^3 of inhaled air
$DC_{ij} \times C_{ij} \times B$ gives Sv per h of exposure at a concentration of 1 WL

d_{ij} in Sv h^{-1}:

	^{218}Po	^{214}Pb	^{214}Bi
1	2.22×10^{-5}	1.17×10^{-5}	0
50	3.00×10^{-6}	1.06×10^{-5}	6.55×10^{-6}
320	6.34×10^{-6}	2.27×10^{-5}	1.80×10^{-5}
2500	2.25×10^{-7}	9.83×10^{-5}	8.74×10^{-7}

4. Total dose for an exposure of 1 WL h is calculated as:

$d = \sum_{i=1}^{3}\sum_{j=1}^{4} d_{i,j}$ d = 4.96 Sv h^{-1} for a concentration of 1 J m^{-3} → DCC = 4.96 Sv (J m^{-3} h)$^{-1}$	$d = \sum_{i=1}^{3}\sum_{j=1}^{4} d_{i,j}$ d = 1.03×10^{-4} Sv h^{-1} for a concentration of 1 WL exposure time: 170 h → DCF =17.5 mSv (WL 170 h)$^{-1}$ = = 17.5 mSv WLM^{-1}

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Figures

Figure 1. Generation and decay scheme of ^{222}Ra daughters.

Figure 2. Combines Human Respiratory Track Model, Human Alimentary Track Model and systematic models using in present studies. ET_1 – extrathoraicic region, ET_2 – posterior nasal passages, $LN_{ET,TH}$ – lymph nodes, BB – bronchial, bb – bronchiolar, AI – alveolar interstitial.

Figure 3. Effective dose (Sv Bq^{-1}) of ^{214}Pb as a function of age and particle activity size.

Figures 1

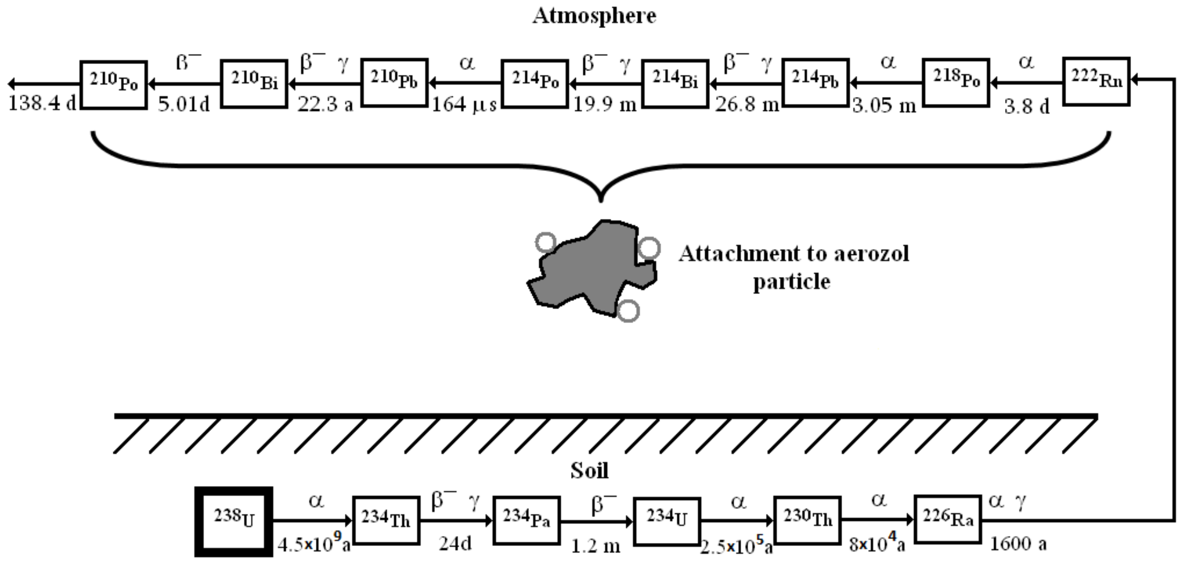
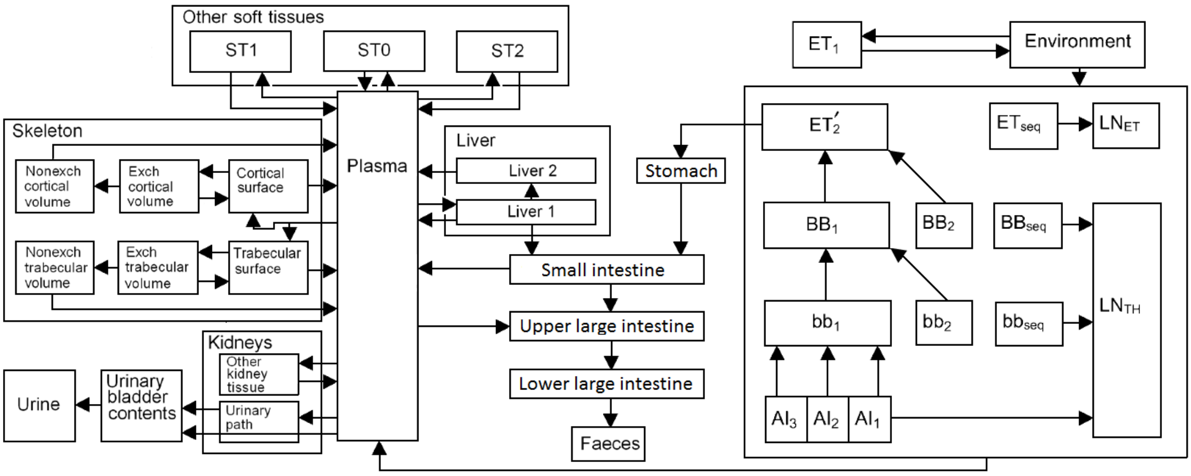

Atmosphere
138.4 d
210Po
β⁻
5.01d
210Bi
β⁻ γ
22.3 a
210Pb
α
164 μs
214Po
β⁻ γ
19.9 m
214Bi
β⁻ γ
26.8 m
214Pb
α
3.05 m
218Po
α
3.8 d
222Rn
Attachment to aerozol particle
Soil
238U
α
4.5×10⁹a
234Th
β⁻ γ
24d
234Pa
β⁻
1.2 m
234U
α
2.5×10⁵a
230Th
α
8×10⁴a
226Ra
α γ
1600 a

Figure 2


Other soft tissues
ST1
ST0
ST2
Skeleton
Nonexch cortical volume
Exch cortical volume
Cortical surface
Nonexch trabecular volume
Exch trabecular volume
Trabecular surface
Plasma
Liver
Liver 2
Liver 1
Kidneys
Other kidney tissue
Urinary path
Urinary bladder contents
Urine
Stomach
Small intestine
Upper large intestine
Lower large intestine
Faeces
ET_1
Environment
ET_2'
ET_{seq}
LN_{ET}
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BB_2
BB_{seq}
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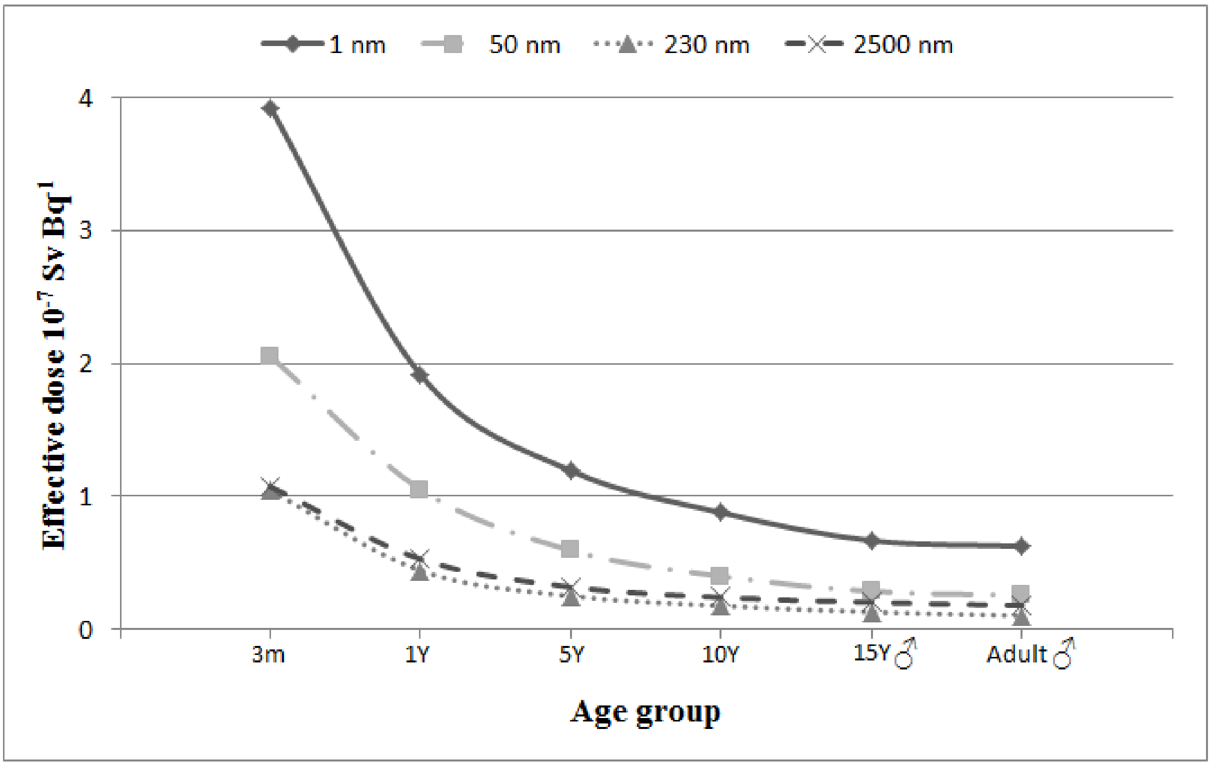
AI_3
AI_2
AI_1

Figure 3


1 nm
50 nm
230 nm
2500 nm
4
3
2
1
0
Effective dose 10-7 Sv Bq-1
3m
1Y
5Y
10Y
15Y♂
Adult♂
Age group

Tables

Table 1. Activity concentrations, $C_{j,i}$ of a mixture of short-lived ^{222}Rn progeny that gives a concentration of 1 WL for either the unattached or the attached progeny.

j	diameter	f_{pj}	$C_{j,i}$ (Bq m^{-3})		
			^{218}Po (i=1)	^{214}Pb (i=2)	^{214}Bi (i=3)
1	1 nm	0.1	2.41×10^4	2.41×10^3	0
2	50 nm	0.135			
3	230 nm	0.747	5.21×10^3	3.91×10^3	3.13×10^3
4	2500 nm	0.018			

Table 2. Inhalation dose coefficients (Sv Bq^{-1}) of ^{218}Po for "mixture" diameters as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.1×10^{-11}	1.3×10^{-11}	5.9×10^{-12}	3.2×10^{-12}	1.8×10^{-12}	1.8×10^{-12}	1.4×10^{-12}	2.0×10^{-12}
Bladder wall	3.8×10^{-11}	1.6×10^{-11}	6.8×10^{-12}	4.0×10^{-12}	2.5×10^{-12}	2.6×10^{-12}	2.0×10^{-12}	2.9×10^{-12}
Bone surfaces	4.7×10^{-10}	1.7×10^{-10}	9.6×10^{-11}	7.1×10^{-11}	5.7×10^{-11}	5.7×10^{-11}	2.2×10^{-11}	2.9×10^{-11}
Brain	2.9×10^{-11}	1.2×10^{-11}	5.4×10^{-12}	2.9×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.3×10^{-12}	1.8×10^{-12}
Breasts	3.0×10^{-11}	1.3×10^{-11}	5.8×10^{-12}	3.2×10^{-12}	1.7×10^{-12}	1.8×10^{-12}	1.4×10^{-12}	2.0×10^{-12}
St wall	3.9×10^{-10}	1.2×10^{-10}	5.0×10^{-11}	2.7×10^{-11}	1.6×10^{-11}	1.6×10^{-11}	1.3×10^{-11}	1.4×10^{-11}
SI wall	1.7×10^{-10}	6.7×10^{-11}	2.8×10^{-11}	1.6×10^{-11}	7.9×10^{-12}	8.1×10^{-12}	6.5×10^{-12}	7.4×10^{-12}
ULI wall	8.4×10^{-11}	3.5×10^{-11}	1.5×10^{-11}	8.3×10^{-12}	4.3×10^{-12}	4.3×10^{-12}	3.5×10^{-12}	4.2×10^{-12}
LLI wall	3.5×10^{-11}	1.4×10^{-11}	6.4×10^{-12}	3.5×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	1.5×10^{-12}	2.1×10^{-12}
Kidneys	7.8×10^{-10}	3.0×10^{-10}	1.5×10^{-10}	9.2×10^{-11}	6.2×10^{-11}	6.3×10^{-11}	5.4×10^{-11}	6.2×10^{-11}
Liver	7.7×10^{-11}	3.7×10^{-11}	1.7×10^{-11}	9.7×10^{-12}	5.6×10^{-12}	5.7×10^{-12}	5.0×10^{-12}	6.7×10^{-12}
Lung	2.1×10^{-7}	1.1×10^{-7}	6.6×10^{-8}	4.7×10^{-8}	3.3×10^{-8}	3.5×10^{-8}	2.9×10^{-8}	3.7×10^{-8}
ET	1.4×10^{-7}	5.7×10^{-8}	2.4×10^{-8}	1.5×10^{-8}	9.1×10^{-9}	9.2×10^{-9}	8.7×10^{-9}	1.0×10^{-8}
Muscle	3.0×10^{-11}	1.3×10^{-11}	5.7×10^{-12}	3.1×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.9×10^{-12}
Ovaries	3.1×10^{-11}	1.3×10^{-11}	5.7×10^{-12}	3.1×10^{-12}	-	1.7×10^{-12}	-	1.9×10^{-12}
Pancreas	3.2×10^{-11}	1.4×10^{-11}	6.1×10^{-12}	3.4×10^{-12}	1.9×10^{-12}	1.9×10^{-12}	1.5×10^{-12}	2.1×10^{-12}
Red marrow	8.3×10^{-11}	2.3×10^{-11}	9.8×10^{-12}	6.7×10^{-12}	4.9×10^{-12}	5.0×10^{-12}	2.9×10^{-12}	3.6×10^{-12}
Skin	2.9×10^{-11}	1.2×10^{-11}	5.4×10^{-12}	3.0×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.3×10^{-12}	1.8×10^{-12}
Spleen	3.4×10^{-11}	1.6×10^{-11}	7.6×10^{-12}	4.6×10^{-12}	2.7×10^{-12}	2.8×10^{-12}	8.7×10^{-11}	2.2×10^{-12}
Testes	2.9×10^{-11}	1.2×10^{-11}	5.3×10^{-12}	2.9×10^{-12}	1.6×10^{-12}	-	1.2×10^{-12}	-
Thymus	3.2×10^{-11}	1.4×10^{-11}	6.1×10^{-12}	3.3×10^{-12}	1.8×10^{-12}	1.9×10^{-12}	1.5×10^{-12}	2.1×10^{-12}
Thyroid	3.0×10^{-11}	1.2×10^{-11}	5.6×10^{-12}	3.0×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	1.3×10^{-12}	1.9×10^{-12}
GB wall	3.1×10^{-11}	1.3×10^{-11}	5.9×10^{-12}	3.2×10^{-12}	1.7×10^{-12}	1.8×10^{-12}	1.4×10^{-12}	2.0×10^{-12}
HT wall	3.2×10^{-11}	1.4×10^{-11}	6.1×10^{-12}	3.4×10^{-12}	1.9×10^{-12}	2.0×10^{-12}	1.5×10^{-12}	2.2×10^{-12}
Uterus	3.0×10^{-11}	1.3×10^{-11}	5.7×10^{-12}	3.1×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	1.4×10^{-12}	1.9×10^{-12}
Remainder	3.5×10^{-9}	1.5×10^{-9}	6.9×10^{-10}	4.0×10^{-10}	2.4×10^{-10}	2.4×10^{-10}	2.3×10^{-10}	2.7×10^{-10}
Colon	6.3×10^{-11}	2.6×10^{-11}	1.1×10^{-11}	6.3×10^{-12}	3.2×10^{-12}	3.3×10^{-12}	2.6×10^{-12}	3.3×10^{-12}
Effective Dose	2.5×10^{-8}	1.6×10^{-8}	7.9×10^{-9}	5.6×10^{-9}	4.0×10^{-9}	4.2×10^{-9}	3.5×10^{-9}	4.4×10^{-9}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table 3. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Pb for "mixture" diameters as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	2.3×10^{-10}	9.7×10^{-11}	4.4×10^{-11}	2.4×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.3×10^{-11}	1.5×10^{-11}
Bladder wall	2.9×10^{-10}	1.2×10^{-10}	5.2×10^{-11}	3.1×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.7×10^{-11}	2.2×10^{-11}
Bone surfaces	3.6×10^{-9}	1.3×10^{-9}	7.5×10^{-10}	5.6×10^{-10}	4.8×10^{-10}	4.8×10^{-10}	1.7×10^{-10}	2.3×10^{-10}
Brain	2.1×10^{-10}	8.9×10^{-11}	4.0×10^{-11}	2.2×10^{-11}	1.2×10^{-11}	1.2×10^{-11}	1.1×10^{-11}	1.4×10^{-11}
Breasts	2.2×10^{-10}	9.6×10^{-11}	4.4×10^{-11}	2.4×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.2×10^{-11}	1.5×10^{-11}
St wall	2.7×10^{-9}	8.6×10^{-10}	3.5×10^{-10}	1.9×10^{-10}	1.1×10^{-10}	1.2×10^{-10}	9.3×10^{-11}	1.0×10^{-10}
SI wall	1.3×10^{-9}	5.3×10^{-10}	2.2×10^{-10}	1.3×10^{-10}	6.3×10^{-11}	6.4×10^{-11}	5.3×10^{-11}	5.8×10^{-11}
ULI wall	6.5×10^{-10}	2.7×10^{-10}	1.2×10^{-10}	6.5×10^{-11}	3.3×10^{-11}	3.4×10^{-11}	2.9×10^{-11}	3.2×10^{-11}
LLI wall	2.6×10^{-10}	1.1×10^{-10}	4.8×10^{-11}	2.6×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.3×10^{-11}	1.6×10^{-11}
Kidneys	6.4×10^{-9}	2.5×10^{-9}	1.2×10^{-9}	7.6×10^{-10}	5.2×10^{-10}	5.2×10^{-10}	4.5×10^{-10}	5.1×10^{-10}
Liver	6.0×10^{-10}	2.9×10^{-10}	1.3×10^{-10}	7.6×10^{-11}	4.4×10^{-11}	4.5×10^{-11}	4.1×10^{-11}	5.2×10^{-11}
Lung	1.0×10^{-6}	5.5×10^{-7}	3.2×10^{-7}	2.3×10^{-7}	1.7×10^{-7}	1.7×10^{-7}	1.5×10^{-7}	1.8×10^{-7}
ET	9.7×10^{-7}	4.1×10^{-7}	1.7×10^{-7}	1.1×10^{-7}	6.5×10^{-8}	6.6×10^{-8}	6.2×10^{-8}	7.1×10^{-8}
Muscle	2.2×10^{-10}	9.4×10^{-11}	4.3×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.2×10^{-11}	1.5×10^{-11}
Ovaries	2.2×10^{-10}	9.5×10^{-11}	4.3×10^{-11}	2.4×10^{-11}	-	1.3×10^{-11}	-	1.5×10^{-11}
Pancreas	2.4×10^{-10}	1.0×10^{-10}	4.6×10^{-11}	2.6×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	1.3×10^{-11}	1.6×10^{-11}
Red marrow	6.3×10^{-10}	1.7×10^{-10}	7.5×10^{-11}	5.2×10^{-11}	4.0×10^{-11}	4.0×10^{-11}	2.4×10^{-11}	2.8×10^{-11}
Skin	2.1×10^{-10}	9.0×10^{-11}	4.1×10^{-11}	2.2×10^{-11}	1.2×10^{-11}	1.2×10^{-11}	1.1×10^{-11}	1.4×10^{-11}
Spleen	2.8×10^{-10}	1.3×10^{-10}	5.9×10^{-11}	3.6×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	1.4×10^{-11}	1.7×10^{-11}
Testes	2.1×10^{-10}	8.9×10^{-11}	4.0×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	-	1.1×10^{-11}	-
Thymus	2.4×10^{-10}	1.0×10^{-10}	4.6×10^{-11}	2.5×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.3×10^{-11}	1.6×10^{-11}
Thyroid	2.2×10^{-10}	9.2×10^{-11}	4.2×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.2×10^{-11}	1.4×10^{-11}
GB wall	2.3×10^{-10}	9.7×10^{-11}	4.5×10^{-11}	2.4×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.2×10^{-11}	1.5×10^{-11}
HT wall	2.3×10^{-10}	1.0×10^{-10}	4.7×10^{-11}	2.6×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	1.3×10^{-11}	1.7×10^{-11}
Uterus	2.2×10^{-10}	9.5×10^{-11}	4.3×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.2×10^{-11}	1.4×10^{-11}
Remainder	4.6×10^{-7}	1.1×10^{-8}	4.6×10^{-9}	2.9×10^{-9}	1.7×10^{-9}	1.7×10^{-9}	1.6×10^{-9}	1.9×10^{-9}
Colon	4.8×10^{-10}	2.0×10^{-10}	8.6×10^{-11}	4.8×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	2.2×10^{-11}	2.5×10^{-11}
Effective Dose	1.5×10^{-7}	6.7×10^{-8}	3.9×10^{-8}	2.8×10^{-8}	2.1×10^{-8}	2.1×10^{-8}	1.8×10^{-8}	2.2×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table 4. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Bi for “mixture” diameters as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	8.4×10^{-11}	3.4×10^{-11}	1.6×10^{-11}	9.0×10^{-12}	5.4×10^{-12}	5.4×10^{-12}	4.4×10^{-12}	5.4×10^{-12}
Bladder wall	9.5×10^{-11}	3.8×10^{-11}	1.6×10^{-11}	9.7×10^{-12}	6.4×10^{-12}	6.4×10^{-12}	5.1×10^{-12}	6.4×10^{-12}
Bone surfaces	1.7×10^{-10}	8.1×10^{-11}	5.3×10^{-11}	2.9×10^{-11}	7.7×10^{-11}	7.7×10^{-11}	2.8×10^{-11}	3.7×10^{-11}
Brain	7.5×10^{-11}	2.9×10^{-11}	1.3×10^{-11}	7.5×10^{-12}	4.5×10^{-12}	4.6×10^{-12}	3.7×10^{-12}	4.5×10^{-12}
Breasts	8.3×10^{-11}	3.3×10^{-11}	1.6×10^{-11}	9.1×10^{-12}	5.3×10^{-12}	5.3×10^{-12}	4.3×10^{-12}	5.2×10^{-12}
St wall	1.8×10^{-9}	5.5×10^{-10}	2.3×10^{-10}	1.2×10^{-10}	7.4×10^{-11}	7.5×10^{-11}	5.9×10^{-11}	6.5×10^{-11}
SI wall	4.6×10^{-10}	1.8×10^{-10}	7.6×10^{-11}	4.3×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	1.8×10^{-11}	2.0×10^{-11}
ULI wall	1.7×10^{-10}	6.7×10^{-11}	2.9×10^{-11}	1.7×10^{-11}	9.0×10^{-12}	9.1×10^{-12}	7.3×10^{-12}	8.4×10^{-12}
LLI wall	8.2×10^{-11}	3.2×10^{-11}	1.4×10^{-11}	8.1×10^{-12}	4.7×10^{-12}	4.8×10^{-12}	3.8×10^{-12}	4.6×10^{-12}
Kidneys	4.2×10^{-9}	1.6×10^{-9}	7.8×10^{-10}	4.9×10^{-10}	3.4×10^{-10}	3.5×10^{-10}	2.8×10^{-10}	3.2×10^{-10}
Liver	1.0×10^{-10}	4.8×10^{-11}	2.2×10^{-11}	1.3×10^{-11}	8.8×10^{-12}	8.9×10^{-12}	5.3×10^{-12}	6.7×10^{-12}
Lung	8.4×10^{-7}	4.5×10^{-7}	2.6×10^{-7}	1.8×10^{-7}	1.4×10^{-7}	1.4×10^{-7}	1.2×10^{-7}	1.4×10^{-7}
ET	1.9×10^{-6}	8.1×10^{-7}	3.4×10^{-7}	2.1×10^{-7}	1.3×10^{-7}	1.3×10^{-7}	1.2×10^{-7}	1.4×10^{-7}
Muscle	8.2×10^{-11}	3.2×10^{-11}	1.5×10^{-11}	8.3×10^{-12}	5.0×10^{-12}	5.0×10^{-12}	4.0×10^{-12}	4.9×10^{-12}
Ovaries	7.9×10^{-11}	3.1×10^{-11}	1.4×10^{-11}	7.9×10^{-12}	-	4.6×10^{-12}	-	4.6×10^{-12}
Pancreas	8.9×10^{-11}	3.6×10^{-11}	1.7×10^{-11}	9.8×10^{-12}	5.9×10^{-12}	6.0×10^{-12}	4.8×10^{-12}	5.9×10^{-12}
Red marrow	9.6×10^{-11}	4.0×10^{-11}	1.8×10^{-11}	1.0×10^{-11}	9.1×10^{-12}	9.1×10^{-12}	5.6×10^{-12}	6.6×10^{-12}
Skin	7.6×10^{-11}	3.0×10^{-11}	1.3×10^{-11}	7.6×10^{-12}	4.5×10^{-12}	4.5×10^{-12}	3.7×10^{-12}	4.5×10^{-12}
Spleen	1.5×10^{-10}	6.8×10^{-11}	3.2×10^{-11}	1.9×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	6.6×10^{-12}	8.0×10^{-12}
Testes	7.4×10^{-11}	2.8×10^{-11}	1.3×10^{-11}	7.1×10^{-12}	4.2×10^{-12}	-	3.4×10^{-12}	-
Thymus	9.6×10^{-11}	3.9×10^{-11}	1.7×10^{-11}	1.0×10^{-11}	5.8×10^{-12}	5.8×10^{-12}	4.7×10^{-12}	5.8×10^{-12}
Thyroid	7.8×10^{-11}	3.1×10^{-11}	1.4×10^{-11}	8.1×10^{-12}	4.9×10^{-12}	4.9×10^{-12}	4.0×10^{-12}	4.8×10^{-12}
GB wall	8.5×10^{-11}	3.3×10^{-11}	1.5×10^{-11}	8.6×10^{-12}	4.9×10^{-12}	4.9×10^{-12}	4.0×10^{-12}	4.8×10^{-12}
HT wall	9.0×10^{-11}	3.7×10^{-11}	1.7×10^{-11}	1.0×10^{-11}	6.3×10^{-12}	6.3×10^{-12}	5.0×10^{-12}	6.3×10^{-12}
Uterus	7.8×10^{-11}	3.1×10^{-11}	1.4×10^{-11}	7.8×10^{-12}	4.6×10^{-12}	4.6×10^{-12}	3.7×10^{-12}	4.5×10^{-12}
Remainder	9.1×10^{-7}	3.9×10^{-7}	1.6×10^{-7}	1.0×10^{-7}	3.2×10^{-8}	3.2×10^{-8}	5.8×10^{-8}	3.4×10^{-8}
Colon	1.3×10^{-10}	5.2×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	7.2×10^{-12}	7.2×10^{-12}	5.8×10^{-12}	6.8×10^{-12}
Effective Dose	1.5×10^{-7}	7.3×10^{-8}	4.0×10^{-8}	2.7×10^{-8}	1.8×10^{-8}	1.8×10^{-8}	1.7×10^{-8}	1.9×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table 5. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Po for “mixture” diameters as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Bladder wall	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.8×10^{-20}	1.6×10^{-20}
Bone surfaces	1.3×10^{-17}	7.1×10^{-18}	5.5×10^{-18}	6.9×10^{-18}	9.9×10^{-18}	9.9×10^{-18}	9.0×10^{-18}	4.5×10^{-18}
Brain	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Breasts	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
St wall	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
SI wall	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
ULI wall	3.8×10^{-19}	1.9×10^{-19}	8.4×10^{-20}	5.3×10^{-20}	3.5×10^{-20}	3.5×10^{-20}	2.8×10^{-20}	1.7×10^{-20}
LLI wall	3.9×10^{-19}	2.0×10^{-19}	8.8×10^{-20}	5.5×10^{-20}	3.6×10^{-20}	3.6×10^{-20}	2.9×10^{-20}	1.7×10^{-20}
Kidneys	1.1×10^{-17}	5.5×10^{-18}	2.7×10^{-18}	1.9×10^{-18}	1.5×10^{-18}	1.5×10^{-18}	1.2×10^{-18}	6.6×10^{-19}
Liver	6.2×10^{-18}	3.3×10^{-18}	1.5×10^{-18}	1.0×10^{-18}	7.3×10^{-19}	7.3×10^{-19}	5.7×10^{-19}	3.7×10^{-19}
Lung	1.2×10^{-13}	6.6×10^{-14}	3.8×10^{-14}	2.7×10^{-14}	2.0×10^{-14}	2.0×10^{-14}	1.7×10^{-14}	2.1×10^{-14}
ET	7.1×10^{-13}	3.1×10^{-13}	1.3×10^{-13}	8.0×10^{-14}	4.7×10^{-14}	4.8×10^{-14}	4.5×10^{-14}	5.2×10^{-14}
Muscle	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Ovaries	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	-	3.4×10^{-20}	2.7×10^{-20}	-
Pancreas	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Red marrow	5.8×10^{-18}	2.5×10^{-18}	1.2×10^{-18}	8.8×10^{-19}	7.5×10^{-19}	7.5×10^{-19}	5.6×10^{-19}	4.2×10^{-19}
Skin	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Spleen	1.2×10^{-17}	5.8×10^{-18}	2.8×10^{-18}	1.8×10^{-18}	1.3×10^{-18}	1.3×10^{-18}	8.9×10^{-19}	5.1×10^{-19}
Testes	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	-	2.7×10^{-20}	-
Thymus	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Thyroid	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
GB wall	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
HT wall	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Uterus	3.7×10^{-19}	1.8×10^{-19}	8.2×10^{-20}	5.2×10^{-20}	3.4×10^{-20}	3.4×10^{-20}	2.7×10^{-20}	1.6×10^{-20}
Remainder	3.4×10^{-13}	1.5×10^{-13}	6.1×10^{-14}	3.8×10^{-14}	2.3×10^{-14}	2.3×10^{-14}	2.2×10^{-14}	2.4×10^{-14}
Colon	3.8×10^{-19}	1.9×10^{-19}	8.6×10^{-20}	5.4×10^{-20}	3.5×10^{-20}	3.5×10^{-20}	2.8×10^{-20}	1.7×10^{-20}
Effective Dose	3.2×10^{-14}	1.5×10^{-14}	7.6×10^{-15}	5.2×10^{-15}	3.5×10^{-15}	3.6×10^{-15}	3.1×10^{-15}	3.8×10^{-15}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table 6

Isotopes	Diameter	Effective dose Sv Bq^{-1}					
		15 y ♂	15 y ♀	average	Adult ♂	Adult ♀	average
^{218}Po	1nm	1.1×10^{-8}	1.2×10^{-8}	1.2×10^{-8}	1.2×10^{-8}	1.3×10^{-8}	1.2×10^{-8}
	50nm	6.1×10^{-9}	6.3×10^{-9}	6.2×10^{-9}	5.5×10^{-9}	6.5×10^{-9}	6.0×10^{-9}
	230nm	2.7×10^{-9}	2.8×10^{-9}	2.7×10^{-9}	2.1×10^{-9}	2.9×10^{-9}	2.5×10^{-9}
	2500nm	3.7×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	3.3×10^{-9}	3.6×10^{-9}	3.5×10^{-9}
^{214}Pb	1nm	6.7×10^{-8}	6.7×10^{-8}	6.7×10^{-8}	6.3×10^{-8}	6.8×10^{-8}	6.5×10^{-8}
	50nm	2.9×10^{-8}	3.0×10^{-8}	2.9×10^{-8}	2.6×10^{-8}	3.1×10^{-8}	2.8×10^{-8}
	230nm	1.3×10^{-8}	1.3×10^{-8}	1.3×10^{-8}	1.0×10^{-8}	1.4×10^{-8}	1.2×10^{-8}
	2500nm	2.0×10^{-8}	2.0×10^{-8}	2.0×10^{-8}	1.8×10^{-8}	2.0×10^{-8}	1.9×10^{-8}
^{214}Bi	1nm	7.0×10^{-8}	7.0×10^{-8}	7.0×10^{-8}	6.5×10^{-8}	7.2×10^{-8}	6.9×10^{-8}
	50nm	2.2×10^{-8}	2.3×10^{-8}	2.3×10^{-8}	2.0×10^{-8}	2.4×10^{-8}	2.2×10^{-8}
	230nm	1.0×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	9.9×10^{-9}	1.1×10^{-8}	1.0×10^{-8}
	2500nm	2.3×10^{-8}	2.3×10^{-8}	2.3×10^{-8}	2.0×10^{-8}	2.3×10^{-8}	2.2×10^{-8}
^{214}Po	1nm	1.4×10^{-14}	1.4×10^{-14}	1.4×10^{-14}	1.3×10^{-14}	1.4×10^{-14}	1.3×10^{-14}
	50nm	3.2×10^{-15}	3.3×10^{-15}	3.3×10^{-15}	2.9×10^{-15}	3.4×10^{-15}	3.1×10^{-15}
	230nm	2.2×10^{-15}	2.2×10^{-15}	2.2×10^{-15}	1.9×10^{-15}	2.4×10^{-15}	2.1×10^{-15}
	2500nm	5.6×10^{-15}	5.6×10^{-15}	5.6×10^{-15}	5.2×10^{-15}	5.8×10^{-15}	5.5×10^{-15}

Table 7. Dose coefficients (Sv Bq^{-1}) calculated in the present work and comparison to the results by Kendall and Smith (2002; 2005)

	Dose coefficient								
	^{218}Po			^{214}Pb			^{214}Bi		
	Kendall and Smith	Present work	Differences %	Kendall and Smith	Present work	Differences %	Kendall and Smith	Present work	Differences %
	1 year old								
Lung	1.1×10^{-7}	1.1×10^{-7}	0	5.4×10^{-7}	5.5×10^{-7}	2	4.3×10^{-7}	4.5×10^{-7}	4
ET	4.0×10^{-8}	5.7×10^{-8}	30	2.9×10^{-7}	4.1×10^{-7}	29	5.5×10^{-7}	8.1×10^{-7}	32
Effective Dose	1.4×10^{-8}	1.6×10^{-8}	13	6.9×10^{-8}	6.7×10^{-8}	-3	5.8×10^{-8}	7.3×10^{-8}	21
	10 year old								
Lung	4.0×10^{-8}	4.7×10^{-8}	15	2.0×10^{-7}	2.3×10^{-7}	13	1.6×10^{-7}	1.8×10^{-7}	11
ET	1.2×10^{-8}	1.5×10^{-8}	20	8.3×10^{-8}	1.1×10^{-7}	25	1.6×10^{-7}	2.1×10^{-7}	24
Effective Dose	4.9×10^{-9}	5.6×10^{-9}	13	2.4×10^{-8}	2.8×10^{-8}	14	2.1×10^{-8}	2.7×10^{-8}	22
	Adult Male								
Lung	2.7×10^{-8}	2.9×10^{-8}	7	1.3×10^{-7}	1.5×10^{-7}	13	1.1×10^{-7}	1.2×10^{-7}	8
ET	6.7×10^{-9}	8.7×10^{-9}	23	4.8×10^{-8}	6.2×10^{-8}	23	9.3×10^{-8}	1.2×10^{-7}	23
Effective Dose	3.3×10^{-9}	3.6×10^{-9}	8	1.6×10^{-8}	1.8×10^{-8}	11	1.4×10^{-8}	1.7×10^{-8}	18

Table 8. Contribution to effective dose from short-lived radon decay products

Diameter	Isotopes	Contribution (%) to effective dose from short-lived radon decay products							
		3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
1nm	^{218}Po	7.2	7.7	8.1	8.1	7.4	8.1	8.6	8.5
	^{214}Pb	44.1	41.8	44.1	44.4	45.3	45.0	45.0	44.4
	^{214}Bi	48.6	50.5	47.8	47.5	47.3	47.0	46.4	47.1
	^{214}Po	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
50nm	^{218}Po	10.4	8.0	10.9	10.7	10.7	10.6	10.7	10.6
	^{214}Pb	50.8	61.8	49.6	50.3	50.8	50.6	50.5	50.4
	^{214}Bi	38.7	30.2	39.5	39.0	38.5	38.8	38.8	39.0
	^{214}Po	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
230nm	^{218}Po	8.3	8.8	9.3	9.3	10.5	10.9	9.5	10.4
	^{214}Pb	45.9	42.2	44.5	45.3	50.6	50.4	45.5	50.2
	^{214}Bi	45.9	48.9	46.3	45.3	38.9	38.8	45.0	39.4
	^{214}Po	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002
2500nm	^{218}Po	5.7	6.2	6.9	7.5	7.5	7.5	7.5	7.3
	^{214}Pb	37.0	37.9	40.3	41.9	43.0	43.0	43.8	43.1
	^{214}Bi	57.2	55.8	52.8	50.6	49.5	49.5	48.7	49.6
	^{214}Po	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002

Table 9. Dose conversion factor of indoor radon progeny for adults

Dose conversion coefficient ($mSv\ WLM^{-1}$)	Dose conversion coefficient ($nSv\ (J\ m^{-3}\ h)^{-1}$)	Reference
18	64	Present study
6 – 8	21 – 28	Jacobi and Eisfeld 1980
6	21	ICRP 1987
4 – 5	14 – 18	ICRP 1993
13	46	Birchall and James 1994
15	53	Marsh and Birchall 2000
8	28	Porstendörfer 2001
7	25	Yu et al. 2001a
12 and 8	42 and 28	Yu et al. 2001b
15	53	Marsh et al. 2002
20	71	James 2004
13	46	Marsh et al. 2005
15	53	Mohamed 2005
15	53	Lau et al. 2006
15	53	Nikezic et al. 2006
6	21	UNSCEAR 2008
6 – 20	21 – 71	Marsh et al. 2010
15	53	Al Jundi et al. 2011

Table A1. Inhalation dose coefficients (Sv Bq^{-1}) of ^{218}Po for 1 nm AMTD as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.9×10^{-11}	1.8×10^{-11}	8.4×10^{-12}	5.0×10^{-12}	2.6×10^{-12}	2.8×10^{-12}	2.6×10^{-12}	3.1×10^{-12}
Bladder wall	4.8×10^{-11}	2.2×10^{-11}	9.7×10^{-12}	6.1×10^{-12}	3.6×10^{-12}	3.9×10^{-12}	3.5×10^{-12}	4.2×10^{-12}
Bone surfaces	6.9×10^{-10}	2.5×10^{-10}	1.5×10^{-10}	1.2×10^{-10}	9.1×10^{-11}	9.7×10^{-11}	3.7×10^{-11}	4.8×10^{-11}
Brain	3.7×10^{-11}	1.7×10^{-11}	7.8×10^{-12}	4.6×10^{-12}	2.5×10^{-12}	2.7×10^{-12}	2.5×10^{-12}	2.9×10^{-12}
Breasts	3.8×10^{-11}	1.8×10^{-11}	8.3×10^{-12}	4.8×10^{-12}	2.5×10^{-12}	2.7×10^{-12}	2.5×10^{-12}	3.0×10^{-12}
St wall	1.2×10^{-9}	3.6×10^{-10}	1.7×10^{-10}	9.7×10^{-11}	6.6×10^{-11}	6.6×10^{-11}	5.2×10^{-11}	5.7×10^{-11}
SI wall	4.9×10^{-10}	1.9×10^{-10}	9.3×10^{-11}	5.5×10^{-11}	3.1×10^{-11}	3.1×10^{-11}	2.5×10^{-11}	2.7×10^{-11}
ULI wall	2.1×10^{-10}	8.6×10^{-11}	4.2×10^{-11}	2.5×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.2×10^{-11}	1.3×10^{-11}
LLI wall	5.5×10^{-11}	2.4×10^{-11}	1.1×10^{-11}	6.7×10^{-12}	3.7×10^{-12}	3.8×10^{-12}	3.4×10^{-12}	3.9×10^{-12}
Kidneys	8.8×10^{-10}	3.5×10^{-10}	1.9×10^{-10}	1.3×10^{-10}	8.0×10^{-11}	8.7×10^{-11}	7.6×10^{-11}	8.4×10^{-11}
Liver	1.0×10^{-10}	4.8×10^{-11}	2.4×10^{-11}	1.5×10^{-11}	8.3×10^{-12}	8.8×10^{-12}	8.3×10^{-12}	1.0×10^{-11}
Lung	4.6×10^{-7}	2.9×10^{-7}	1.8×10^{-7}	1.4×10^{-7}	9.1×10^{-8}	1.0×10^{-7}	9.8×10^{-8}	1.1×10^{-7}
ET	4.6×10^{-7}	1.9×10^{-7}	9.4×10^{-8}	6.1×10^{-8}	4.1×10^{-8}	4.1×10^{-8}	3.8×10^{-8}	4.4×10^{-8}
Muscle	4.0×10^{-11}	1.9×10^{-11}	8.5×10^{-12}	5.0×10^{-12}	2.7×10^{-12}	2.8×10^{-12}	2.6×10^{-12}	3.1×10^{-12}
Ovaries	4.2×10^{-11}	1.9×10^{-11}	9.1×10^{-12}	5.4×10^{-12}	-	3.1×10^{-12}	-	3.4×10^{-12}
Pancreas	4.3×10^{-11}	2.0×10^{-11}	9.6×10^{-12}	5.8×10^{-12}	3.2×10^{-12}	3.4×10^{-12}	3.1×10^{-12}	3.7×10^{-12}
Red marrow	1.2×10^{-10}	3.1×10^{-11}	1.5×10^{-11}	1.1×10^{-11}	7.9×10^{-12}	8.3×10^{-12}	5.0×10^{-12}	5.8×10^{-12}
Skin	3.7×10^{-11}	1.7×10^{-11}	7.9×10^{-12}	4.6×10^{-12}	2.4×10^{-12}	2.6×10^{-12}	2.4×10^{-12}	2.9×10^{-12}
Spleen	4.6×10^{-11}	1.9×10^{-11}	1.0×10^{-11}	6.7×10^{-12}	3.9×10^{-12}	4.1×10^{-12}	2.8×10^{-12}	3.3×10^{-12}
Testes	3.7×10^{-11}	1.7×10^{-11}	7.7×10^{-12}	4.4×10^{-12}	2.3×10^{-12}	-	2.3×10^{-12}	-
Thymus	4.5×10^{-11}	2.1×10^{-11}	9.4×10^{-12}	5.4×10^{-12}	2.8×10^{-12}	2.9×10^{-12}	2.7×10^{-12}	3.2×10^{-12}
Thyroid	3.7×10^{-11}	1.7×10^{-11}	8.0×10^{-12}	4.7×10^{-12}	2.5×10^{-12}	2.7×10^{-12}	2.5×10^{-12}	3.0×10^{-12}
GB wall	4.3×10^{-11}	2.0×10^{-11}	9.5×10^{-12}	5.5×10^{-12}	2.8×10^{-12}	3.0×10^{-12}	2.7×10^{-12}	3.3×10^{-12}
HT wall	4.0×10^{-11}	1.9×10^{-11}	8.8×10^{-12}	5.1×10^{-12}	2.7×10^{-12}	2.9×10^{-12}	2.7×10^{-12}	3.2×10^{-12}
Uterus	4.1×10^{-11}	1.9×10^{-11}	8.9×10^{-12}	5.3×10^{-12}	2.8×10^{-12}	3.0×10^{-12}	2.7×10^{-12}	3.3×10^{-12}
Remainder	3.5×10^{-10}	1.4×10^{-10}	7.6×10^{-11}	4.1×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	2.3×10^{-11}	3.4×10^{-11}
Colon	1.4×10^{-10}	6.0×10^{-11}	2.9×10^{-11}	1.7×10^{-11}	9.5×10^{-12}	9.7×10^{-12}	8.1×10^{-12}	8.9×10^{-12}
Effective Dose	5.6×10^{-8}	3.5×10^{-8}	2.2×10^{-8}	1.6×10^{-8}	1.1×10^{-8}	1.2×10^{-8}	1.2×10^{-8}	1.3×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A2. Inhalation dose coefficients (Sv Bq^{-1}) of ^{218}Po for 50 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	4.9×10^{-11}	2.0×10^{-11}	8.9×10^{-12}	5.0×10^{-12}	2.8×10^{-12}	2.8×10^{-12}	1.0×10^{-12}	3.2×10^{-12}
Bladder wall	6.1×10^{-11}	2.4×10^{-11}	1.0×10^{-11}	6.3×10^{-12}	4.0×10^{-12}	4.0×10^{-12}	2.0×10^{-12}	4.5×10^{-12}
Bone surfaces	6.8×10^{-10}	2.5×10^{-10}	1.4×10^{-10}	1.1×10^{-10}	8.6×10^{-11}	8.5×10^{-11}	3.3×10^{-11}	4.5×10^{-11}
Brain	4.6×10^{-11}	1.8×10^{-11}	8.1×10^{-12}	4.5×10^{-12}	2.5×10^{-12}	2.5×10^{-12}	7.5×10^{-13}	2.8×10^{-12}
Breasts	4.8×10^{-11}	1.9×10^{-11}	8.9×10^{-12}	5.1×10^{-12}	2.8×10^{-12}	2.8×10^{-12}	1.0×10^{-12}	3.1×10^{-12}
St wall	1.6×10^{-10}	5.0×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	8.4×10^{-12}	8.4×10^{-12}	5.3×10^{-12}	7.9×10^{-12}
SI wall	8.9×10^{-11}	3.4×10^{-11}	1.6×10^{-11}	9.2×10^{-12}	5.0×10^{-12}	5.1×10^{-12}	2.7×10^{-12}	5.0×10^{-12}
ULI wall	6.6×10^{-11}	2.6×10^{-11}	1.2×10^{-11}	6.8×10^{-12}	3.7×10^{-12}	3.7×10^{-12}	1.7×10^{-12}	3.9×10^{-12}
LLI wall	4.8×10^{-11}	1.9×10^{-11}	8.5×10^{-12}	4.8×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	8.4×10^{-13}	2.9×10^{-12}
Kidneys	1.2×10^{-9}	4.9×10^{-10}	2.4×10^{-10}	1.5×10^{-10}	1.0×10^{-10}	1.0×10^{-10}	9.0×10^{-11}	1.0×10^{-10}
Liver	1.1×10^{-10}	5.5×10^{-11}	2.5×10^{-11}	1.5×10^{-11}	8.8×10^{-12}	8.8×10^{-12}	6.7×10^{-12}	1.0×10^{-11}
Lung	3.6×10^{-7}	1.9×10^{-7}	1.1×10^{-7}	7.1×10^{-8}	5.1×10^{-8}	5.3×10^{-8}	4.6×10^{-8}	5.4×10^{-8}
ET	4.4×10^{-8}	1.7×10^{-8}	8.6×10^{-9}	5.5×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	3.4×10^{-9}	4.0×10^{-9}
Muscle	4.7×10^{-11}	1.9×10^{-11}	8.4×10^{-12}	4.7×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	8.5×10^{-13}	3.0×10^{-12}
Ovaries	4.7×10^{-11}	1.8×10^{-11}	8.3×10^{-12}	4.6×10^{-12}	-	2.5×10^{-12}	-	2.9×10^{-12}
Pancreas	4.9×10^{-11}	2.0×10^{-11}	8.8×10^{-12}	5.0×10^{-12}	2.8×10^{-12}	2.8×10^{-12}	1.0×10^{-12}	3.1×10^{-12}
Red marrow	1.2×10^{-10}	3.3×10^{-11}	1.5×10^{-11}	1.0×10^{-11}	7.6×10^{-12}	7.5×10^{-12}	3.2×10^{-12}	5.6×10^{-12}
Skin	4.6×10^{-11}	1.8×10^{-11}	8.2×10^{-12}	4.6×10^{-12}	2.5×10^{-12}	2.5×10^{-12}	7.8×10^{-13}	2.9×10^{-12}
Spleen	3.5×10^{-11}	2.5×10^{-11}	1.2×10^{-11}	7.2×10^{-12}	4.3×10^{-12}	4.3×10^{-12}	6.3×10^{-10}	3.4×10^{-12}
Testes	4.6×10^{-11}	1.8×10^{-11}	8.1×10^{-12}	4.5×10^{-12}	2.5×10^{-12}	-	7.2×10^{-13}	-
Thymus	4.9×10^{-11}	2.0×10^{-11}	8.9×10^{-12}	5.1×10^{-12}	2.9×10^{-12}	2.9×10^{-12}	1.1×10^{-12}	3.2×10^{-12}
Thyroid	4.7×10^{-11}	1.9×10^{-11}	8.4×10^{-12}	4.7×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	8.4×10^{-13}	2.9×10^{-12}
GB wall	4.8×10^{-11}	1.9×10^{-11}	8.5×10^{-12}	4.8×10^{-12}	2.6×10^{-12}	2.6×10^{-12}	8.6×10^{-13}	3.0×10^{-12}
HT wall	5.0×10^{-11}	2.0×10^{-11}	9.4×10^{-12}	5.4×10^{-12}	3.1×10^{-12}	3.1×10^{-12}	1.2×10^{-12}	3.4×10^{-12}
Uterus	4.7×10^{-11}	1.8×10^{-11}	8.3×10^{-12}	4.6×10^{-12}	2.5×10^{-12}	2.5×10^{-12}	7.7×10^{-13}	2.9×10^{-12}
Remainder	9.8×10^{-11}	3.8×10^{-11}	1.8×10^{-11}	9.8×10^{-12}	5.5×10^{-12}	5.5×10^{-12}	7.2×10^{-12}	7.1×10^{-12}
Colon	5.8×10^{-11}	2.3×10^{-11}	1.0×10^{-11}	5.9×10^{-12}	3.3×10^{-12}	3.3×10^{-12}	1.4×10^{-12}	3.5×10^{-12}
Effective Dose	4.3×10^{-8}	2.2×10^{-8}	1.3×10^{-8}	8.5×10^{-9}	6.1×10^{-9}	6.3×10^{-9}	5.5×10^{-9}	6.5×10^{-9}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A3. Inhalation dose coefficients (Sv Bq^{-1}) of ^{218}Po for 230 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	2.7×10^{-11}	1.1×10^{-11}	5.0×10^{-12}	2.6×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	1.3×10^{-12}	1.7×10^{-12}
Bladder wall	3.3×10^{-11}	1.4×10^{-11}	5.7×10^{-12}	3.3×10^{-12}	2.1×10^{-12}	2.1×10^{-12}	1.8×10^{-12}	2.4×10^{-12}
Bone surfaces	4.0×10^{-10}	1.5×10^{-10}	8.0×10^{-11}	5.8×10^{-11}	4.6×10^{-11}	4.7×10^{-11}	1.8×10^{-11}	2.4×10^{-11}
Brain	2.5×10^{-11}	1.0×10^{-11}	4.5×10^{-12}	2.4×10^{-12}	1.3×10^{-12}	1.3×10^{-12}	1.2×10^{-12}	1.5×10^{-12}
Breasts	2.6×10^{-11}	1.1×10^{-11}	4.9×10^{-12}	2.6×10^{-12}	1.4×10^{-12}	1.5×10^{-12}	1.3×10^{-12}	1.6×10^{-12}
St wall	3.0×10^{-10}	9.7×10^{-11}	3.6×10^{-11}	1.9×10^{-11}	9.9×10^{-12}	1.0×10^{-11}	8.3×10^{-12}	9.1×10^{-12}
SI wall	1.3×10^{-10}	5.4×10^{-11}	2.1×10^{-11}	1.1×10^{-11}	5.1×10^{-12}	5.2×10^{-12}	4.5×10^{-12}	4.9×10^{-12}
ULI wall	6.7×10^{-11}	2.8×10^{-11}	1.1×10^{-11}	6.1×10^{-12}	2.9×10^{-12}	3.0×10^{-12}	2.6×10^{-12}	2.9×10^{-12}
LLI wall	2.9×10^{-11}	1.2×10^{-11}	5.2×10^{-12}	2.8×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	1.4×10^{-12}	1.6×10^{-12}
Kidneys	6.8×10^{-10}	2.6×10^{-10}	1.3×10^{-10}	7.6×10^{-11}	5.2×10^{-11}	5.3×10^{-11}	4.5×10^{-11}	5.2×10^{-11}
Liver	6.7×10^{-11}	3.2×10^{-11}	1.4×10^{-11}	8.0×10^{-12}	4.6×10^{-12}	4.7×10^{-12}	4.2×10^{-12}	5.5×10^{-12}
Lung	1.5×10^{-7}	7.6×10^{-8}	4.4×10^{-8}	3.1×10^{-8}	2.2×10^{-8}	2.3×10^{-8}	1.8×10^{-8}	2.4×10^{-8}
ET	1.0×10^{-7}	4.4×10^{-8}	1.7×10^{-8}	1.0×10^{-8}	5.4×10^{-9}	5.5×10^{-9}	5.2×10^{-9}	6.0×10^{-9}
Muscle	2.6×10^{-11}	1.1×10^{-11}	4.8×10^{-12}	2.5×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.3×10^{-12}	1.6×10^{-12}
Ovaries	2.6×10^{-11}	1.1×10^{-11}	4.8×10^{-12}	2.5×10^{-12}	-	1.4×10^{-12}	-	1.6×10^{-12}
Pancreas	2.7×10^{-11}	1.2×10^{-11}	5.1×10^{-12}	2.7×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	1.4×10^{-12}	1.7×10^{-12}
Red marrow	7.2×10^{-11}	1.9×10^{-11}	8.2×10^{-12}	5.5×10^{-12}	4.0×10^{-12}	4.1×10^{-12}	2.5×10^{-12}	3.0×10^{-12}
Skin	2.5×10^{-11}	1.0×10^{-11}	4.6×10^{-12}	2.4×10^{-12}	1.3×10^{-12}	1.3×10^{-12}	1.2×10^{-12}	1.5×10^{-12}
Spleen	3.2×10^{-11}	1.4×10^{-11}	6.4×10^{-12}	3.8×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	1.5×10^{-12}	1.8×10^{-12}
Testes	2.5×10^{-11}	1.0×10^{-11}	4.5×10^{-12}	2.4×10^{-12}	1.3×10^{-12}	-	1.2×10^{-12}	-
Thymus	2.7×10^{-11}	1.2×10^{-11}	5.1×10^{-12}	2.7×10^{-12}	1.5×10^{-12}	1.5×10^{-12}	1.4×10^{-12}	1.7×10^{-12}
Thyroid	2.5×10^{-11}	1.1×10^{-11}	4.7×10^{-12}	2.5×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.3×10^{-12}	1.6×10^{-12}
GB wall	2.7×10^{-11}	1.1×10^{-11}	4.9×10^{-12}	2.6×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.3×10^{-12}	1.6×10^{-12}
HT wall	2.7×10^{-11}	1.2×10^{-11}	5.2×10^{-12}	2.8×10^{-12}	1.6×10^{-12}	1.6×10^{-12}	1.4×10^{-12}	1.8×10^{-12}
Uterus	2.6×10^{-11}	1.1×10^{-11}	4.8×10^{-12}	2.5×10^{-12}	1.4×10^{-12}	1.4×10^{-12}	1.3×10^{-12}	1.6×10^{-12}
Remainder	1.0×10^{-10}	4.2×10^{-11}	1.8×10^{-11}	9.2×10^{-12}	4.6×10^{-12}	4.7×10^{-12}	4.2×10^{-12}	6.3×10^{-12}
Colon	5.1×10^{-11}	2.1×10^{-11}	8.7×10^{-12}	4.7×10^{-12}	2.3×10^{-12}	2.4×10^{-12}	2.1×10^{-12}	2.4×10^{-12}
Effective Dose	1.8×10^{-8}	1.2×10^{-8}	5.2×10^{-9}	3.7×10^{-9}	2.7×10^{-9}	2.8×10^{-9}	2.1×10^{-9}	2.9×10^{-9}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A4. Inhalation dose coefficients (Sv Bq^{-1}) of ^{218}Po for 2500 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.1×10^{-11}	1.4×10^{-11}	6.8×10^{-12}	4.0×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	2.1×10^{-12}	2.5×10^{-12}
Bladder wall	3.9×10^{-11}	1.6×10^{-11}	7.8×10^{-12}	5.0×10^{-12}	3.2×10^{-12}	3.2×10^{-12}	2.8×10^{-12}	3.5×10^{-12}
Bone surfaces	5.6×10^{-10}	2.0×10^{-10}	1.2×10^{-10}	9.7×10^{-11}	7.7×10^{-11}	7.7×10^{-11}	3.0×10^{-11}	3.9×10^{-11}
Brain	3.0×10^{-11}	1.3×10^{-11}	6.3×10^{-12}	3.7×10^{-12}	2.1×10^{-12}	2.1×10^{-12}	2.0×10^{-12}	2.3×10^{-12}
Breasts	3.1×10^{-11}	1.3×10^{-11}	6.6×10^{-12}	3.9×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	2.0×10^{-12}	2.4×10^{-12}
St wall	1.1×10^{-9}	3.2×10^{-10}	1.4×10^{-10}	7.5×10^{-11}	4.6×10^{-11}	4.6×10^{-11}	3.7×10^{-11}	4.0×10^{-11}
SI wall	4.3×10^{-10}	1.7×10^{-10}	7.4×10^{-11}	4.3×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	1.8×10^{-11}	1.9×10^{-11}
ULI wall	1.9×10^{-10}	7.4×10^{-11}	3.4×10^{-11}	1.9×10^{-11}	1.0×10^{-11}	1.0×10^{-11}	8.5×10^{-12}	9.1×10^{-12}
LLI wall	4.6×10^{-11}	1.9×10^{-11}	9.2×10^{-12}	5.4×10^{-12}	2.9×10^{-12}	2.9×10^{-12}	2.7×10^{-12}	3.0×10^{-12}
Kidneys	7.0×10^{-10}	2.8×10^{-10}	1.5×10^{-10}	1.0×10^{-10}	7.2×10^{-11}	7.2×10^{-11}	6.4×10^{-11}	7.1×10^{-11}
Liver	8.2×10^{-11}	3.9×10^{-11}	2.0×10^{-11}	1.2×10^{-11}	7.2×10^{-12}	7.2×10^{-12}	6.8×10^{-12}	8.5×10^{-12}
Lung	6.4×10^{-8}	3.9×10^{-8}	3.1×10^{-8}	2.6×10^{-8}	2.5×10^{-8}	2.5×10^{-8}	2.2×10^{-8}	2.4×10^{-8}
ET	3.8×10^{-7}	1.6×10^{-7}	6.9×10^{-8}	4.4×10^{-8}	2.6×10^{-8}	2.6×10^{-8}	2.5×10^{-8}	2.8×10^{-8}
Muscle	3.2×10^{-11}	1.4×10^{-11}	6.8×10^{-12}	4.0×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	2.1×10^{-12}	2.5×10^{-12}
Ovaries	3.4×10^{-11}	1.5×10^{-11}	7.3×10^{-12}	4.3×10^{-12}	-	2.4×10^{-12}	-	2.7×10^{-12}
Pancreas	3.5×10^{-11}	1.5×10^{-11}	7.7×10^{-12}	4.7×10^{-12}	2.7×10^{-12}	2.7×10^{-12}	2.4×10^{-12}	2.9×10^{-12}
Red marrow	9.5×10^{-11}	2.5×10^{-11}	1.2×10^{-11}	8.8×10^{-12}	6.7×10^{-12}	6.7×10^{-12}	4.1×10^{-12}	4.7×10^{-12}
Skin	3.0×10^{-11}	1.3×10^{-11}	6.3×10^{-12}	3.7×10^{-12}	2.1×10^{-12}	2.1×10^{-12}	2.0×10^{-12}	2.3×10^{-12}
Spleen	3.7×10^{-11}	1.6×10^{-11}	8.5×10^{-12}	5.6×10^{-12}	3.4×10^{-12}	3.4×10^{-12}	2.3×10^{-12}	2.8×10^{-12}
Testes	3.0×10^{-11}	1.3×10^{-11}	6.2×10^{-12}	3.6×10^{-12}	2.0×10^{-12}	-	1.9×10^{-12}	-
Thymus	3.6×10^{-11}	1.5×10^{-11}	7.4×10^{-12}	4.3×10^{-12}	2.3×10^{-12}	2.3×10^{-12}	2.2×10^{-12}	2.6×10^{-12}
Thyroid	3.0×10^{-11}	1.3×10^{-11}	6.4×10^{-12}	3.8×10^{-12}	2.2×10^{-12}	2.2×10^{-12}	2.0×10^{-12}	2.4×10^{-12}
GB wall	3.5×10^{-11}	1.5×10^{-11}	7.6×10^{-12}	4.4×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.2×10^{-12}	2.6×10^{-12}
HT wall	3.2×10^{-11}	1.4×10^{-11}	7.0×10^{-12}	4.1×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.2×10^{-12}	2.6×10^{-12}
Uterus	3.3×10^{-11}	1.5×10^{-11}	7.2×10^{-12}	4.2×10^{-12}	2.4×10^{-12}	2.4×10^{-12}	2.2×10^{-12}	2.6×10^{-12}
Remainder	1.9×10^{-7}	7.9×10^{-8}	3.5×10^{-8}	2.2×10^{-8}	1.3×10^{-8}	1.3×10^{-8}	1.3×10^{-8}	1.4×10^{-8}
Colon	1.3×10^{-10}	5.0×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	6.9×10^{-12}	6.9×10^{-12}	6.0×10^{-12}	6.5×10^{-12}
Effective Dose	1.7×10^{-8}	8.7×10^{-9}	5.5×10^{-9}	4.3×10^{-9}	3.7×10^{-9}	3.7×10^{-9}	3.3×10^{-9}	3.6×10^{-9}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A5. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Pb for 1 nm AMTD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	2.8×10^{-10}	1.2×10^{-10}	6.3×10^{-11}	3.7×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	1.9×10^{-11}	2.3×10^{-11}
Bladder wall	3.6×10^{-10}	1.5×10^{-10}	7.3×10^{-11}	4.6×10^{-11}	3.0×10^{-11}	3.0×10^{-11}	2.6×10^{-11}	3.2×10^{-11}
Bone surfaces	5.3×10^{-9}	1.9×10^{-9}	1.2×10^{-9}	9.5×10^{-10}	8.0×10^{-10}	7.9×10^{-10}	2.9×10^{-10}	3.8×10^{-10}
Brain	2.7×10^{-10}	1.1×10^{-10}	5.8×10^{-11}	3.4×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
Breasts	2.8×10^{-10}	1.2×10^{-10}	6.1×10^{-11}	3.6×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
St wall	8.6×10^{-9}	2.6×10^{-9}	1.2×10^{-9}	6.9×10^{-10}	4.7×10^{-10}	4.7×10^{-10}	3.7×10^{-10}	4.0×10^{-10}
SI wall	3.9×10^{-9}	1.5×10^{-9}	7.4×10^{-10}	4.4×10^{-10}	2.5×10^{-10}	2.5×10^{-10}	2.0×10^{-10}	2.1×10^{-10}
ULI wall	1.7×10^{-9}	6.6×10^{-10}	3.3×10^{-10}	1.9×10^{-10}	1.1×10^{-10}	1.1×10^{-10}	9.1×10^{-11}	9.9×10^{-11}
LLI wall	4.1×10^{-10}	1.7×10^{-10}	8.6×10^{-11}	5.0×10^{-11}	2.9×10^{-11}	2.9×10^{-11}	2.6×10^{-11}	2.9×10^{-11}
Kidneys	7.2×10^{-9}	2.8×10^{-9}	1.5×10^{-9}	1.0×10^{-9}	7.2×10^{-10}	7.1×10^{-10}	6.2×10^{-10}	6.8×10^{-10}
Liver	7.7×10^{-10}	3.7×10^{-10}	1.9×10^{-10}	1.2×10^{-10}	6.9×10^{-11}	6.8×10^{-11}	6.4×10^{-11}	8.0×10^{-11}
Lung	2.6×10^{-6}	1.6×10-06	9.9×10^{-7}	7.3×10^{-7}	5.6×10^{-7}	5.5×10^{-7}	5.2×10^{-7}	5.6×10^{-7}
ET	3.3×10^{-6}	1.4×10-06	6.7×10^{-7}	4.3×10^{-7}	3.0×10^{-7}	3.0×10^{-7}	2.7×10^{-7}	3.2×10^{-7}
Muscle	2.9×10^{-10}	1.3×10^{-10}	6.4×10^{-11}	3.7×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	1.9×10^{-11}	2.3×10^{-11}
Ovaries	3.1×10^{-10}	1.3×10^{-10}	6.8×10^{-11}	4.0×10^{-11}	-	2.3×10^{-11}	-	2.5×10^{-11}
Pancreas	3.2×10^{-10}	1.4×10^{-10}	7.2×10^{-11}	4.4×10^{-11}	2.6×10^{-11}	2.6×10^{-11}	2.4×10^{-11}	2.8×10^{-11}
Red marrow	8.8×10^{-10}	2.3×10^{-10}	1.1×10^{-10}	8.3×10^{-11}	6.6×10^{-11}	6.5×10^{-11}	3.9×10^{-11}	4.4×10^{-11}
Skin	2.7×10^{-10}	1.2×10^{-10}	5.8×10^{-11}	3.4×10^{-11}	1.9×10^{-11}	1.9×10^{-11}	1.8×10^{-11}	2.1×10^{-11}
Spleen	3.3×10^{-10}	1.5×10^{-10}	7.9×10^{-11}	5.1×10^{-11}	3.2×10^{-11}	3.1×10^{-11}	2.1×10^{-11}	2.5×10^{-11}
Testes	2.6×10^{-10}	1.1×10^{-10}	5.6×10^{-11}	3.2×10^{-11}	1.8×10^{-11}	-	1.7×10^{-11}	-
Thymus	3.4×10^{-10}	1.5×10^{-10}	7.1×10^{-11}	4.1×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	2.0×10^{-11}	2.4×10^{-11}
Thyroid	2.7×10^{-10}	1.2×10^{-10}	5.9×10^{-11}	3.5×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
GB wall	3.2×10^{-10}	1.3×10^{-10}	7.2×10^{-11}	4.1×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	2.1×10^{-11}	2.4×10^{-11}
HT wall	3.0×10^{-10}	1.3×10^{-10}	6.6×10^{-11}	3.8×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	2.0×10^{-11}	2.4×10^{-11}
Uterus	3.0×10^{-10}	1.3×10^{-10}	6.6×10^{-11}	3.9×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	2.0×10^{-11}	2.4×10^{-11}
Remainder	1.7×10^{-6}	1.0×10^{-9}	5.4×10^{-10}	3.0×10^{-10}	1.8×10^{-1}	1.8×10^{-10}	1.7×10^{-10}	2.5×10^{-10}
Colon	1.1×10^{-9}	4.5×10^{-10}	2.2×10^{-10}	1.3×10^{-10}	7.5×10^{-11}	7.5×10^{-11}	6.3×10^{-11}	6.9×10^{-11}
Effective Dose	3.9×10^{-7}	1.9×10^{-7}	1.2×10^{-7}	8.8×10^{-8}	6.7×10^{-8}	6.7×10^{-8}	6.3×10^{-8}	6.8×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A6. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Pb for 50 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.5×10^{-10}	1.5×10^{-10}	6.8×10^{-11}	3.8×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	2.0×10^{-11}	2.4×10^{-11}
Bladder wall	4.4×10^{-10}	1.9×10^{-10}	7.9×10^{-11}	4.9×10^{-11}	3.2×10^{-11}	3.1×10^{-11}	2.9×10^{-11}	3.5×10^{-11}
Bone surfaces	5.1×10^{-9}	1.9×10^{-9}	1.1×10^{-9}	8.4×10^{-10}	7.2×10^{-10}	7.2×10^{-10}	2.7×10^{-10}	3.6×10^{-10}
Brain	3.2×10^{-10}	1.4×10^{-10}	6.1×10^{-11}	3.4×10^{-11}	1.9×10^{-11}	1.9×10^{-11}	1.8×10^{-11}	2.1×10^{-11}
Breasts	3.4×10^{-10}	1.5×10^{-10}	6.8×10^{-11}	3.9×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	2.0×10^{-11}	2.4×10^{-11}
St wall	1.1×10^{-9}	3.6×10^{-10}	1.7×10^{-10}	9.6×10^{-11}	6.1×10^{-11}	6.1×10^{-11}	5.0×10^{-11}	5.8×10^{-11}
SI wall	6.7×10^{-10}	2.6×10^{-10}	1.2×10^{-10}	7.1×10^{-11}	3.9×10^{-11}	3.9×10^{-11}	3.4×10^{-11}	3.9×10^{-11}
ULI wall	4.8×10^{-10}	2.0×10^{-10}	9.1×10^{-11}	5.2×10^{-11}	2.9×10^{-11}	2.9×10^{-11}	2.6×10^{-11}	3.0×10^{-11}
LLI wall	3.4×10^{-10}	1.4×10^{-10}	6.4×10^{-11}	3.6×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
Kidneys	1.0×10^{-8}	4.0×10^{-9}	2.0×10^{-9}	1.3×10^{-9}	8.5×10^{-10}	8.4×10^{-10}	7.5×10^{-10}	8.4×10^{-10}
Liver	9.0×10^{-10}	4.4×10^{-10}	2.0×10^{-10}	1.2×10^{-10}	7.0×10^{-11}	6.9×10^{-11}	6.5×10^{-11}	8.2×10^{-11}
Lung	1.7×10^{-6}	8.7×10^{-7}	4.9×10^{-7}	3.3×10^{-7}	2.4×10^{-7}	2.5×10^{-7}	2.1×10^{-7}	2.6×10^{-7}
ET	3.2×10^{-7}	1.3×10^{-7}	6.2×10^{-8}	4.0×10^{-8}	2.7×10^{-8}	2.7×10^{-8}	2.4×10^{-8}	2.9×10^{-8}
Muscle	3.3×10^{-10}	1.4×10^{-10}	6.4×10^{-11}	3.6×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
Ovaries	3.3×10^{-10}	1.4×10^{-10}	6.2×10^{-11}	3.5×10^{-11}	-	1.9×10^{-11}	-	2.2×10^{-11}
Pancreas	3.4×10^{-10}	1.5×10^{-10}	6.7×10^{-11}	3.8×10^{-11}	2.1×10^{-11}	2.1×10^{-11}	2.0×10^{-11}	2.4×10^{-11}
Red marrow	9.1×10^{-10}	2.6×10^{-10}	1.1×10^{-10}	7.9×10^{-11}	6.0×10^{-11}	6.0×10^{-11}	3.8×10^{-11}	4.3×10^{-11}
Skin	3.2×10^{-10}	1.4×10^{-10}	6.2×10^{-11}	3.5×10^{-11}	1.9×10^{-11}	1.9×10^{-11}	1.8×10^{-11}	2.2×10^{-11}
Spleen	4.3×10^{-10}	2.0×10^{-10}	9.1×10^{-11}	5.7×10^{-11}	3.4×10^{-11}	3.4×10^{-11}	2.2×10^{-11}	2.6×10^{-11}
Testes	3.2×10^{-10}	1.4×10^{-10}	6.1×10^{-11}	3.4×10^{-11}	1.8×10^{-11}	-	1.8×10^{-11}	-
Thymus	3.4×10^{-10}	1.5×10^{-10}	6.8×10^{-11}	3.9×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	2.1×10^{-11}	2.5×10^{-11}
Thyroid	3.3×10^{-10}	1.4×10^{-10}	6.4×10^{-11}	3.6×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
GB wall	3.4×10^{-10}	1.4×10^{-10}	6.4×10^{-11}	3.6×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
HT wall	3.6×10^{-10}	1.6×10^{-10}	7.2×10^{-11}	4.1×10^{-11}	2.4×10^{-11}	2.4×10^{-11}	2.2×10^{-11}	2.7×10^{-11}
Uterus	3.3×10^{-10}	1.4×10^{-10}	6.2×10^{-11}	3.5×10^{-11}	1.9×10^{-11}	1.9×10^{-11}	1.8×10^{-11}	2.2×10^{-11}
Remainder	7.2×10^{-10}	2.9×10^{-10}	1.4×10^{-10}	7.4×10^{-11}	4.2×10^{-11}	4.2×10^{-11}	3.9×10^{-11}	5.3×10^{-11}
Colon	4.2×10^{-10}	1.7×10^{-10}	8.0×10^{-11}	4.5×10^{-11}	2.5×10^{-11}	2.5×10^{-11}	2.3×10^{-11}	2.7×10^{-11}
Effective Dose	2.1×10^{-7}	1.1×10^{-7}	5.9×10^{-8}	4.0×10^{-8}	2.9×10^{-8}	3.0×10^{-8}	2.6×10^{-8}	3.1×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A7. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Pb for 230 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	2.0×10^{-10}	8.4×10^{-11}	3.8×10^{-11}	2.0×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	1.0×10^{-11}	1.3×10^{-11}
Bladder wall	2.5×10^{-10}	1.1×10^{-10}	4.4×10^{-11}	2.5×10^{-11}	1.6×10^{-11}	1.7×10^{-11}	1.4×10^{-11}	1.8×10^{-11}
Bone surfaces	3.1×10^{-9}	1.2×10^{-9}	6.3×10^{-10}	4.6×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	1.4×10^{-10}	1.9×10^{-10}
Brain	1.8×10^{-10}	7.7×10^{-11}	3.4×10^{-11}	1.8×10^{-11}	9.9×10^{-12}	1.0×10^{-11}	9.1×10^{-12}	1.1×10^{-11}
Breasts	2.0×10^{-10}	8.3×10^{-11}	3.7×10^{-11}	2.0×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	1.0×10^{-11}	1.2×10^{-11}
St wall	2.1×10^{-9}	6.8×10^{-10}	2.5×10^{-10}	1.3×10^{-10}	7.1×10^{-11}	7.3×10^{-11}	5.9×10^{-11}	6.5×10^{-11}
SI wall	1.0×10^{-9}	4.2×10^{-10}	1.6×10^{-10}	8.9×10^{-11}	4.0×10^{-11}	4.1×10^{-11}	3.5×10^{-11}	3.8×10^{-11}
ULI wall	5.2×10^{-10}	2.2×10^{-10}	8.7×10^{-11}	4.8×10^{-11}	2.3×10^{-11}	2.3×10^{-11}	2.0×10^{-11}	2.3×10^{-11}
LLI wall	2.2×10^{-10}	9.2×10^{-11}	3.9×10^{-11}	2.1×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	1.0×10^{-11}	1.2×10^{-11}
Kidneys	5.6×10^{-9}	2.2×10^{-9}	1.0×10^{-9}	6.3×10^{-10}	4.3×10^{-10}	4.3×10^{-10}	3.7×10^{-10}	4.2×10^{-10}
Liver	5.2×10^{-10}	2.5×10^{-10}	1.1×10^{-10}	6.3×10^{-11}	3.6×10^{-11}	3.7×10^{-11}	3.3×10^{-11}	4.3×10^{-11}
Lung	7.1×10^{-7}	3.7×10^{-7}	2.1×10^{-7}	1.5×10^{-7}	1.1×10^{-7}	1.1×10^{-7}	8.5×10^{-8}	1.2×10^{-7}
ET	7.3×10^{-7}	3.1×10^{-7}	1.2×10^{-7}	7.2×10^{-8}	3.8×10^{-8}	3.9×10^{-8}	3.7×10^{-8}	4.3×10^{-8}
Muscle	1.9×10^{-10}	8.2×10^{-11}	3.6×10^{-11}	1.9×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	9.6×10^{-12}	1.2×10^{-11}
Ovaries	1.9×10^{-10}	8.2×10^{-11}	3.6×10^{-11}	1.9×10^{-11}	-	1.1×10^{-11}	-	1.2×10^{-11}
Pancreas	2.0×10^{-10}	8.7×10^{-11}	3.9×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	1.2×10^{-11}	1.0×10^{-11}	1.3×10^{-11}
Red marrow	5.5×10^{-10}	1.5×10^{-10}	6.3×10^{-11}	4.2×10^{-11}	3.2×10^{-11}	3.2×10^{-11}	1.9×10^{-11}	2.3×10^{-11}
Skin	1.9×10^{-10}	7.8×10^{-11}	3.4×10^{-11}	1.8×10^{-11}	1.0×10^{-11}	1.0×10^{-11}	9.2×10^{-12}	1.1×10^{-11}
Spleen	2.5×10^{-10}	1.1×10^{-10}	5.0×10^{-11}	2.9×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	1.4×10^{-11}
Testes	1.8×10^{-10}	7.7×10^{-11}	3.4×10^{-11}	1.8×10^{-11}	9.6×10^{-12}	-	8.9×10^{-12}	-
Thymus	2.1×10^{-10}	8.8×10^{-11}	3.9×10^{-11}	2.1×10^{-11}	1.1×10^{-11}	1.2×10^{-11}	1.0×10^{-11}	1.3×10^{-11}
Thyroid	1.9×10^{-10}	8.0×10^{-11}	3.5×10^{-11}	1.9×10^{-11}	1.0×10^{-11}	1.0×10^{-11}	9.5×10^{-12}	1.2×10^{-11}
GB wall	2.0×10^{-10}	8.4×10^{-11}	3.7×10^{-11}	2.0×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	9.7×10^{-12}	1.2×10^{-11}
HT wall	2.0×10^{-10}	8.8×10^{-11}	4.0×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	1.2×10^{-11}	1.1×10^{-11}	1.4×10^{-11}
Uterus	1.9×10^{-10}	8.2×10^{-11}	3.6×10^{-11}	1.9×10^{-11}	1.0×10^{-11}	1.0×10^{-11}	9.4×10^{-12}	1.2×10^{-11}
Remainder	3.6×10^{-7}	3.1×10^{-10}	1.3×10^{-10}	6.8×10^{-11}	3.4×10^{-11}	3.5×10^{-11}	3.2×10^{-11}	4.6×10^{-11}
Colon	3.9×10^{-10}	1.6×10^{-10}	6.7×10^{-11}	3.6×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.6×10^{-11}	1.8×10^{-11}
Effective Dose	1.0×10^{-7}	4.4×10^{-8}	2.5×10^{-8}	1.8×10^{-8}	1.3×10^{-8}	1.3×10^{-8}	1.0×10^{-8}	1.4×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A8. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Pb for 2500 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	2.3×10^{-10}	9.9×10^{-11}	5.0×10^{-11}	3.0×10^{-11}	1.7×10^{-11}	1.7×10^{-11}	1.6×10^{-11}	1.9×10^{-11}
Bladder wall	2.9×10^{-10}	1.2×10^{-10}	5.9×10^{-11}	3.8×10^{-11}	2.4×10^{-11}	2.4×10^{-11}	2.2×10^{-11}	2.7×10^{-11}
Bone surfaces	4.4×10^{-9}	1.6×10^{-9}	9.6×10^{-10}	7.7×10^{-10}	6.4×10^{-10}	6.4×10^{-10}	2.4×10^{-10}	3.1×10^{-10}
Brain	2.1×10^{-10}	9.2×10^{-11}	4.6×10^{-11}	2.7×10^{-11}	1.6×10^{-11}	1.6×10^{-11}	1.5×10^{-11}	1.7×10^{-11}
Breasts	2.3×10^{-10}	9.8×10^{-11}	4.9×10^{-11}	2.9×10^{-11}	1.6×10^{-11}	1.6×10^{-11}	1.5×10^{-11}	1.8×10^{-11}
St wall	7.5×10^{-9}	2.2×10^{-9}	9.7×10^{-10}	5.3×10^{-10}	3.2×10^{-10}	3.2×10^{-10}	2.6×10^{-10}	2.8×10^{-10}
SI wall	3.5×10^{-9}	1.3×10^{-9}	5.9×10^{-10}	3.4×10^{-10}	1.7×10^{-10}	1.7×10^{-10}	1.4×10^{-10}	1.5×10^{-10}
ULI wall	1.5×10^{-9}	5.8×10^{-10}	2.6×10^{-10}	1.5×10^{-10}	7.8×10^{-11}	7.8×10^{-11}	6.6×10^{-11}	7.1×10^{-11}
LLI wall	3.4×10^{-10}	1.4×10^{-10}	6.9×10^{-11}	4.0×10^{-11}	2.2×10^{-11}	2.2×10^{-11}	2.0×10^{-11}	2.3×10^{-11}
Kidneys	5.7×10^{-9}	2.2×10^{-9}	1.2×10^{-9}	8.4×10^{-10}	5.9×10^{-10}	5.9×10^{-10}	5.2×10^{-10}	5.8×10^{-10}
Liver	6.3×10^{-10}	3.0×10^{-10}	1.5×10^{-10}	9.5×10^{-11}	5.6×10^{-11}	5.6×10^{-11}	5.3×10^{-11}	6.6×10^{-11}
Lung	3.3×10^{-7}	2.0×10^{-7}	1.6×10^{-7}	1.4×10^{-7}	1.3×10^{-7}	1.3×10^{-7}	1.1×10^{-7}	1.2×10^{-7}
ET	2.7×10^{-6}	1.1×10^{-6}	4.9×10^{-7}	3.1×10^{-7}	1.9×10^{-7}	1.9×10^{-7}	1.8×10^{-7}	2.0×10^{-7}
Muscle	2.3×10^{-10}	1.0×10^{-10}	5.1×10^{-11}	3.0×10^{-11}	1.7×10^{-11}	1.7×10^{-11}	1.6×10^{-11}	1.9×10^{-11}
Ovaries	2.5×10^{-10}	1.1×10^{-10}	5.5×10^{-11}	3.2×10^{-11}	-	1.8×10^{-11}	-	2.0×10^{-11}
Pancreas	2.6×10^{-10}	1.1×10^{-10}	5.8×10^{-11}	3.5×10^{-11}	2.0×10^{-11}	2.0×10^{-11}	1.9×10^{-11}	2.2×10^{-11}
Red marrow	7.2×10^{-10}	1.9×10^{-10}	9.0×10^{-11}	6.7×10^{-11}	5.2×10^{-11}	5.2×10^{-11}	3.1×10^{-11}	3.6×10^{-11}
Skin	2.2×10^{-10}	9.4×10^{-11}	4.7×10^{-11}	2.7×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	1.7×10^{-11}
Spleen	2.7×10^{-10}	1.2×10^{-10}	6.5×10^{-11}	4.3×10^{-11}	2.6×10^{-11}	2.6×10^{-11}	1.8×10^{-11}	2.1×10^{-11}
Testes	2.1×10^{-10}	9.1×10^{-11}	4.5×10^{-11}	2.6×10^{-11}	1.5×10^{-11}	-	1.4×10^{-11}	-
Thymus	2.7×10^{-10}	1.2×10^{-10}	5.6×10^{-11}	3.2×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.6×10^{-11}	2.0×10^{-11}
Thyroid	2.2×10^{-10}	9.3×10^{-11}	4.7×10^{-11}	2.8×10^{-11}	1.6×10^{-11}	1.6×10^{-11}	1.5×10^{-11}	1.8×10^{-11}
GB wall	2.6×10^{-10}	1.1×10^{-10}	5.7×10^{-11}	3.3×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.7×10^{-11}	2.0×10^{-11}
HT wall	2.4×10^{-10}	1.0×10^{-10}	5.3×10^{-11}	3.1×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.7×10^{-11}	2.0×10^{-11}
Uterus	2.4×10^{-10}	1.1×10^{-10}	5.3×10^{-11}	3.1×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.6×10^{-11}	1.9×10^{-11}
Remainder	1.3×10^{-6}	5.6×10^{-7}	2.5×10^{-7}	1.5×10^{-7}	9.3×10^{-8}	9.3×10^{-8}	8.9×10^{-8}	1.0×10^{-7}
Colon	9.7×10^{-10}	3.9×10^{-10}	1.8×10^{-10}	1.0×10^{-10}	5.4×10^{-11}	5.4×10^{-11}	4.6×10^{-11}	5.0×10^{-11}
Effective Dose	1.1×10^{-7}	5.3×10^{-8}	3.2×10^{-8}	2.4×10^{-8}	2.0×10^{-8}	2.0×10^{-8}	1.8×10^{-8}	2.0×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A9. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Bi for 1 nm AMTD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	9.5×10^{-11}	3.8×10^{-11}	2.0×10^{-11}	1.2×10^{-11}	7.6×10^{-12}	7.5×10^{-12}	6.1×10^{-12}	7.2×10^{-12}
Bladder wall	1.1×10^{-10}	4.2×10^{-11}	2.0×10^{-11}	1.3×10^{-11}	8.9×10^{-12}	8.8×10^{-12}	6.9×10^{-12}	8.4×10^{-12}
Bone surfaces	1.9×10^{-10}	8.9×10^{-11}	6.4×10^{-11}	3.8×10^{-11}	1.0×10^{-10}	9.9×10^{-11}	2.9×10^{-11}	3.7×10^{-11}
Brain	8.6×10^{-11}	3.3×10^{-11}	1.7×10^{-11}	1.1×10^{-11}	7.1×10^{-12}	7.0×10^{-12}	5.8×10^{-12}	6.7×10^{-12}
Breasts	9.5×10^{-11}	3.8×10^{-11}	2.0×10^{-11}	1.2×10^{-11}	7.1×10^{-12}	7.1×10^{-12}	5.7×10^{-12}	6.7×10^{-12}
St wall	5.8×10^{-9}	1.7×10^{-9}	8.1×10^{-10}	4.6×10^{-10}	3.1×10^{-10}	3.1×10^{-10}	2.4×10^{-10}	2.7×10^{-10}
SI wall	1.3×10^{-9}	5.1×10^{-10}	2.5×10^{-10}	1.5×10^{-10}	8.4×10^{-11}	8.4×10^{-11}	6.7×10^{-11}	7.3×10^{-11}
ULI wall	3.7×10^{-10}	1.5×10^{-10}	7.4×10^{-11}	4.4×10^{-11}	2.6×10^{-11}	2.6×10^{-11}	2.0×10^{-11}	2.3×10^{-11}
LLI wall	1.1×10^{-10}	4.2×10^{-11}	2.1×10^{-11}	1.3×10^{-11}	7.9×10^{-12}	7.8×10^{-12}	6.3×10^{-12}	7.3×10^{-12}
Kidneys	4.6×10^{-9}	1.7×10^{-9}	9.4×10^{-10}	6.4×10^{-10}	4.6×10^{-10}	4.5×10^{-10}	3.6×10^{-10}	4.0×10^{-10}
Liver	1.2×10^{-10}	5.4×10^{-11}	2.7×10^{-11}	1.8×10^{-11}	1.2×10^{-11}	1.2×10^{-11}	6.4×10^{-12}	7.9×10^{-12}
Lung	2.3×10^{-6}	1.3×10^{-6}	8.3×10^{-7}	6.1×10^{-7}	4.6×10^{-7}	4.6×10^{-7}	4.3×10^{-7}	4.7×10^{-7}
ET	6.3×10^{-6}	2.6×10^{-6}	1.3×10^{-6}	8.4×10^{-7}	5.7×10^{-7}	5.7×10^{-7}	5.3×10^{-7}	6.1×10^{-7}
Muscle	1.0×10^{-10}	4.1×10^{-11}	2.1×10^{-11}	1.3×10^{-11}	7.8×10^{-12}	7.8×10^{-12}	6.2×10^{-12}	7.5×10^{-12}
Ovaries	9.6×10^{-11}	3.9×10^{-11}	2.0×10^{-11}	1.2×10^{-11}	-	7.4×10^{-12}	-	7.0×10^{-12}
Pancreas	1.2×10^{-10}	4.8×10^{-11}	2.6×10^{-11}	1.7×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	8.6×10^{-12}	1.0×10^{-11}
Red marrow	1.1×10^{-10}	4.5×10^{-11}	2.3×10^{-11}	1.4×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	7.2×10^{-12}	8.2×10^{-12}
Skin	8.8×10^{-11}	3.4×10^{-11}	1.7×10^{-11}	1.1×10^{-11}	6.5×10^{-12}	6.4×10^{-12}	5.2×10^{-12}	6.1×10^{-12}
Spleen	1.7×10^{-10}	7.6×10^{-11}	4.1×10^{-11}	2.6×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	9.0×10^{-12}	1.1×10^{-11}
Testes	8.2×10^{-11}	3.1×10^{-11}	1.5×10^{-11}	9.4×10^{-12}	5.6×10^{-12}	-	4.4×10^{-12}	-
Thymus	1.4×10^{-10}	5.8×10^{-11}	2.7×10^{-11}	1.6×10^{-11}	8.8×10^{-12}	8.8×10^{-12}	6.9×10^{-12}	8.5×10^{-12}
Thyroid	8.8×10^{-11}	3.5×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	7.4×10^{-12}	7.3×10^{-12}	6.1×10^{-12}	7.0×10^{-12}
GB wall	1.1×10^{-10}	4.3×10^{-11}	2.4×10^{-11}	1.4×10^{-11}	7.6×10^{-12}	7.6×10^{-12}	6.1×10^{-12}	7.2×10^{-12}
HT wall	1.1×10^{-10}	4.3×10^{-11}	2.2×10^{-11}	1.4×10^{-11}	8.6×10^{-12}	8.5×10^{-12}	6.7×10^{-12}	8.1×10^{-12}
Uterus	9.5×10^{-11}	3.8×10^{-11}	1.9×10^{-11}	1.2×10^{-11}	7.2×10^{-12}	7.1×10^{-12}	5.6×10^{-12}	6.8×10^{-12}
Remainder	3.2×10^{-6}	1.3×10^{-6}	6.5×10^{-7}	4.2×10^{-7}	2.9×10^{-7}	2.9×10^{-7}	2.6×10^{-7}	3.1×10^{-7}
Colon	2.6×10^{-10}	1.0×10^{-10}	5.1×10^{-11}	3.1×10^{-11}	1.8×10^{-11}	1.8×10^{-11}	1.4×10^{-11}	1.6×10^{-11}
Effective Dose	4.3×10^{-7}	2.3×10^{-7}	1.3×10^{-7}	9.4×10^{-8}	7.0×10^{-8}	7.0×10^{-8}	6.5×10^{-8}	7.2×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A10. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Bi for 50 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	1.4×10^{-10}	5.6×10^{-11}	2.5×10^{-11}	1.5×10^{-11}	8.8×10^{-12}	8.7×10^{-12}	7.4×10^{-12}	8.8×10^{-12}
Bladder wall	1.5×10^{-10}	6.1×10^{-11}	2.6×10^{-11}	1.6×10^{-11}	1.1×10^{-11}	1.0×10^{-11}	8.6×10^{-12}	1.1×10^{-11}
Bone surfaces	2.7×10^{-10}	1.3×10^{-10}	8.6×10^{-11}	4.9×10^{-11}	1.3×10^{-10}	1.3×10^{-10}	5.1×10^{-11}	6.5×10^{-11}
Brain	1.2×10^{-10}	4.7×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	7.1×10^{-12}	7.1×10^{-12}	6.0×10^{-12}	7.1×10^{-12}
Breasts	1.3×10^{-10}	5.5×10^{-11}	2.5×10^{-11}	1.5×10^{-11}	8.6×10^{-12}	8.6×10^{-12}	7.5×10^{-12}	8.7×10^{-12}
St wall	6.4×10^{-10}	2.0×10^{-10}	9.3×10^{-11}	5.3×10^{-11}	3.5×10^{-11}	3.5×10^{-11}	2.7×10^{-11}	3.1×10^{-11}
SI wall	2.3×10^{-10}	9.0×10^{-11}	4.2×10^{-11}	2.5×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	9.7×10^{-12}	1.3×10^{-11}
ULI wall	1.5×10^{-10}	6.1×10^{-11}	2.8×10^{-11}	1.6×10^{-11}	9.3×10^{-12}	9.3×10^{-12}	7.6×10^{-12}	9.0×10^{-12}
LLI wall	1.2×10^{-10}	4.9×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	7.2×10^{-12}	7.2×10^{-12}	6.0×10^{-12}	7.2×10^{-12}
Kidneys	6.9×10^{-9}	2.6×10^{-9}	1.3×10^{-9}	8.3×10^{-10}	5.7×10^{-10}	5.7×10^{-10}	4.8×10^{-10}	5.3×10^{-10}
Liver	1.7×10^{-10}	7.8×10^{-11}	3.5×10^{-11}	2.2×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	9.2×10^{-12}	1.1×10^{-11}
Lung	1.4×10^{-6}	6.9×10^{-7}	3.9×10^{-7}	2.6×10^{-7}	1.9×10^{-7}	1.9×10^{-7}	1.7×10^{-7}	2.0×10^{-7}
ET	5.6×10^{-7}	2.3×10^{-7}	1.1×10^{-7}	7.4×10^{-8}	5.0×10^{-8}	5.0×10^{-8}	4.5×10^{-8}	5.3×10^{-8}
Muscle	1.3×10^{-10}	5.1×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	7.8×10^{-12}	7.8×10^{-12}	6.5×10^{-12}	7.8×10^{-12}
Ovaries	1.2×10^{-10}	4.8×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	-	7.1×10^{-12}	-	7.1×10^{-12}
Pancreas	1.3×10^{-10}	5.4×10^{-11}	2.5×10^{-11}	1.5×10^{-11}	8.7×10^{-12}	8.7×10^{-12}	7.2×10^{-12}	8.7×10^{-12}
Red marrow	1.5×10^{-10}	6.5×10^{-11}	3.0×10^{-11}	1.7×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	9.7×10^{-12}	1.1×10^{-11}
Skin	1.2×10^{-10}	4.9×10^{-11}	2.2×10^{-11}	1.3×10^{-11}	7.3×10^{-12}	7.3×10^{-12}	6.2×10^{-12}	7.3×10^{-12}
Spleen	2.3×10^{-10}	1.1×10^{-10}	5.1×10^{-11}	3.0×10^{-11}	2.1×10^{-11}	2.0×10^{-11}	1.1×10^{-11}	1.3×10^{-11}
Testes	1.2×10^{-10}	4.7×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	6.9×10^{-12}	-	5.8×10^{-12}	-
Thymus	1.3×10^{-10}	5.6×10^{-11}	2.6×10^{-11}	1.5×10^{-11}	9.1×10^{-12}	9.1×10^{-12}	7.8×10^{-12}	9.2×10^{-12}
Thyroid	1.3×10^{-10}	5.1×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	7.7×10^{-12}	7.7×10^{-12}	6.5×10^{-12}	7.7×10^{-12}
GB wall	1.3×10^{-10}	5.1×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	7.6×10^{-12}	7.6×10^{-12}	6.4×10^{-12}	7.6×10^{-12}
HT wall	1.4×10^{-10}	6.0×10^{-11}	2.8×10^{-11}	1.7×10^{-11}	1.0×10^{-11}	1.0×10^{-11}	8.6×10^{-12}	1.0×10^{-11}
Uterus	1.2×10^{-10}	4.8×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	7.1×10^{-12}	7.1×10^{-12}	5.9×10^{-12}	7.1×10^{-12}
Remainder	6.0×10^{-10}	2.3×10^{-10}	1.2×10^{-10}	6.5×10^{-11}	3.8×10^{-11}	3.8×10^{-11}	3.4×10^{-11}	5.0×10^{-11}
Colon	1.4×10^{-10}	5.6×10^{-11}	2.5×10^{-11}	1.5×10^{-11}	8.4×10^{-12}	8.4×10^{-12}	6.9×10^{-12}	8.2×10^{-12}
Effective Dose	1.6×10^{-7}	8.3×10^{-8}	4.7×10^{-8}	3.1×10^{-8}	2.2×10^{-8}	2.3×10^{-8}	2.0×10^{-8}	2.4×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A11. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Bi for 230 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	7.4×10^{-11}	3.0×10^{-11}	1.3×10^{-11}	7.4×10^{-12}	4.5×10^{-12}	4.5×10^{-12}	3.6×10^{-12}	4.5×10^{-12}
Bladder wall	8.4×10^{-11}	3.3×10^{-11}	1.4×10^{-11}	8.1×10^{-12}	5.3×10^{-12}	5.4×10^{-12}	4.2×10^{-12}	5.4×10^{-12}
Bone surfaces	1.5×10^{-10}	7.1×10^{-11}	4.6×10^{-11}	2.4×10^{-11}	6.5×10^{-11}	6.5×10^{-11}	2.4×10^{-11}	3.2×10^{-11}
Brain	6.5×10^{-11}	2.5×10^{-11}	1.1×10^{-11}	6.2×10^{-12}	3.7×10^{-12}	3.7×10^{-12}	3.0×10^{-12}	3.7×10^{-12}
Breasts	7.3×10^{-11}	2.9×10^{-11}	1.3×10^{-11}	7.6×10^{-12}	4.4×10^{-12}	4.4×10^{-12}	3.6×10^{-12}	4.4×10^{-12}
St wall	1.4×10^{-9}	4.4×10^{-10}	1.6×10^{-10}	8.6×10^{-11}	4.5×10^{-11}	4.7×10^{-11}	3.8×10^{-11}	4.1×10^{-11}
SI wall	3.6×10^{-10}	1.5×10^{-10}	5.6×10^{-11}	3.1×10^{-11}	1.4×10^{-11}	1.4×10^{-11}	1.2×10^{-11}	1.3×10^{-11}
ULI wall	1.4×10^{-10}	5.6×10^{-11}	2.3×10^{-11}	1.3×10^{-11}	6.4×10^{-12}	6.6×10^{-12}	5.3×10^{-12}	6.1×10^{-12}
LLI wall	7.1×10^{-11}	2.8×10^{-11}	1.2×10^{-11}	6.6×10^{-12}	3.8×10^{-12}	3.9×10^{-12}	3.1×10^{-12}	3.8×10^{-12}
Kidneys	3.7×10^{-9}	1.4×10^{-9}	6.7×10^{-10}	4.1×10^{-10}	2.9×10^{-10}	2.9×10^{-10}	2.3×10^{-10}	2.7×10^{-10}
Liver	9.2×10^{-11}	4.2×10^{-11}	1.9×10^{-11}	1.1×10^{-11}	7.4×10^{-12}	7.4×10^{-12}	4.4×10^{-12}	5.6×10^{-12}
Lung	5.7×10^{-7}	2.9×10^{-7}	1.6×10^{-7}	1.2×10^{-7}	8.4×10^{-8}	8.7×10^{-8}	6.7×10^{-8}	9.2×10^{-8}
ET	1.5×10^{-6}	6.4×10^{-7}	2.4×10^{-7}	1.5×10^{-7}	7.6×10^{-8}	7.8×10^{-8}	7.5×10^{-8}	8.4×10^{-8}
Muscle	7.1×10^{-11}	2.8×10^{-11}	1.2×10^{-11}	6.8×10^{-12}	4.1×10^{-12}	4.1×10^{-12}	3.3×10^{-12}	4.1×10^{-12}
Ovaries	6.9×10^{-11}	2.7×10^{-11}	1.2×10^{-11}	6.5×10^{-12}	-	3.8×10^{-12}	-	3.7×10^{-12}
Pancreas	7.7×10^{-11}	3.1×10^{-11}	1.4×10^{-11}	8.0×10^{-12}	4.7×10^{-12}	4.8×10^{-12}	3.8×10^{-12}	4.8×10^{-12}
Red marrow	8.4×10^{-11}	3.5×10^{-11}	1.6×10^{-11}	8.4×10^{-12}	7.6×10^{-12}	7.6×10^{-12}	4.6×10^{-12}	5.6×10^{-12}
Skin	6.7×10^{-11}	2.6×10^{-11}	1.1×10^{-11}	6.3×10^{-12}	3.7×10^{-12}	3.8×10^{-12}	3.0×10^{-12}	3.7×10^{-12}
Spleen	1.3×10^{-10}	5.9×10^{-11}	2.7×10^{-11}	1.6×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	5.4×10^{-12}	6.7×10^{-12}
Testes	6.5×10^{-11}	2.5×10^{-11}	1.1×10^{-11}	5.9×10^{-12}	3.5×10^{-12}	-	2.8×10^{-12}	-
Thymus	8.2×10^{-11}	3.3×10^{-11}	1.5×10^{-11}	8.1×10^{-12}	4.7×10^{-12}	4.8×10^{-12}	3.8×10^{-12}	4.8×10^{-12}
Thyroid	6.9×10^{-11}	2.7×10^{-11}	1.2×10^{-11}	6.7×10^{-12}	4.0×10^{-12}	4.0×10^{-12}	3.2×10^{-12}	4.0×10^{-12}
GB wall	7.4×10^{-11}	2.9×10^{-11}	1.3×10^{-11}	7.0×10^{-12}	4.0×10^{-12}	4.0×10^{-12}	3.2×10^{-12}	4.0×10^{-12}
HT wall	7.9×10^{-11}	3.2×10^{-11}	1.5×10^{-11}	8.4×10^{-12}	5.2×10^{-12}	5.3×10^{-12}	4.1×10^{-12}	5.3×10^{-12}
Uterus	6.8×10^{-11}	2.7×10^{-11}	1.2×10^{-11}	6.4×10^{-12}	3.7×10^{-12}	3.8×10^{-12}	3.0×10^{-12}	3.7×10^{-12}
Remainder	7.3×10^{-7}	3.2×10^{-7}	1.2×10^{-7}	7.3×10^{-8}	4.5×10^{-11}	4.6×10^{-11}	3.7×10^{-8}	6.3×10^{-11}
Colon	1.1×10^{-10}	4.4×10^{-11}	1.8×10^{-11}	1.0×10^{-11}	5.3×10^{-12}	5.4×10^{-12}	4.3×10^{-12}	5.1×10^{-12}
Effective Dose	1.0×10^{-7}	5.1×10^{-8}	2.6×10^{-8}	1.8×10^{-8}	1.0×10^{-8}	1.0×10^{-8}	9.9×10^{-9}	1.1×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A12. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Bi for 2500 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	7.3×10^{-11}	3.0×10^{-11}	1.6×10^{-11}	1.0×10^{-11}	6.2×10^{-12}	6.2×10^{-12}	5.1×10^{-12}	6.0×10^{-12}
Bladder wall	8.3×10^{-11}	3.3×10^{-11}	1.6×10^{-11}	1.1×10^{-11}	7.3×10^{-12}	7.3×10^{-12}	5.8×10^{-12}	7.1×10^{-12}
Bone surfaces	1.5×10^{-10}	7.2×10^{-11}	5.4×10^{-11}	3.2×10^{-11}	8.8×10^{-11}	8.8×10^{-11}	2.8×10^{-11}	3.6×10^{-11}
Brain	6.5×10^{-11}	2.6×10^{-11}	1.4×10^{-11}	8.7×10^{-12}	5.6×10^{-12}	5.6×10^{-12}	4.6×10^{-12}	5.4×10^{-12}
Breasts	7.2×10^{-11}	3.0×10^{-11}	1.6×10^{-11}	9.8×10^{-12}	5.9×10^{-12}	5.9×10^{-12}	4.8×10^{-12}	5.7×10^{-12}
St wall	5.2×10^{-9}	1.5×10^{-9}	6.5×10^{-10}	3.6×10^{-10}	2.2×10^{-10}	2.2×10^{-10}	1.7×10^{-10}	1.9×10^{-10}
SI wall	1.2×10^{-9}	4.5×10^{-10}	2.0×10^{-10}	1.2×10^{-10}	5.9×10^{-11}	5.9×10^{-11}	4.8×10^{-11}	5.1×10^{-11}
ULI wall	3.2×10^{-10}	1.3×10^{-10}	5.9×10^{-11}	3.5×10^{-11}	1.9×10^{-11}	1.9×10^{-11}	1.5×10^{-11}	1.7×10^{-11}
LLI wall	8.5×10^{-11}	3.4×10^{-11}	1.7×10^{-11}	1.1×10^{-11}	6.2×10^{-12}	6.2×10^{-12}	5.1×10^{-12}	5.9×10^{-12}
Kidneys	3.5×10^{-9}	1.3×10^{-9}	7.5×10^{-10}	5.2×10^{-10}	3.8×10^{-10}	3.8×10^{-10}	3.1×10^{-10}	3.4×10^{-10}
Liver	9.5×10^{-11}	4.4×10^{-11}	2.3×10^{-11}	1.5×10^{-11}	1.0×10^{-11}	1.0×10^{-11}	5.7×10^{-12}	7.0×10^{-12}
Lung	2.7×10^{-7}	1.7×10^{-7}	1.3×10^{-7}	1.1×10^{-7}	1.1×10^{-7}	1.1×10^{-7}	9.3×10^{-8}	1.0×10^{-7}
ET	5.5×10^{-6}	2.3×10^{-6}	1.0×10^{-6}	6.4×10^{-7}	3.8×10^{-7}	3.8×10^{-7}	3.7×10^{-7}	4.1×10^{-7}
Muscle	7.7×10^{-11}	3.2×10^{-11}	1.6×10^{-11}	1.0×10^{-11}	6.2×10^{-12}	6.2×10^{-12}	5.0×10^{-12}	6.0×10^{-12}
Ovaries	7.6×10^{-11}	3.1×10^{-11}	1.6×10^{-11}	9.8×10^{-12}	-	5.9×10^{-12}	-	5.7×10^{-12}
Pancreas	9.1×10^{-11}	3.9×10^{-11}	2.1×10^{-11}	1.3×10^{-11}	8.3×10^{-12}	8.3×10^{-12}	6.8×10^{-12}	8.1×10^{-12}
Red marrow	8.5×10^{-11}	3.6×10^{-11}	1.9×10^{-11}	1.2×10^{-11}	1.1×10^{-11}	1.1×10^{-11}	6.2×10^{-12}	7.2×10^{-12}
Skin	6.7×10^{-11}	2.7×10^{-11}	1.4×10^{-11}	8.5×10^{-12}	5.3×10^{-12}	5.3×10^{-12}	4.3×10^{-12}	5.1×10^{-12}
Spleen	1.4×10^{-10}	6.3×10^{-11}	3.4×10^{-11}	2.2×10^{-11}	1.5×10^{-11}	1.5×10^{-11}	7.8×10^{-12}	9.2×10^{-12}
Testes	6.3×10^{-11}	2.5×10^{-11}	1.2×10^{-11}	7.7×10^{-12}	4.7×10^{-12}	-	3.8×10^{-12}	-
Thymus	1.1×10^{-10}	4.5×10^{-11}	2.1×10^{-11}	1.2×10^{-11}	6.9×10^{-12}	6.9×10^{-12}	5.6×10^{-12}	6.8×10^{-12}
Thyroid	6.7×10^{-11}	2.7×10^{-11}	1.4×10^{-11}	9.1×10^{-12}	5.8×10^{-12}	5.8×10^{-12}	4.9×10^{-12}	5.6×10^{-12}
GB wall	8.8×10^{-11}	3.5×10^{-11}	1.9×10^{-11}	1.1×10^{-11}	6.1×10^{-12}	6.1×10^{-12}	5.0×10^{-12}	5.9×10^{-12}
HT wall	8.0×10^{-11}	3.4×10^{-11}	1.8×10^{-11}	1.1×10^{-11}	7.0×10^{-12}	7.0×10^{-12}	5.6×10^{-12}	6.8×10^{-12}
Uterus	7.4×10^{-11}	3.1×10^{-11}	1.5×10^{-11}	9.5×10^{-12}	5.7×10^{-12}	5.7×10^{-12}	4.6×10^{-12}	5.5×10^{-12}
Remainder	2.8×10^{-6}	1.2×10^{-6}	5.1×10^{-7}	3.2×10^{-7}	1.9×10^{-7}	1.9×10^{-7}	1.8×10^{-7}	2.1×10^{-7}
Colon	2.2×10^{-10}	8.8×10^{-11}	4.1×10^{-11}	2.5×10^{-11}	1.3×10^{-11}	1.3×10^{-11}	1.1×10^{-11}	1.2×10^{-11}
Effective Dose	1.7×10^{-7}	7.8×10^{-8}	4.2×10^{-8}	2.9×10^{-8}	2.3×10^{-8}	2.3×10^{-8}	2.0×10^{-8}	2.3×10^{-8}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A13. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Po for 1 nm AMTD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Bladder wall	4.0×10^{-19}	2.0×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Bone surfaces	1.4×10^{-17}	7.5×10^{-18}	6.5×10^{-18}	8.8×10^{-18}	1.3×10^{-17}	1.3×10^{-17}	3.3×10^{-18}	4.3×10^{-18}
Brain	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Breasts	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
St wall	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
SI wall	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
ULI wall	4.1×10^{-19}	2.0×10^{-19}	9.9×10^{-20}	6.8×10^{-20}	4.5×10^{-20}	4.5×10^{-20}	1.4×10^{-20}	1.6×10^{-20}
LLI wall	4.3×10^{-19}	2.1×10^{-19}	1.0×10^{-19}	7.1×10^{-20}	4.7×10^{-20}	4.7×10^{-20}	1.5×10^{-20}	1.7×10^{-20}
Kidneys	1.2×10^{-17}	5.8×10^{-18}	3.2×10^{-18}	2.4×10^{-18}	1.9×10^{-18}	1.9×10^{-18}	5.7×10^{-19}	6.2×10^{-19}
Liver	6.7×10^{-18}	3.5×10^{-18}	1.8×10^{-18}	1.3×10^{-18}	9.5×10^{-19}	9.4×10^{-19}	2.8×10^{-19}	3.5×10^{-19}
Lung	3.5×10^{-13}	2.1×10^{-13}	1.3×10^{-13}	9.2×10^{-14}	7.0×10^{-14}	7.0×10^{-14}	6.5×10^{-14}	7.1×10^{-14}
ET	2.3×10^{-12}	9.7×10^{-13}	4.8×10^{-13}	3.1×10^{-13}	2.1×10^{-13}	2.1×10^{-13}	2.0×10^{-13}	2.3×10^{-13}
Muscle	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Ovaries	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	-	4.4×10^{-20}	-	1.5×10^{-20}
Pancreas	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Red marrow	6.2×10^{-18}	2.7×10^{-18}	1.4×10^{-18}	1.1×10^{-18}	9.8×10^{-19}	9.7×10^{-19}	3.6×10^{-19}	4.0×10^{-19}
Skin	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Spleen	1.3×10^{-17}	6.1×10^{-18}	3.2×10^{-18}	2.4×10^{-18}	1.6×10^{-18}	1.6×10^{-18}	4.1×10^{-19}	4.8×10^{-19}
Testes	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	-	1.3×10^{-20}	-
Thymus	4.0×10^{-19}	2.0×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Thyroid	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
GB wall	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
HT wall	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Uterus	4.0×10^{-19}	1.9×10^{-19}	9.6×10^{-20}	6.6×10^{-20}	4.4×10^{-20}	4.4×10^{-20}	1.3×10^{-20}	1.5×10^{-20}
Remainder	1.2×10^{-12}	4.8×10^{-13}	2.4×10^{-13}	1.5×10^{-13}	1.1×10^{-13}	1.1×10^{-13}	9.8×10^{-14}	1.1×10^{-13}
Colon	4.2×10^{-19}	2.0×10^{-19}	1.0×10^{-19}	6.9×10^{-20}	4.6×10^{-20}	4.6×10^{-20}	1.4×10^{-20}	1.6×10^{-20}
Effective Dose	1.0×10^{-13}	4.9×10^{-14}	2.7×10^{-14}	1.9×10^{-14}	1.4×10^{-14}	1.4×10^{-14}	1.3×10^{-14}	1.4×10^{-14}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A14. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Po for 50 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.7×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Bladder wall	5.9×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.7×10^{-20}	5.6×10^{-20}	5.6×10^{-20}	5.2×10^{-20}	2.9×10^{-20}
Bone surfaces	2.1×10^{-17}	1.2×10^{-17}	8.9×10^{-18}	1.2×10^{-17}	1.6×10^{-17}	1.6×10^{-17}	1.7×10^{-17}	8.1×10^{-18}
Brain	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Breasts	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
St wall	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
SI wall	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
ULI wall	6.0×10^{-19}	3.1×10^{-19}	1.4×10^{-19}	8.9×10^{-20}	5.7×10^{-20}	5.7×10^{-20}	5.2×10^{-20}	3.0×10^{-20}
LLI wall	6.2×10^{-19}	3.2×10^{-19}	1.4×10^{-19}	9.2×10^{-20}	5.9×10^{-20}	5.9×10^{-20}	5.5×10^{-20}	3.1×10^{-20}
Kidneys	1.8×10^{-17}	9.0×10^{-18}	4.4×10^{-18}	3.2×10^{-18}	2.4×10^{-18}	2.4×10^{-18}	2.2×10^{-18}	1.2×10^{-18}
Liver	9.9×10^{-18}	5.4×10^{-18}	2.4×10^{-18}	1.8×10^{-18}	1.2×10^{-18}	1.2×10^{-18}	1.1×10^{-18}	6.6×10^{-19}
Lung	2.0×10^{-13}	1.0×10^{-13}	5.6×10^{-14}	3.7×10^{-14}	2.7×10^{-14}	2.8×10^{-14}	2.4×10^{-14}	2.8×10^{-14}
ET	2.0×10^{-13}	8.1×10^{-14}	4.1×10^{-14}	2.7×10^{-14}	1.8×10^{-14}	1.8×10^{-14}	1.7×10^{-14}	1.9×10^{-14}
Muscle	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Ovaries	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	-	5.5×10^{-20}	-	2.9×10^{-20}
Pancreas	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Red marrow	9.2×10^{-18}	4.2×10^{-18}	1.9×10^{-18}	1.5×10^{-18}	1.2×10^{-18}	1.2×10^{-18}	1.0×10^{-18}	7.5×10^{-19}
Skin	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Spleen	1.9×10^{-17}	9.5×10^{-18}	4.5×10^{-18}	3.1×10^{-18}	2.1×10^{-18}	2.1×10^{-18}	1.7×10^{-18}	9.0×10^{-19}
Testes	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	-	5.1×10^{-20}	-
Thymus	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Thyroid	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
GB wall	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
HT wall	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.7×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Uterus	5.8×10^{-19}	3.0×10^{-19}	1.3×10^{-19}	8.6×10^{-20}	5.6×10^{-20}	5.5×10^{-20}	5.1×10^{-20}	2.9×10^{-20}
Remainder	1.2×10^{-16}	4.9×10^{-17}	2.7×10^{-17}	1.5×10^{-17}	9.1×10^{-18}	9.2×10^{-18}	8.6×10^{-18}	1.3×10^{-17}
Colon	6.1×10^{-19}	3.1×10^{-19}	1.4×10^{-19}	9.0×10^{-20}	5.8×10^{-20}	5.8×10^{-20}	5.3×10^{-20}	3.0×10^{-20}
Effective Dose	2.3×10^{-14}	1.2×10^{-14}	6.7×10^{-15}	4.5×10^{-15}	3.2×10^{-15}	3.3×10^{-15}	2.9×10^{-15}	3.4×10^{-15}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A15. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Po for 230 nm AMAD as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Bladder wall	3.3×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.4×10^{-20}	2.9×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Bone surfaces	1.2×10^{-17}	6.2×10^{-18}	4.7×10^{-18}	5.8×10^{-18}	8.3×10^{-18}	8.3×10^{-18}	8.2×10^{-18}	3.9×10^{-18}
Brain	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Breasts	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
St wall	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
SI wall	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
ULI wall	3.3×10^{-19}	1.7×10^{-19}	7.2×10^{-20}	4.4×10^{-20}	2.9×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
LLI wall	3.5×10^{-19}	1.7×10^{-19}	7.6×10^{-20}	4.6×10^{-20}	3.0×10^{-20}	3.0×10^{-20}	2.6×10^{-20}	1.5×10^{-20}
Kidneys	9.9×10^{-18}	4.8×10^{-18}	2.3×10^{-18}	1.6×10^{-18}	1.2×10^{-18}	1.2×10^{-18}	1.0×10^{-18}	5.7×10^{-19}
Liver	5.5×10^{-18}	2.9×10^{-18}	1.3×10^{-18}	8.8×10^{-19}	6.1×10^{-19}	6.1×10^{-19}	5.1×10^{-19}	3.2×10^{-19}
Lung	8.2×10^{-14}	4.2×10^{-14}	2.4×10^{-14}	1.7×10^{-14}	1.2×10^{-14}	1.3×10^{-14}	9.7×10^{-15}	1.3×10^{-14}
ET	5.5×10^{-13}	2.4×10^{-13}	9.0×10^{-14}	5.5×10^{-14}	2.8×10^{-14}	2.9×10^{-14}	2.8×10^{-14}	3.2×10^{-14}
Muscle	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Ovaries	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	-	2.9×10^{-20}	-	1.4×10^{-20}
Pancreas	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Red marrow	5.1×10^{-18}	2.2×10^{-18}	1.0×10^{-18}	7.4×10^{-19}	6.3×10^{-19}	6.3×10^{-19}	5.0×10^{-19}	3.6×10^{-19}
Skin	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Spleen	1.1×10^{-17}	5.1×10^{-18}	2.4×10^{-18}	1.5×10^{-18}	1.1×10^{-18}	1.1×10^{-18}	8.0×10^{-19}	4.4×10^{-19}
Testes	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	-	2.5×10^{-20}	-
Thymus	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Thyroid	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
GB wall	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
HT wall	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Uterus	3.2×10^{-19}	1.6×10^{-19}	7.1×10^{-20}	4.3×10^{-20}	2.8×10^{-20}	2.9×10^{-20}	2.5×10^{-20}	1.4×10^{-20}
Remainder	2.7×10^{-13}	1.2×10^{-13}	4.5×10^{-14}	2.7×10^{-14}	1.4×10^{-14}	1.5×10^{-14}	1.4×10^{-14}	1.6×10^{-14}
Colon	3.4×10^{-19}	1.7×10^{-19}	7.4×10^{-20}	4.5×10^{-20}	3.0×10^{-20}	3.0×10^{-20}	2.6×10^{-20}	1.5×10^{-20}
Effective Dose	2.4×10^{-14}	1.1×10^{-14}	5.1×10^{-15}	3.4×10^{-15}	2.2×10^{-15}	2.2×10^{-15}	1.9×10^{-15}	2.4×10^{-15}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female

Table A16. Inhalation dose coefficients (Sv Bq^{-1}) of ^{214}Po for 2500 nm AMAD diameter as a function of age.

Organs\Age	3 mo	1 y	5 y	10 y	15 y ♂	15 y ♀	Adult ♂	Adult ♀
Adrenals	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
Bladder wall	3.3×10^{-19}	1.7×10^{-19}	8.3×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
Bone surfaces	1.2×10^{-17}	6.3×10^{-18}	5.5×10^{-18}	7.6×10^{-18}	1.1×10^{-17}	1.1×10^{-17}	1.1×10^{-17}	4.3×10^{-18}
Brain	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
Breasts	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.5×10^{-20}
St wall	3.3×10^{-19}	1.6×10^{-19}	8.3×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
SI wall	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
ULI wall	3.4×10^{-19}	1.7×10^{-19}	8.5×10^{-20}	5.9×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.5×10^{-20}	1.6×10^{-20}
LLI wall	3.5×10^{-19}	1.8×10^{-19}	8.9×10^{-20}	6.2×10^{-20}	4.1×10^{-20}	4.1×10^{-20}	3.7×10^{-20}	1.7×10^{-20}
Kidneys	9.9×10^{-18}	4.9×10^{-18}	2.7×10^{-18}	2.1×10^{-18}	1.7×10^{-18}	1.7×10^{-18}	1.4×10^{-18}	6.3×10^{-19}
Liver	5.6×10^{-18}	3.0×10^{-18}	1.5×10^{-18}	1.2×10^{-18}	8.3×10^{-19}	8.3×10^{-19}	7.1×10^{-19}	3.5×10^{-19}
Lung	4.1×10^{-14}	2.6×10^{-14}	2.0×10^{-14}	1.7×10^{-14}	1.6×10^{-14}	1.6×10^{-14}	1.4×10^{-14}	1.5×10^{-14}
ET	2.1×10^{-12}	8.8×10^{-13}	3.9×10^{-13}	2.4×10^{-13}	1.5×10^{-13}	1.5×10^{-13}	1.4×10^{-13}	1.6×10^{-13}
Muscle	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
Ovaries	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	-	3.9×10^{-20}	-	1.5×10^{-20}
Pancreas	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.5×10^{-20}
Red marrow	5.1×10^{-18}	2.3×10^{-18}	1.2×10^{-18}	9.8×10^{-19}	8.6×10^{-19}	8.6×10^{-19}	6.9×10^{-19}	4.0×10^{-19}
Skin	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.5×10^{-20}
Spleen	1.1×10^{-17}	5.2×10^{-18}	2.8×10^{-18}	2.0×10^{-18}	1.4×10^{-18}	1.4×10^{-18}	1.1×10^{-18}	4.8×10^{-19}
Testes	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	-	3.4×10^{-20}	-
Thymus	3.3×10^{-19}	1.6×10^{-19}	8.3×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
Thyroid	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
GB wall	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.5×10^{-20}
HT wall	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.6×10^{-20}
Uterus	3.3×10^{-19}	1.6×10^{-19}	8.2×10^{-20}	5.7×10^{-20}	3.9×10^{-20}	3.9×10^{-20}	3.4×10^{-20}	1.5×10^{-20}
Remainder	1.1×10^{-12}	4.4×10^{-13}	1.9×10^{-13}	1.2×10^{-13}	7.3×10^{-14}	7.3×10^{-14}	7.0×10^{-14}	7.8×10^{-14}
Colon	3.4×10^{-19}	1.7×10^{-19}	8.7×10^{-20}	6.0×10^{-20}	4.0×10^{-20}	4.0×10^{-20}	3.6×10^{-20}	1.6×10^{-20}
Effective Dose	5.8×10^{-14}	2.5×10^{-14}	1.2×10^{-14}	8.1×10^{-15}	5.6×10^{-15}	5.6×10^{-15}	5.2×10^{-15}	5.8×10^{-15}

St – Stomach; SI – Small intestine; ULI – Upper large intestine; LLI – Lower large intestine; ET – Extrathoracic; GB – Gallbladder; HT – Heart, ♂ – male, ♀ – female