INHALATION DOSE ASSESSMENT FOR IODINE CONSIDERING PARTICLE SIZE DISTRIBUTION

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^{131}I are radionuclides of major concern under a nuclear reactor accident. In the absence of specific information, to evaluate the inhalation dose of ^{131}I, it is assumed that the particle size is 1 ㎛ and Type F for the members of the public. Because the inhalation dose depends on the particulate properties, in this research, we evaluated the sensitivity of the inhalation dose for members of the public based on the particle size distribution. Using the Human Respiratory Tract Model in ICRP66, for Type F, M and S, we evaluated the effective dose and committed equivalent dose for thyroid as a function of the particle size. If the inhalation dose is 1 when the particle size of ^{131}I is 1 ㎛, for Type F, the differences are from 0.7 to 2.3. For Type M or S, the relative ratios are larger than for Type F according to the particle size. The relative ratios are from 0.5 to 3.3 for Type M and from 0.3 to 4.5 for Type S. These trends are showed all age groups. As a result, because the inhalation doses by ^{131}I are varied greatly according to the particle size, it is necessary to consider it very carefully.

I. INTRODUCTION

The Fukushima accident raised greater concern regarding the protection of the public in the event of an emergency at a nuclear facility. During a nuclear accident, inhalation may be the main exposure pathway for radionuclides. Radioiodines are radionuclides of major concern under a nuclear reactor accident, and are concentrated in the thyroid of the exposed person for at least a brief period after inhalation. There are at least 24 radioisotopes of iodine, and ^{132}I, ^{133}I, ^{134}I and ^{135}I are produced in greater yields than ^{131}I in the thermal neutron fission of ^{235}U. However, because of its relatively long half-life, thyroidal irradiation by a nuclear accident is ascribed almost entirely to ^{131}I. (Ref.1) Therefore, we evaluated the inhalation dose by ^{131}I among the radioiodines in this research. In the absence of specific information, to evaluate the inhalation dose by ^{131}I for the members of the public, it is assumed that the particle size is 1 ㎛ AMAD and Type F. Because the inhalation dose depends on the particulate properties, in this research, for Type F, M and S, we evaluated the sensitivity of the inhalation dose for ^{131}I based on the particle size.

II. METHOD

To evaluate the inhalation of ^{131}I, the Human Respiratory Tract Model (Ref. 2) was used in this study. In this model, the respiratory tract was divided into extrathoracic(ET), bronchial(BB), bronchiolar(bb) and alveolar-interstitial(AI) regions based on anatomical, cytological, physiological, radiobiological, and aerosol deposition and clearance considerations. For the purpose of dosimetry, the morphological and cytological dimensions are assigned to these regions for the reference workers and scaled to apply to members of the general population, 3 mon, 1 y, 5 y, 10 y, 15 y and adults. The values of regional deposition in the human respiratory tract are tabulated in ICRP 66 for members of the public considering four reference levels of exercise: sleep, sitting, light exercise, and heavy exercise. They deal with aerosols ranging in size from 0.0006 ㎛ to 0.2 ㎛ AMTD (Activity Median Thermodynamic Diameter) and from 0.5 ㎛ to 20 ㎛ AMAD (Activity Median Aerodynamic Diameter). These values are calculated for aerosols having a log-normal particle size distribution with a geometric standard deviation (σ_g) of 1.0 to 2.5. The density and particle shape factor are assumed as 3 $g \cdot cm^{-3}$ and 1.5. Using the values of regional deposition, daily time budget, and ventilation parameter, as shown Table I, we calculated the total deposition of inhaled aerosols except ET_1 for members of the public as a function of the particle size. The material deposited in ET_1 is removed through extrinsic means. The results are shown in Fig. 1, and the total deposition in respiratory has similar trend for all age groups.

TABLE I. Daily time budget and ventilation parameters

Exercise level	3mon		1y		5y		10y		15y		Adult	
	h	m^3h^{-1}	h	m^3h^{-1}	h	m^3h^{-1}	h	m^3h^{-1}	h	m^3h^{-1}	h	m^3h^{-1}
Sleep	17.0	0.09	14.0	0.15	12.0	0.24	10.0	0.31	10.0	0.42	8.0	0.45
Sitting			3.33	0.22	4.0	0.32	4.67	0.38	5.5	0.48	6.0	0.54
Light Exercise	7.0	0.19	6.67	0.35	8.0	0.57	9.33	1.12	7.5	1.38	9.75	1.5
Heavy Exercise									1.0	2.92	0.25	3.0

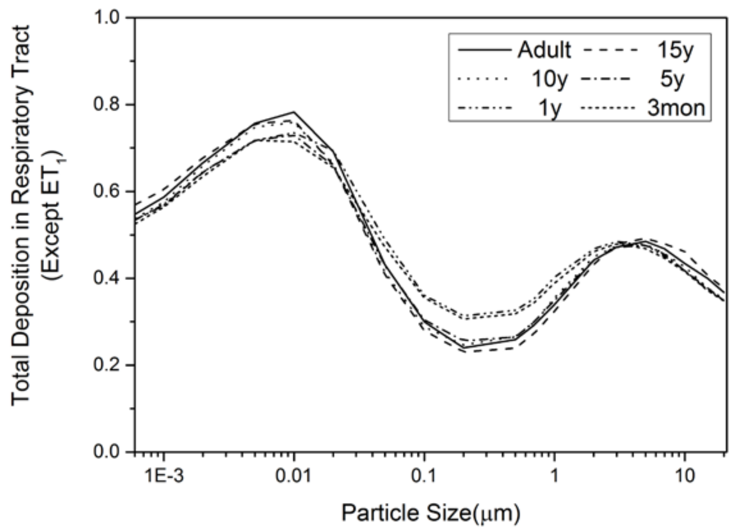

Fig. 1. Total deposition of aerosol except ET_1 for members of the public as a function of the particle size (0.0006 μm - 20 μm)

II.A. Inhalation Dose by Particle Size Distribution

As shown in Fig.1, the total depositions in the respiratory tract of individuals are governed by the size distribution of the aerosol particles. Using the total deposition value of the aerosol and inhalation dose coefficient for ^{131}I (Ref. 3) by members of the public, we calculated the committed equivalent dose coefficients for the thyroid and the effective dose coefficients (Sv Bq^{-1}), the results of which are shown in Fig. 2. We assumed the material as Type F, and almost all material deposited in BB, bb, AI and 50 % of ET_2 reaches the blood quickly and the dose depends on the total deposition except ET_1. The other 50 % of the material deposited ET_2 is transported to the gastrointestinal (GI) tract. All age groups have a similar trend for effective dose coefficients and committed equivalent dose coefficients for the thyroid. The effective dose coefficients increased from 0.0006 μm to 0.01 μm, and then decreased to 0.2 μm. For a particle size of 0.2 μm to 5 μm, the effective dose coefficients increased and then decreased from 5 μm particles. As a results, when the particle size distributions are from 0.0006 μm to 20 μm, the effective dose coefficients are from 5.23×10^{-9} (Sv Bq^{-1}) to 1.71×10^{-8} (Sv Bq^{-1}) for adults. Because the effective dose coefficient is 7.40×10^{-9} (Sv Bq^{-1}) when the particle size is 1 μm, the inhalation dose can be underestimated by 71 % or overestimated by 231 % according to the particle size.

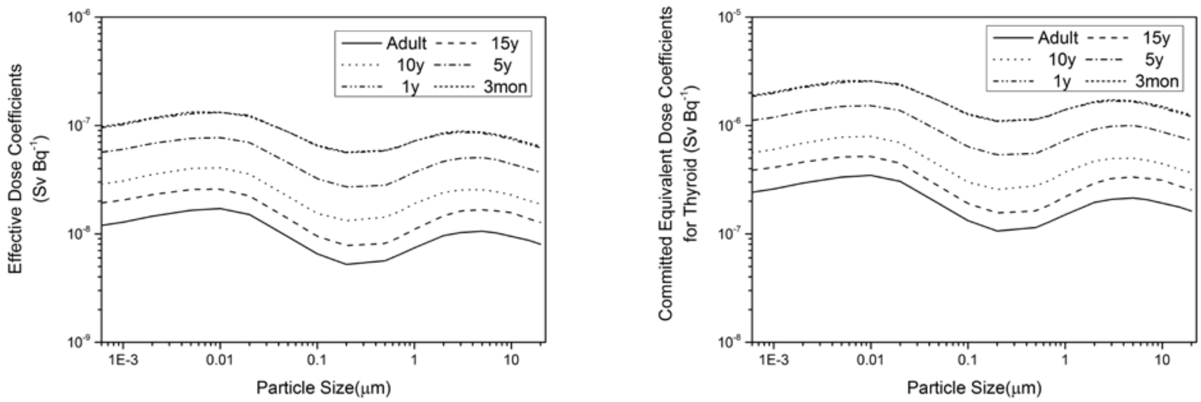

Fig. 2. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size (Sv Bq^{-1})

II.B. Inhalation Dose by Absorption Type

Usually, the absorption type for ^{131}I is assumed as Type F. But in this research, we evaluated the committed equivalent dose coefficients for the thyroid and the effective dose coefficients (Sv Bq^{-1}) for Type M and S as a function of the particle size. For a moderately soluble Type M material deposited in respiratory tract, 10 % of BB and bb, 5 % of ET_2 and 70 % of AI are absorbed in the body fluids. For the Type S material, about 10 % of deposited material in AI reaches the body fluids. The fraction of material absorbed through the GI tract can be shown using the f_1 value. The f_1 values for ^{131}I are shown in Table II.

TABLE II. f_1 values for ^{131}I

Absorption Type	f_1 value					
	3mon	1y	5y	10y	15y	Adult
Type F	1.0	1.0	1.0	1.0	1.0	1.0
Type M	0.2	0.1	0.1	0.1	0.1	0.1
Type S	0.02	0.01	0.01	0.01	0.01	0.01

For all age groups, we calculated the effective dose coefficients and the committed equivalent dose coefficients for the thyroid using the f_1 values as shown in Fig. 3, 4, 5, 6, 7 and 8. The x in figures indicated the values by 1 ㎛ and Type F particle. For adults, the effective dose coefficients are from 1.22×10^{-9} (Sv Bq^{-1}) to 7.90×10^{-9} (Sv Bq^{-1}) for the Type M and from 5.06×10^{-10} (Sv Bq^{-1}) to 7.24×10^{-9} (Sv Bq^{-1}) for the Type S based on the particle size distribution. Because the effective dose coefficient is 2.40 $\times10^{-9}$ (Sv Bq^{-1}) for the Type M when the particle size is 1 ㎛, the inhalation dose can be underestimated by 51 % or overestimated by 329 % according to the particle size. For the Type S, the inhalation dose can be underestimated by 32 % or overestimated by 452 % comparing with the value by 1 ㎛. In the case of Type M and S, the ratios by underestimation or overestimation according to the particle size are larger than for the ratio by Type F. These trends also are showed other age groups. For example, for 3mon, the inhalation dose can be underestimated by 79 % or overestimated by 185 % in the case of the Type F. The underestimation ratio by the Types M and S are 61 % and 45 %, respectively. And the overestimation ratio by the Types M and S are 330 % and 458 %, respectively.

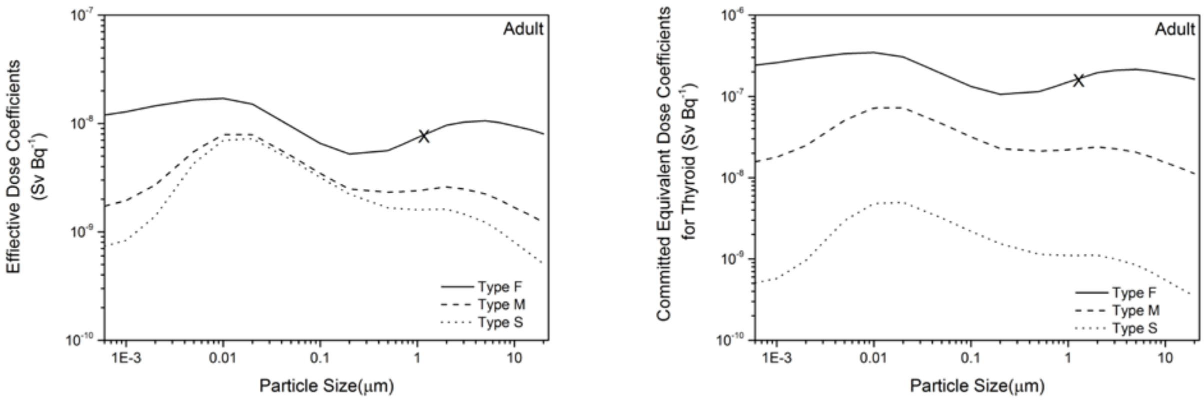

Fig. 3. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size and absorption type (Adult, Sv Bq^{-1})

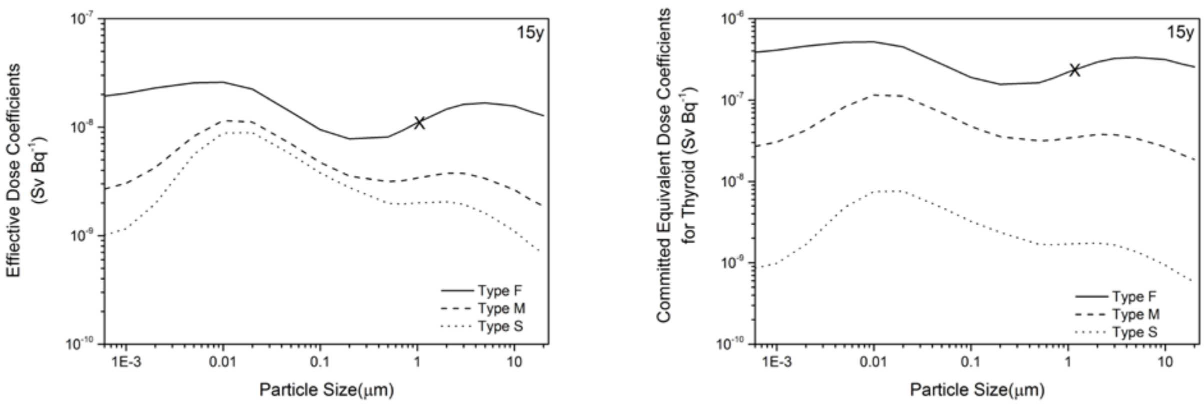

Fig. 4. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size and absorption type (15 y, Sv Bq^{-1})

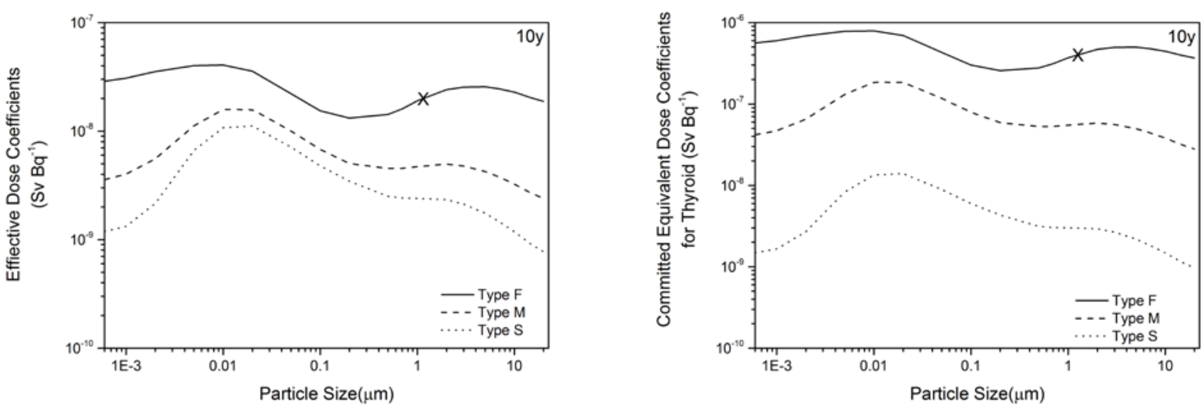

Fig. 5. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size and absorption type (10 y, Sv Bq^{-1})

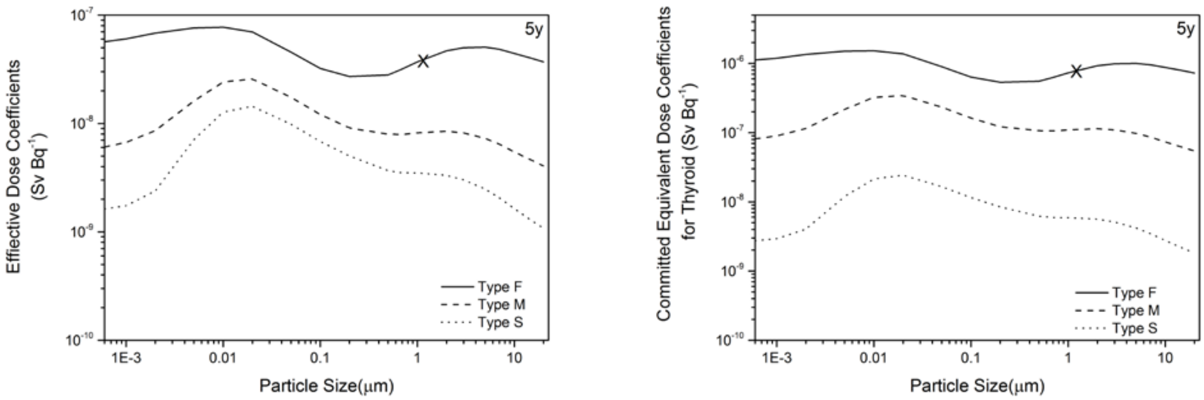

Fig. 6. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size and absorption type (5 y, Sv Bq^{-1})

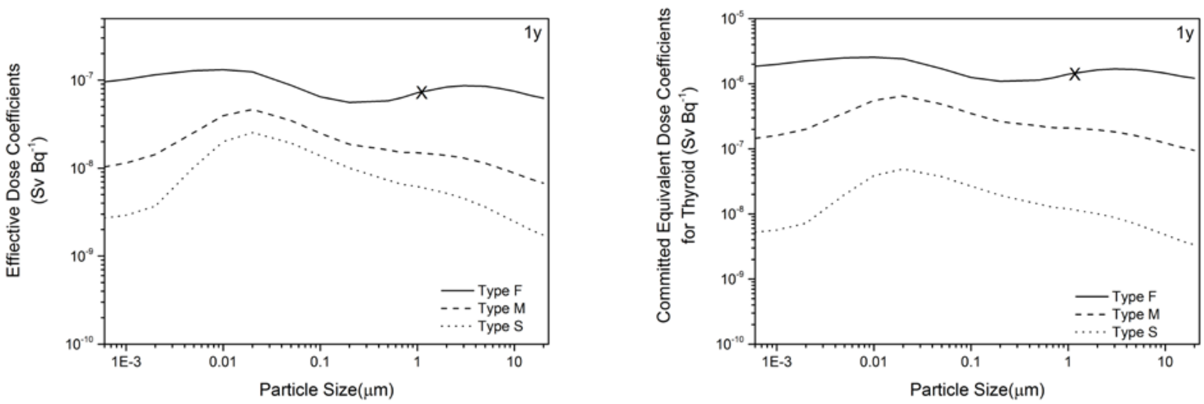

Fig. 7. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size and absorption type (1 y, Sv Bq^{-1})

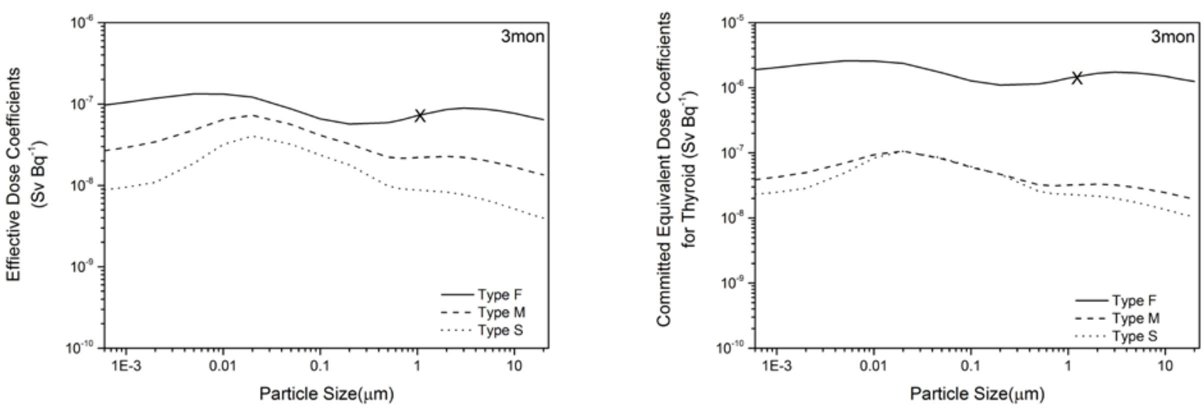

Fig. 8. Effective dose coefficients and committed equivalent dose coefficients for the thyroid as a function of the particle size and absorption type (3 mon, Sv Bq^{-1})

III. RESULTS AND DISCUSSION

When a reactor accident occurs, ^{131}I is an important radionuclide to protect the members of the public. In the absence of specific information on the particle properties, we assumed that the size and absorption type for ^{131}I are 1 ㎛ and Type F. In this research, we evaluated the sensitivity of the inhalation dose by ^{131}I according to the particle size distribution per absorption type. If the inhalation dose is 1 when the particle size of ^{131}I is 1 ㎛, the relative doses are varied greatly as the particle size is changed from 0.0006 ㎛ to 20 ㎛. The results are represented in Fig. 9 for Types F, M and S. For Type F, the differences are from 0.7 to 2.3 for adults, and the other groups also show similar trends. This means that the inhalation dose can be underestimated when the particle size is smaller than 0.05 ㎛ or larger than 1 ㎛. For Types M or S, the relative ratios are larger than Type F according to the particle size. The relative ratios are from 0.5 to 3.3 for Type M, and there are possibilities to underestimate the inhalation dose for particle of 0.002 ㎛ to 0.2 ㎛ in size. For particles larger than 5 ㎛, the inhalation dose can be overestimated contrary to Type F. The relative dose for Type S is similar to that of Type M, however the ratio differences are larger. The relative ratios for Type S are from 0.3 to 4.5, and it is possible to underestimated the inhalation dose for particles smaller than 1 ㎛. In other words, the inhalation dose by ^{131}I is varied greatly according to the particle size per absorption type. Specially, because the particle size from 0.005 ㎛ to 0.05 ㎛ can greatly affect the inhalation dose, it is necessary to consider the particle size very carefully.

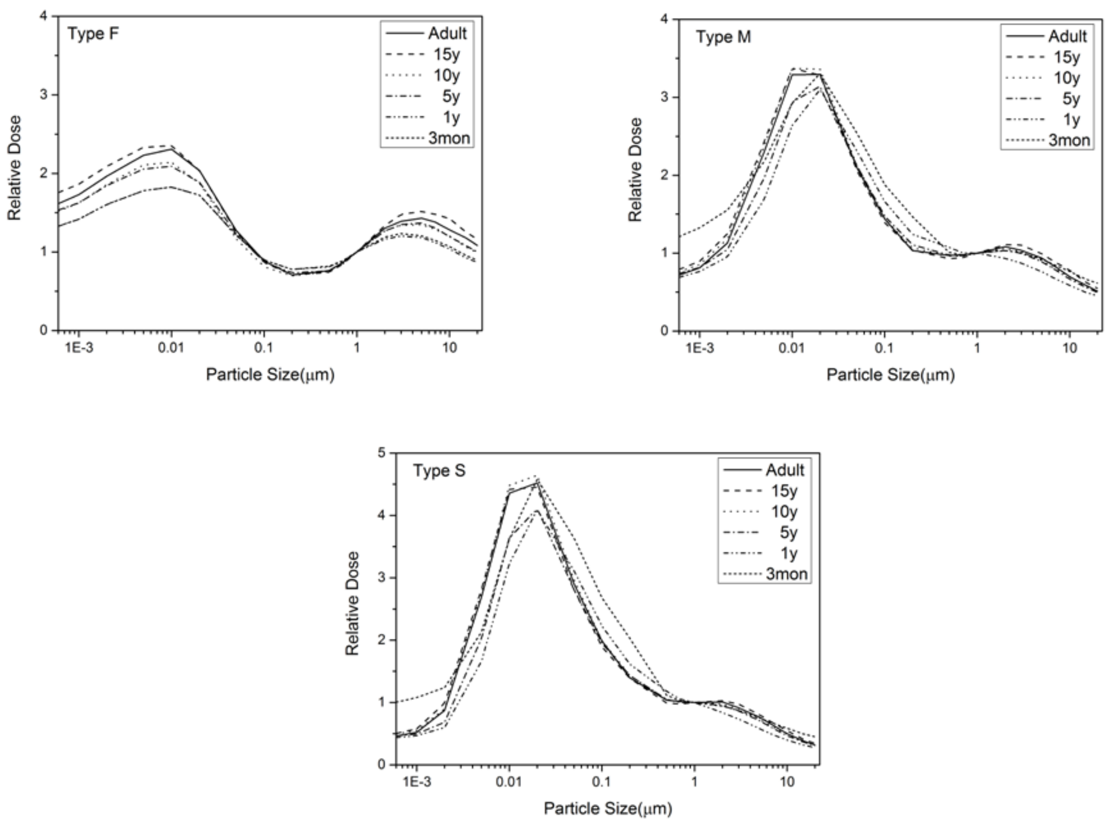

Fig. 9. Relative doses according to the particle size distribution per absorption type

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