Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22, 2009

Internal Dose Conversion Coefficients of Domestic Reference Animal and Pants for Dose Assessment of Non-human Species

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1. Introduction

Traditionally, radiation protection has been focused on a radiation exposure of human beings. In the international radiation protection community, one of the recent key issues is to establish the methodology for assessing the radiological impact of an ionizing radiation on non-human species for an environmental protection [1, 2]. To assess the radiological impact to non-human species dose conversion coefficients are essential. This paper describes the methodology to calculate the internal dose conversion coefficient for non-human species and presents calculated internal dose conversion coefficients of 25 radionuclides for 8 domestic reference animal and plants.

2. Models

In this section the uniform isotropic model [3, 4] to calculate the internal dose conversion coefficients of non-human biota is described.

2.1 Uniform Isotropic Model

To calculate the internal dose conversion coefficient for non-human species, the following assumptions are made.

1) Target organism is present in an infinite homogeneous environmental media
2) The activity of an organism is uniform throughout its body.
3) The densities of the environmental medium and the organisms' body are equal. This assumption is reasonable for an aquatic system where the difference in density between water and an organism is small. However, it is also applied for other media such as soil because the effect of the surrounding media on the energy absorption is known to be small.

Under above assumptions, the internal radiation dose rates for specific source activity (μ Gyd^{-1} per Bqkg^{-1}) can be expressed by

$$D_{\text{int}} = \sum_{\nu} \left(\sum_{i} E_i y_i \phi(E_i) + \int N_{\beta}(E) E \phi(E) dE \right) \quad (1)$$

where ν denotes a radiation type (α, β, γ); E_i (MeV) and y_i (decay^{-1}) are energy and yield of the discrete energy radiations per decay of the radionuclide; $N_{\beta}(E)$ (decay^{-1}MeV^{-1}) is the energy spectrum of β − particles; $\phi(E)$ is the absorbed energy fraction, which is defined as the fraction of energy emitted by a decaying radionuclide that is absorbed within the organism

2.2 Absorbed Energy Fraction

The absorbed energy fraction in Eq.(1) is a fundamental quantity for estimating internal radiation dose rate. The value is greatly dependent on the size of organisms as well as the radiation energy. Ulanovsky and Proel [4] proposed an empirical equation to calculate the absorbed energy fraction of organisms of a non-spherical shape (ellipsoid), ϕ, using the absorbed fraction for a spherical shape, ϕ_s.

$$\phi(E) = RF\,(E, M, \eta) \times \phi_s(E) \quad (2)$$

where *RF* is the rescaling factor, which is the function of *E*, *M*(mass of organism), and *η*(ratio of surface of ellipsoidal shape to that of sphere), and its value is unity for a spherical type; ϕ_s is the absorbed fraction for a spherical organism of the same mass (*M*) with an ellipsoidal organism.

In this work ϕ_s is calculated by the Monte Carlo simulation with the following assumptions.

1) Radiation source: electron and photon
2) Energy range (*E*): 10keV to 5MeV
3) Energy cut-off: 1keV for electron, 10keV for photon
4) Range of organism mass (*M*): 10^{-6} kg to 10^{3} kg
5) Medium size: more than 20 mean free path of photon in water.

Low-energy radiation (all α −particles and β with less than 10keV) has been considered as non-penetrating into a material like tissue so that the absorption fraction of a low energy radiation may be assumed to be unity.

3. Results and Discussion

3.1 Absorbed fraction

The absorbed energy fraction of electron and photon for a spherical shape is shown in Fig.1. The value of the absorbed fraction ranges from unity for low energy and large organisms to an order of 10^{-5} for high energy of photon and small organisms. The mean free path of photon is considerably longer than the range of electrons, and thus the energy absorption of photon within organisms is less that of electron. This leads to a higher absorbed fraction for electron than photon.

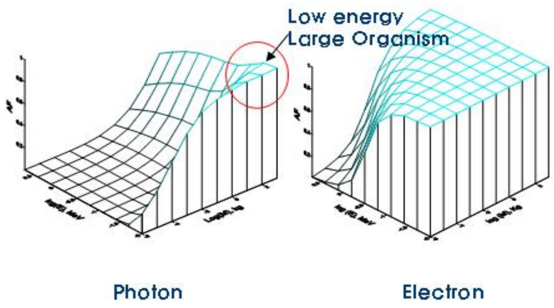

Fig.1 Effect of the energy and mass on the absorbed fraction for a spherical shape of photon and electron.

3.2 Internal Dose Conversion Coefficient

Table 1 shows the domestic reference organisms that were used in the calculation of the internal dose conversion coefficient. The reference animal and plants (RAPs) were selected based on the ICRP new recommendation [2] and EIR (Environmental Impact Report) for the Gyeongju ILLW repository. The size of the selected organisms was taken from the "Endemic Species of Korea" [5]. The shape of all the organisms was assumed to be ellipsoid. For an ellipsoid, a, b, and c is respectively the lengths of the major, 1st minor and 2nd minor axis

Table 1: Geometry of the domestic RAPS

Organism	Size (cm)		
	a major axis	b minor axis	c minor axis
Pine tree	1000	30	30
Rat	10	3	2.5
Roe deer	105	50	50
Frog	3.2	3	2
Snake	85	1	1
Crucian	8	3	1
Bee	1.8	0.5	0.5
Earthworm	9.5	0.4	0.4

For the above selected domestic organisms, internal dose conversion coefficients (DCC_{int}) were calculated for 25 radionuclides (^{3}H, ^{7}Be, ^{14}C, ^{40}K, ^{51}Cr, ^{54}Mn, ^{59}Fe, ^{58}Co, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{99}Tc, ^{106}Ru, ^{129}I, ^{131}I, ^{136}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{144}Ce, ^{238}U, ^{239}Pu, ^{240}Pu). The radionuclides came from the environmental radiation monitoring program of Gyeongju ILLW repository, and are being considered primary in the non-human species dose assessment tool (called K-BIOTA) under the development. The transformation data of the radionuclides were referenced from the ICRP 38[6], and the β-energy spectrum was extracted from the DexRax32 code of the Oak Ridge National Laboratories, USA [7]. In all the calculations, the progenies with half lives less than 10 days of each radionuclide were incorporated in the DCC_{int} calculation of its parent radionuclide.

Fig.2 shows the calculated internal dose conversion coefficients for 4 organisms. The DCC_{int} (μ Gyd^{-1} per $Bqkg^{-1}$) covers a wide range from 10^{-6} to 10^{-2} according to the radionuclide and organism (size). It appears higher for alpha radionuclides such as ^{239}Pu, ^{240}Pu, and ^{238}U and for large organisms such as roe-deer and pine tree. As described in the result of the absorbed energy fraction, it is because the radiation energy is deposited more in organisms when the energy is low and the organism is large.

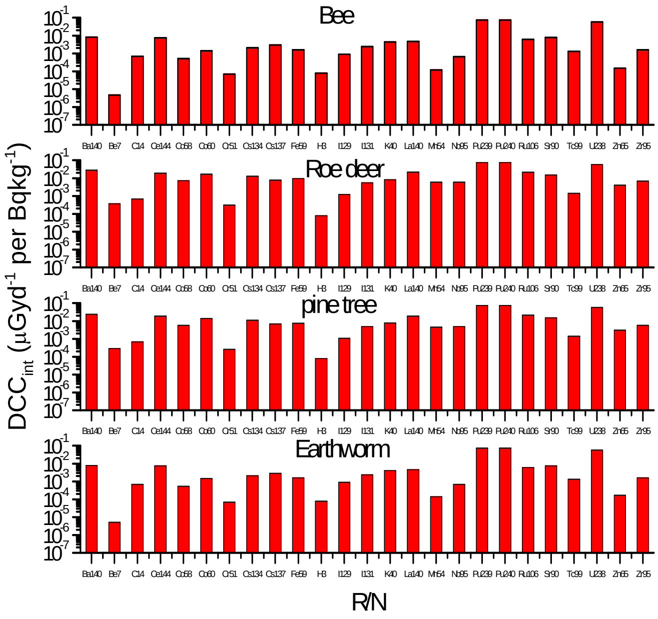

Fig.2 Calculated internal dose conversion coefficients of bee, roe-deer, pine tree and earthworm

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