K-BIOTA: A Computer Program for Assessing Radiation Doses to Non-human Species

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1. Introduction

Recently, the Internal Commission on Radiological Protection (ICRP) stressed the importance of the environmental protection from the ionizing radiation [1], and subsequently proposed the reference animal and plant (RAPs) concept, and the methodology to evaluate non-human species radiation dose [2]. In order to apply an integrated methodology of addressing the international recent issue for the protection of the environment from the ionizing radiation to the Korean ecological environment, the K-BIOTA, a computer program for assessing radiation doses to non-human species, is presently being developed. This paper describes the components and methodologies that are considered in the K-BIOTA.

2. K-BIOTA

The K-BIOTA was designed to analyze radiation exposures to organisms which live in terrestrial and aquatic ecosystems, as a result of the radionuclide release into environment. The code calculates not only the dose conversion coefficients for the selected organisms and radionuclides, but also the mean absorbed dose rate for the whole body of the selected organism resulting from external and internal exposures. Basic equation for the whole body absorbed dose rate (D_{tot}) for a specified organism in a reference environmental medium was

$$D_{tot} = \sum_i (CR_i \times DCC_{\text{int},i} + DCC_{ext,i}) C_{i,m} \quad (1)$$

where CR_i (Bq/kg organism per Bq/kg medium) was the concentration ratio of radionuclide i, $C_{i,m}$ (Bq/kg medium) was the average concentration of radionuclide i in the reference environmental medium and $DCC_{int,i}$ (μG/d per Bq/kg organism) and $DCC_{ext,i}$ (μGy/d per Bq/kg medium) are the internal and external dose conversion coefficients of radionuclide i for the reference organism, respectively. Dose conversion coefficients, concentration ratios, and the concentration of environmental medium were critical input data that should be priorly defined to calculate the absorbed dose rate for a target organism. Fig.1 shows the constituent components of the K-BIOTA. The basal components that constitute the K-BIOTA were described briefly below.

2.1 Reference Animals and plant (RAPs)

Reference organisms are series of targets that provide a basis for the evaluation of radiation dose rate. Seven animals (rat, roe deer, frog, snake, minnow, bee, and earthworm) and one plant (pine tree) were considered as the reference organisms (RAPs) in the present version of the K-BIOTA. They were selected based on the ICRP new recommendation issued in 2007 [1] and EIR (Environmental Impact Report) for the Gyeongju ILLW repository. It is noted that the present organisms were not selected for regulatory purpose, but for establishing the frame of the K-BIOTA

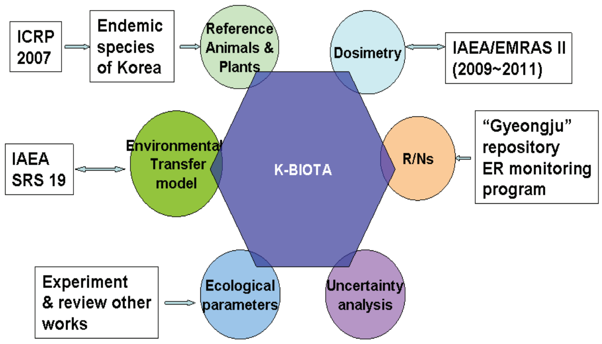

Fig.1 Constituent components of K-BIOTA

2.2 Radionuclides

At the present version of the K-BIOTA, twenty-five 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) was considered as the potential source term of causing radiological damage to organisms. The radionuclides were taken from the environmental radiation monitoring program of Gyeongju ILLW repository.

2.3 Dosimetric model

Dose conversion coefficients are one of the critical components that are required to calculate dose rate. Internal dose conversion coefficients for all the selected reference organisms were calculated by the uniform isotropic model [3-4]. The uniform isotropic model assumes the homogeneous distributions of radionuclides in organisms although often the radionuclide concentration displays variation in a tissue or organs of the organism. Also, the model assumes that there is no difference in density between target organisms and surrounding environment. For the simplicity of modeling, the geometry of all the organisms was assumed to be ellipsoid. The size of the selected organisms was taken from the "Endemic Species of Korea" [5]. The calculated internal dose conversion coefficients (μGy/d per Bq/kg) were in the range from

10^{-6} to 10^{-2} according to the type of radionuclide and organism [6]. The values were higher for alpha radionuclides and for large organisms because the radiation energy was deposited more in organisms when the energy is low and the organism was large.

External dose conversion coefficients for an aquatic organism were obtained by the uniform isotropic model [4], while that for a terrestrial organism were obtained by the Monte Carlo simulation for a photon transport in a reference environment [7]. The calculated external dose conversion coefficients were in the range from 0 to 0.035 (μGy/d per Bq/kg) (Fig.2). For all the animals considered, the external dose conversion coefficients were higher for γ emitting radionuclides, while the values were extremely small (less than 10^{-5}) for radionuclides that emit a low energy radiation [8]. The low energy radiation was not strong enough to penetrate effectively into the tissue of the target organism. For the same reason, the radionuclides that emitted a low energy radiation became a very important contributor in the internal dose rate.

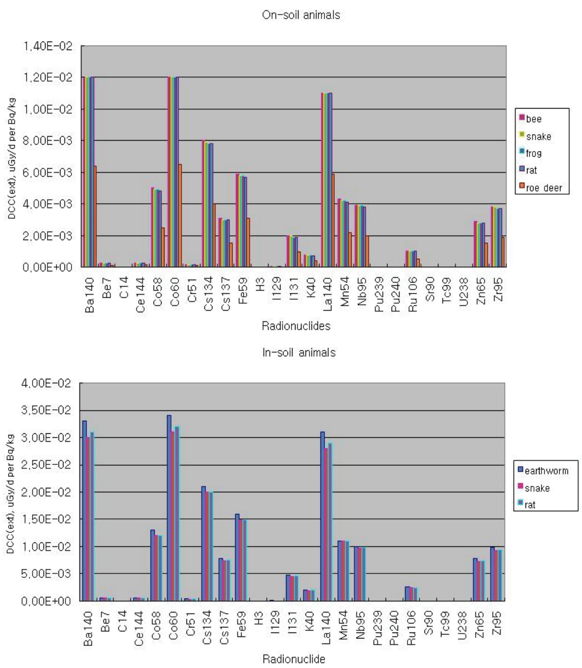

Fig.2 External dose conversion coefficients for on-soil and in-soil animals

2.4 Ecological Parameters

Concentration ratios, equilibrium distribution coefficient between water and sediment, and occupancy factor (fraction of time that organism spends at a specified site) are kinds of the basic ecological parameters that are required to calculate the dose rate to biota. These parameters should be harmonized with the ecological characteristic of individual country. To be used in the K-BIOTA, the CRs for the Korean endemic species are being measured in the laboratory, in parallel with the reviewing data from the literatures. For examples, the time-dependent CR of ^{137}Cs, ^{85}Sr, and ^{65}Zn for the Chinese Minnow (*Moroco oxycephalus*) were measured. The CRs of ^{137}Cs, ^{85}Sr, and ^{65}Zn for an earthworm are to be measured.

2.5 Environmental Radionuclide Transfer Model

The concentration of environmental medium (soil, and river, lake) is generally obtained from the monitoring of radionuclides at the interest site. In the K-BIOTA, the medium concentration as input data for the dose calculation was defined by two ways (optional); the direct input of the measurement value or the estimation by the environmental transfer model based on the release rate of radionuclide. Of environmental transfer models, the convective dispersion model was applied to estimate the radionuclide concentration in a saturated soil, and the IAEA SRS-19 models [9] are adopted to determine the radionuclide concentration in river and lake.

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