Metabolism of Radiocarbon and Tritium in the Human Body

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Abstract

In the radiation safety assessments for nuclear facilities including the first commercial spent nuclear fuel reprocessing plant in Rokkasho, Japan, the internal doses of the pubic due to ingested ^{14}C and tritium have been estimated using the dose conversion factors based on the simple ICRP metabolic models in the human body. Although the biological half-life of tritium water (HTO) in the human body was examined in several cases, actual data on the metabolism of organic ^{14}C and organically bound tritium (OBT) in diet are quite limited. The objectives of this research program are to establish experimentally the metabolic models of organic ^{14}C and OBT in the human body for more realistic dose estimation. To obtain metabolic parameter values of ^{14}C, which are also utilized for OBT, as a substitute for ^{14}C we used the stable isotope of ^{13}C to label organic molecules for oral administration experiments.

Until FY 2018, various ^{13}C-labeled nutrients were administered to volunteers, followed by measuring the ^{13}C concentration in their breath and hair as representatives of inorganic and organic excreta, respectively. Metabolic models were constructed based on our results for each nutrient. The 50-year cumulative body burden for ^{14}C, as an index of the committed dose of the radioisotope ^{14}C, was estimated by each model. The combined metabolic model, named the IES model (^{14}C), was developed using the models for each nutrient. The dose coefficient from ingested organic ^{14}C in uniformly contaminated foods having average nutritional compositions according to the National Health and Nutrition Survey by the Japanese government was calculated by the IES model (^{14}C). In FY 2018 and 2019, ^{13}C-labeled ingredients (peanut and soybean) were administered to volunteers and metabolic models were constructed for each ingredient. All processes of the experiment were approved by the IES Review Board for Human Subject Experiments, and written informed consents were obtained from all volunteers. The conservative estimations of the 50-year cumulative body burden by the IES model (^{14}C) corresponding to the nutrient compositions of those ingredients were larger than the conservative estimations by the individual metabolic models for those ingredients. Therefore, we concluded that the IES model (^{14}C) was adequate to obtain a dose coefficient for ingredients and, consequently, for members of the general public. The IES model (^{3}H) was developed by modifying the IES model (^{14}C). The conservative estimation of the dose coefficient value for ingested OBT ($9.5 \pm 3.5 \times 10^{-11}$) was larger than the value recommended by the ICRP (4.2×10^{-11}).

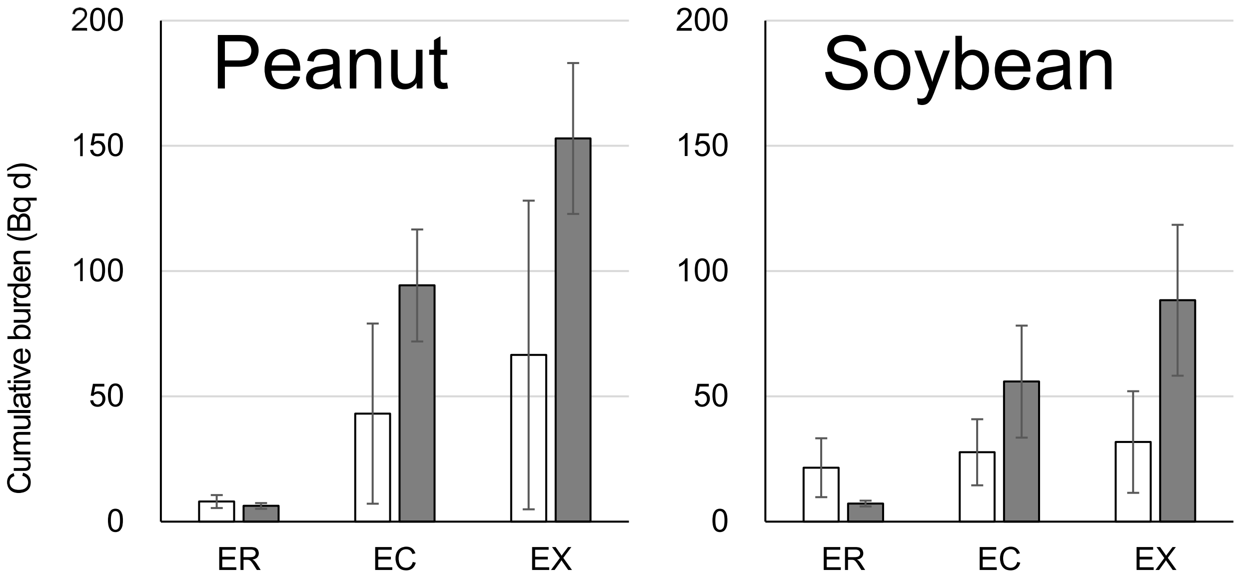

Fig.1 Cumulative body burden for 50 years after an ingestion of 1 Bq of ^{14}C in each ingredient.

Open bars show the estimation by the ^{13}C metabolic model for each ingredient. Shaded bars show the prediction by the IES model (^{14}C) corresponding to the nutrient composition of each ingredient. ER, not conservative estimation. EC, conservative estimation. Ex, extra-conservative estimation.

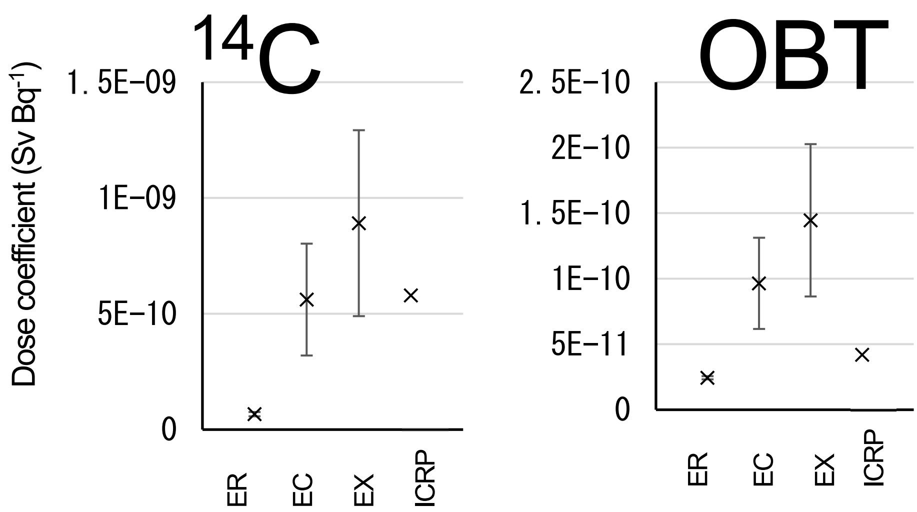

Fig.2 Dose coefficients for organic ^{14}C and OBT ingestion.

OBT, organically bound tritium. ER, not conservative estimation. EC, conservative estimation. Ex, extra-conservative estimation. ICRP, recommended dose coefficient by the ICRP.