Metabolism of Radiocarbon and Tritium in the Human Body

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Abstract

In the radiation safety assessment 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 objective of this research program is 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, we used the stable isotope ^{13}C to label organic molecules in oral administration experiments as a substitute for ^{14}C.

Until FY 2017, 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. In FY2018, hair samples from volunteers administered with ^{13}C-labeled phenylalanine or glucose were measured, and ^{13}C-labeled peanut was administered to volunteers, followed by collecting breath and hair samples. The breath samples were measured for ^{13}C, and the hair samples will be analyzed in FY 2019. 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.

A metabolic model was constructed based on our result for each nutrient. Data for ^{13}C inventories in the breath and hair samples were treated as representatives of inorganic and organic excretion. When the sum of ^{13}C inventories via both excretions after correction of the digestive tract absorption ratio was lower than the administered inventory, the differences between them was assumed as an undetected fraction, which had the residence time of C in adipose tissue. The 50-year cumulative body burden for ^{14}C was estimated by each model for eight nutrients, and showed that the burden of monounsaturated and polyunsaturated fatty acids were distinctly large among the nutrients. Contribution of undetected fraction to the burden was dominant for unsaturated fatty acids. We coupled eight metabolic models in series, which could estimate the retention of ^{14}C ingested in various nutritional compositions, and named it the IES model. The cumulative body burden for 50 y was estimated by the IES model for 1 Bq of ^{14}C intake through uniformly contaminated foods having average nutritional composition according to the National Health and Nutrition Survey by the Ministry of Health, Labour and Welfare, Japan. A large proportion of the result estimated by the IES model was contributed by the undetected fractions. Although the result by the IES model had a large error, it roughly agreed with the value obtained by the ICRP model.

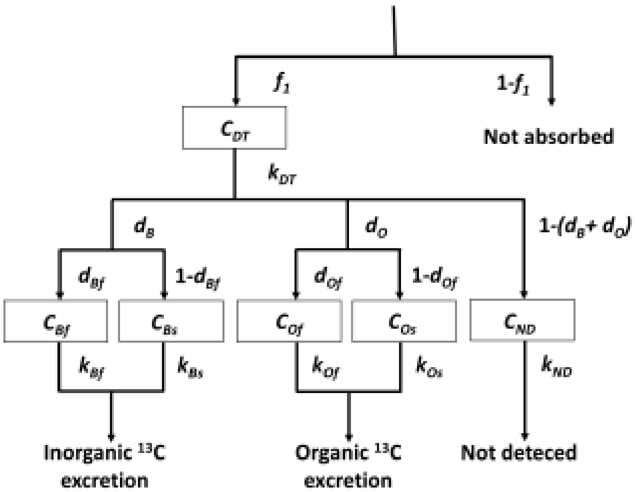

Fig.1 Structure of the metabolic model for ingested ^{13}C.

Compartments of ^{13}C: C_{DT}, digestive tract; C_{Bf} and C_{Bs}, fast and slow compartments for inorganic excretion, respectively; C_{Of} and C_{Os}, fast and slow compartments for organic excretion; C_{ND}, compartment for undetected fraction. f_1, absorption ratio; d_B, d_{Bf}, d_O, d_{Of}, distribution factors; k_{Bf}, k_{Bs}, k_{Of}, k_{Os}, k_{ND}, elimination rate constants.

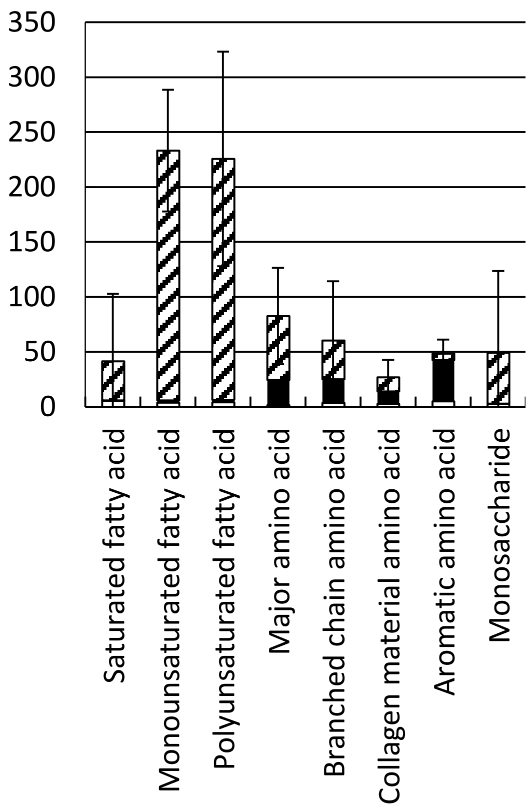

Fig. 2 Cumulative body burden for 50 years after an ingestion of 1 Bq of ^{14}C in nutrients estimated by a metabolic model for each nutrient.

Open, filled, and hatched areas show the burden from inorganic excretion, organic excretion and undetected fraction, respectively.

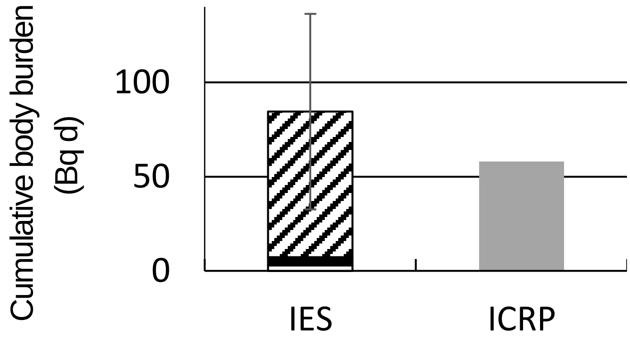

Fig. 3 Cumulative body burden for 50 years after an ingestion of 1 Bq of ^{14}C intake through uniformly contaminated foods having average nutritional composition according to the National Health and Nutrition Survey by