CO10-1 Assessment of Internal doses from Environmental medias contaminated by the Fukushima Daiichi Nuclear Power Plant accident: Absorption fraction of Cs-137 from contaminated wild boars lived in Fukushima prefecture

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INTRODUCTION: Fukushima Dai-ichi nuclear power plant (FDNPP) accident had released large amount of radioactive substances into the environment. Consequently, the living residents within the contaminated area were under threat of radiation exposure externally and internally. Ingestion of contaminated foodstuffs is one potential internal exposure pathways. From the experiences of the FDNPP accident, it is indicated that though the ingestion exposure was not sufficiently high compared to the contribution from external exposures, it still poses a long-term radiological risk and social impacts so that the evaluation of internal dosimetry needs to be addressed appropriately.

Internal dose form ingestion pathway is evaluated by using the committed effective dose coefficient, which is recommended by the International Commission on Radiological Protection (ICRP). The coefficients depend on body and organ masses, excretion rates from the urinary bladder and absorption fraction of ingested radionuclide from the gastrointestinal system. In particular, The ICRP adopted the absorption fraction is set to be 1 under an assumption that the all the Cs would be absorbed. However, this assumption is valid only to soluble form. If the absorption faction varied, this variability results in large uncertainties in the calculations of the coefficient (Pratama et al., 2017; 2018).

In the light of this background, to explore the insight on the absorption fraction of radionuclides in gastrointestinal, we are carrying out *in-vitro* digestion (IVD) tests for the environmental samples contaminated by Cs-137 from the FDNPP accident. As the first step of our project, we performed the in-vitro digestion test for the contaminated soils so far (Takahara et al., 2017). In this study, we focused on the absorption fraction of Cs-137 in foodstuffs contaminated by the FDNPP accident.

EXPERIMENTS: A boar living in difficult-to-return zone was obtained from a local hunter in November 2017. Thereafter, the boar meat was divided into three parts which are loin, belly and ham (n = 3). Each part were then split into 1 kg size meat and stored at -20 °C until the time of experiments in January 2019. The meats were minced by using a grounder. 5 g of each part of grounded meat were taken to be used for the IVD test.

In-vitro digestion test

The IVD test was adapted from standardized in vitro digestion method “INFOGEST” proposed by an international consensus in 2014 (Minekus et al., 2014). According to this method, we simulated oral phase, gastric phase, and intestinal phase.

Radioactivity measurement

Before the IVD test, the radioactivities in the meat samples were measured. The measurements were performed with an error of several percent using a high-purity germanium detector (ORTEC, GMX-30190). After the IVD test, we also measured the radioacvities in the liquid samples extracted with the IVD test.

RESULTS: As shown in Table 1, the radioactivities of loin, belly and ham is 1,863 Bq kg^{-1}, 1,810 Bq kg^{-1} and 1,652 Bq kg^{-1}, respectively. In addition, the absorption fractions were evaluated for each sample as the ratio of radioactivity in row meat to those in extraction. As the consequently, the absorption fraction of Cs-137 was evaluated in the range of 87%–93%. In our experiment, any differences of the concentration and the absorption fraction of Cs-137 in the meat samples of wild boar among the parts were not observed.

The absorption fraction of Cs in dietary sources been reported in the previous studies. It is generally accepted that Cs ingested as soluble Cs is well absorbed in the gastrointestinal tracts of humans and animals. Furthermore, radioactive Cs in foodstuffs is almost equally available for absorption in humans and animals (i.e. A result of literature review is described in Takahara et al. (2017)). As compared to these results, the absorption fraction from our experiment is not in contradiction to the previous ones. This result indicates that the dose coefficients of the ICRP recommended is reasonable for the dose assessment of the Fukushima case.

Table 1 Results of radioactivity measurement

Sample	Radioactivity (Bq kg^{-1})		Absorption fraction in Small intestinal
	Row meat	Extraction	
Loin	1,863	1,592	87%
Belly	1,810	1,596	88%
Ham	1,652	1,537	93%

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CO10-2 Transfer of Cesium and Potassium to Lettuce (*Lactuca sativa var. crispa*) in Hydroponic Culture

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INTRODUCTION: A large amount of radioactive materials was released into the environment by the Fukushima accident. Among them, Cs-137 is considered as one of critical radionuclides increasing public exposure. The evaluation of exposure requires, in general, environmental parameters, such as transfer factor (TF) and translocation ratio (TR), and it is desirable that they are obtained by using carrier-free radionuclide for convenience of experiment. Based on the knowledge that the behavior of cesium in biota is similar to that of potassium due to chemical analogy, carrier-free tracer of Cs-136 and K-43 was produced and the TF and TR values of both nuclides to lettuce in hydroponic culture were investigated.

EXPERIMENTS: Cs-136 and K-43 were produced from a barium and calcium target through a photonuclear reaction, respectively. The powder of $BaCl_2$ and $CaCl_2$ in each quartz test tube was heated at 350 ^{o}C for 5 hrs and then the dehydrated powder was encapsulated under a vacuum. The quartz tube inserted into an aluminum folder was irradiated with photons, which was generated by bombardment of platinum sheet (2 mm) with electrons of 30 MeV, for 12 hrs at the KURNS-LINAC [1].

Cesium and potassium was purified by removal of barium and calcium, respectively, as carbonate and then by cation exchange chromatography. Irradiated samples were dissolved with H_2O and added with ammonium carbonate solution to precipitate $BaCO_3$ and $CaCO_3$. After centrifugation the supernatant was heated to remove ammonium chloride. The residual was dissolved with HCl and diluted to 0.1 M HCl. The resulting solution was load onto cation exchange resin. The resin was washed with 1 M HCl to elute cesium or potassium.

The transfer of both elements to Lettuce (*Lactuca sativa var. crispa*) [2] was determined. Seedlings obtained commercially were grown in a nutrient solution [3] for several days and then exposed in a fresh solution containing Cs-136 and K-43 (Fig. 1). After one or three days exposure, seedlings harvested were divided into roots and leaves. The radioactivity of both parts and the nutrient solution was determined by γ-spectrometry. These results yielded the TF value from solution to lettuce and the TR value from root to leaf where TF and TR were defined as the ratio of the specific activity in root or leaf to that in nutrient solution in unit of Lkg^{-1} and the specific activity ratio of leaf to root in unit-less, respectively.

RESULTS: The induced radioactivity of Cs-136 and K-43 was 100 and 50 kBq, respectively. The purification results in the radio activity of barium and calcium under detection limit, which showing that each tracer of Cs-136 and K-43 was high purity and high specific activity. However, the cesium tracer purified contained Cs-129 produced simultaneously, which derives many photo-peaks on a gamma spectrum. It is desired to use this tracer after this nuclide decays. Each purification method, namely precipitation or chromatography, can decrease the radio activity of barium and calcium to a lower detection limit whereas the residue of their salts was slightly observed. In this study both methods were combined to obtain high-purity tracers.

The values of TF and TR are listed in Table 1. After three days of cultivating the TF values of both elements significantly increased, suggesting they totally transferred to lettuce. In contrast to TF, the values of TR showed some difference between two elements and that lower value of cesium would be caused by some plant physiology. Even though further investigations are required for the migration mechanism of these elements in plants, in this study, we prepared carrier-free radioactive tracers suitable for the investigations.

Fig. 1 Hydroponic cultivation of lettuce in a growth chamber

Table 1 Transfer factor and translocation ratio of potassium and cesium to lettuce

Element	Potassium		Cesium	
Exposure time	1d	3d	1d	3d
TF (root)	27	6700	26	16000
TF (leaf)	11	7000	5.3	2100
TR (leaf/root)	0.40	1.04	0.21	0.13

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CO10-3 Analysis of Radiocesium Interception Potential of Coniferous and Deciduous Forest-Floor Soil

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INTRODUCTION: Radioactive cesium from nuclear accident is known retained strongly in the soil surface for a long time. Study of vertical distribution of radiocesium shows that it was strongly adsorbed by clay minerals in soils and most of deposited radiocesium remains in the surface soil. Understanding the adsorption characteristic of radioactive cesium in soil is a key to minimize the radiation exposure to local population. We collected top-soil samples from Takizawa Research Forest of Iwate University. They were from different type of forest vegetation which are coniferous and deciduous forest. Here, we measured their radiocesium interception potential (RIP) as an index of their radiocesium retention ability.

MATERIALS AND METHODS: The study site was located about 250 km far from Fukushima Daiichi NPP. The soil type is Andosol or Kuroboku soil according to the Japan soil classification. The soil samples used in the experiment were collected from the top-soil (0-10 cm). Four areas of field sampling were selected in two groups of coniferous forest floor and two groups of deciduous forest floor. In coniferous forest floor, the point sampling location were chosen based on their major vegetation type, such as the evergreen Sugi trees (Cryptomeria japonica) and Karamatsu trees (Larix kaempferi). The major vegetation type in around deciduous forest is other broadleaf forest and Japanese Oak trees such as Konara trees (Quercus serrata). Therefore, soil sample that used in this research were named as C1 and C2 respectively for soil sample from coniferous forest area, D1 and D2 respectively for soil sample from deciduous forest area. Soil samples were air-dried at 50 °C for 6 days and sieved through 2mm sieve. About 1.0 g of soil samples was put into a dialysis bag (Visking tube dialysis membrane, size 19.1 mm, As One) along with 5 mL of equilibration solution (0.1 mol/L $CaCl_2$ and 0.5 mmol/L KCl solution), and then transferred to 250 mL plastic bottle containing 200 mL of equilibration solution as outer solution. The solution was shaken for 2 h twice a day during 5 days dialysis using magnetic stirrer. Before shaking the solution, the outer solution was renewed each time to maintain the desired condition. After first step of dialysis, the bag was put into a new 50 mL plastic bottle containing the outer solution and each bottle was added with same mass amount of Cs concentration. In this study, radioactive tracer of 10 kBq of carrier ^{134}Cs and 2.5μg of stable ^{133}Cs were added respecricely. In the second step of dialysis also each bottle was shaken continuously during 5 d. After diluted, the outer solution was filtered using a membrane filter with a pore size of 0.45μm. The remained of Cs concentration then analysed using HPGe detector for radioactive tracer addition and ICP MS for stable Cs addition. The RIP value can be obtained as the product of distribution coefficient value of Cs and the concentration of K^+ in equilibration solution.

RESULTS AND DISCUSSION: In this study we compared RIP value of soils that used radioactive Cesium carrier ^{134}Cs and stable Cesium ^{133}Cs. The RIP values of coniferous soils were varied from 109.44 to 225.96 mmol kg^{-1}, and RIP of deciduous soils varied from 155.21 to 199.68 mmol kg^{-1}. The range of RIP values are in similar range between both of them and it was within the range reported for andosol soils collected worldwide (94 – 1320 mmol kg^{-1}) by Vandebroek et. al. Comparison of RIP values between coniferous and deciduous soil is presented in Figure 4. It shows that RIP measurement using stable Cs is not so different from radiocesium and the measurement using stable Cs is also possible.

Figure 1. Comparison of RIP values.