Soil-to-Plant Transfer Factors of ^{137}Cs for Fresh and Aged Depositions

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1. Introduction

In steady-state food chain models for routine releases, radionuclide concentrations in crop plants due to root uptake are estimated using soil-to-plant transfer factors (TFs) defined as the ratio of plant concentration to soil concentration [1,2]. Of various radionuclides released from nuclear facilities, ^{137}Cs is regarded as one of the most important radionuclides in terms of the ingestion radiation dose. Its half-life is 30 y and its mobility in soil is very low [3,4]. Accordingly, considerable fractions of the ^{137}Cs activity deposited onto farmlands will stay in the root-zone soil for many years, possibly decades. In this paper, a long-term evaluation of root uptake of ^{137}Cs by rice and Chinese cabbage plants were discussed by comparing the TF data acquired from greenhouse experiments and fallout field studies.

2. Materials and Methods

2.1 Greenhouse experiments

Rice and Chinese cabbage plants were grown on pots and/or small lysimeters placed in greenhouses [5-7]. Fig. 1 shows rice plants grown on small lysimeters. A few weeks before planting, the top about 20 cm soils in the pots or lysimeters were mixed with radioactive solutions containing ^{137}Cs. Agricultural practices were made as required until harvest. Plant samples were collected at normal harvest time and analyzed for ^{137}Cs activity by means of gamma spectrometry. TF values were calculated as follows;

$$TF = \frac{plant\,concnetration\left(Bqkg^{-1}\right)}{soil\,concentration\left(Bqkg^{-1}-dry\right)} \quad (1)$$

Fig. 1. Rice plants grown on small lysimeters.

2.2 Field studies

From 1994 to 1995, samples of rice and Chinese cabbage plants at harvest time and associated soils were collected from agricultural fields in 33 areas of South Korea [8]. Soil samples were collected from three points in each field using a core sampler.

The soils from three points were put together to become composite samples. The plant and soil samples were carried to the laboratory and analyzed for the ^{137}Cs activity in the same way as mentioned above. TF values were also calculated using Equation (1). Only 12 TF values could be acquired for each plant species because of generally very low ^{137}Cs concentrations in the plant samples.

3. Results and Discussions

2.1 TF values for fresh and aged depositions

Tables I and II summarize the ^{137}Cs TF values from the greenhouse experiments (fresh deposition) and the field studies (aged deposition) for rice and Chinese cabbage, respectively [5-7]. The sampling in the field studies were performed about 15 years after China had made their last nuclear test in the atmosphere.

For brown rice, TF values of the ^{137}Cs aged in soil mostly for decades were several times lower than those of the freshly-deposited ^{137}Cs. There is only one value of the freshly deposited ^{137}Cs for Chinese cabbage. This TF value is higher than any of 12 TF values for aged deposition by factors of 6-160. Moreover, the pH of the pot soil for the single TF value was higher than the average for the 12 field soils. It is well known that root uptake of radiocesium generally decreases with an increasing soil pH [9,10].

Those observed significant decreases in the TF value of ^{137}Cs for aged deposition is mainly attributable to the fact that ^{137}Cs is easily fixed by soil matrices to become unavailable for plant uptake [8,11].

Table I: Transfer Factors of ^{137}Cs for Brown Rice

Deposition	N	TF values for brown rice [a]		
		Min.	Max.	GM [b]
Fresh	10	8.1×10^{-3}	1.5×10^{-1}	3.1×10^{-2}
Aged	12	1.2×10^{-3}	1.1×10^{-2}	4.5×10^{-3}

[a] for dry plants
[b] Geometric mean.

Table II: Transfer Factors of ^{137}Cs for Chinese cabbage

Deposition	N	TF values for Chinese cabbage [a]		
		Min.	Max.	GM [b]
Fresh	1	-	-	1.1×10^{-1}[c]
Aged	12	6.8×10^{-4}	1.7×10^{-2}	2.7×10^{-3}

[a] for fresh plants
[b] Geometric mean
[c] single value.

2.2 Considerations for Modeling

In existing steady-state food chain models, a single TF value is generally used for a plant-radionuclide combination to evaluate root uptake of the radionuclide accumulated in soil for a build-up time of usually tens of years [1,2]. If the annual decrease in the TF value of ^{137}Cs by soil fixation is not considered, a significant overestimation of root uptake may occur. For such radionuclides as ^{137}Cs, therefore, it would be desirable to use different TF values for the soil deposition in different years. For doing this, a substantial change of the model structure for root-uptake estimation may be required.

4. Conclusions

For rice and Chinese cabbage, TF values of ^{137}Cs were significantly higher for fresh depositions than for aged depositions. This supports that it is desirable to use different TF values for the soil deposition in different years. Further studies should be performed both by experimentalists and by modelers to make a more realistic approach to the time-dependence of the TF value.

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