Parameter Data on the Radiocesium Transfer to Korean Staple Food Crops Following a Nuclear Accident

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1. Introduction

In order to decide an optimum countermeasure against farmland contaminations following a severe NPP accident, it is necessary to have a reliable tool for predicting the concentrations of radiocesium in crop plants. For the estimation of radionuclide concentrations in crop plants, various transfer parameters, which quantify the radionuclide transfer from one compartment to the next, are used in general [1,2]. Some amount of transfer parameter data has been produced at the Korea Atomic Energy Research Institute (KAERI) over the last 30 years [3,4]. The present work was conducted to collate the KAERI data on radiocesium in staple food crops and to suggest effective ways of using them for assessing the environmental impact of a nuclear accident.

2. Materials and Methods

Radiocesium transfer data produced for rice, Chinese cabbage and radish at the KAERI were collected through literature survey. The data sources were KAERI reports and published papers [3-11]. Most of the data had been produced by means of radiotracer experiments in a KAERI greenhouse built for radioisotope experiments. For Chinese cabbage and radish, some IAEA data [2] were added due to a lack of KAERI data. Statistical analyses and intuitive estimations were made with the collected data to derive representative values or standard data of the transfer parameters. Fig. 1 is a schematic diagram of the radiocesium transfer from the atmosphere to food plants [4].

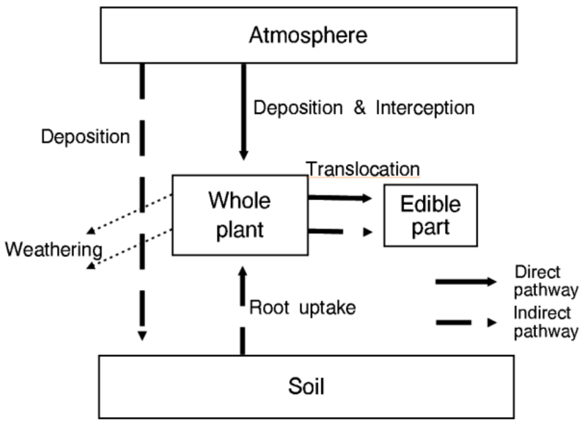

Fig. 1. Radiocesium transfer to food plants.

3. Results and Discussions

In the case of the indirect plant-contamination pathway, the data of the traditional soil-to-plant transfer factor (TF, dimensionless) and those of the transfer factor (TF_{area}, m^2 kg^{-1}) based on the ground-surface deposition density were provided [4,9]. With regard to the direct contamination pathway, the data on the plant interception fraction (IF), weathering half-life (T_w, d) and translocation factor (TLF) were provided [4,7].

The practical usage of the derived representative values or standard data for accidental releases of radiocesium was proposed. The standard data are intended to be used in predicting the plant concentrations of radiocesium due to an accidental release during plant growth. They are given as a representative value for each of several deposition times during the growing seasons. The parameters of this category are the TF_{area}, IF, T_w and TLF (Tables I and II). In the case of the TF, representative values were proposed for the pre-planting deposition without specifying the time of deposition.

Appropriate interpolation and extrapolation may be necessary for the times of deposition which are not included in Tables I and II [3,9,12]. If the actual growth periods are longer or shorter than those for the standard

Table I. Proposed Standard Data for TF_{area}

Plant	Time of deposition		TF_{area} (m^2 kg^{-1})
	DAP	DBH	
Brown rice (dry)	13	125	5.6E-04
	40	98	8.0E-04
	67	71	2.8E-03
	89	49	2.2E-03
	112	26	2.1E-04
Chinese cabbage (fresh)	13	58	3.3E-04
	27	44	4.1E-04
	42	29	3.5E-04
	56	15	6.2E-04
Radish root (fresh)	13	62	7.0E-05
	27	48	1.4E-04
	42	33	4.3E-04
	58	17	2.1E-04

DAP: days after planting
DBH: days before harvest.

data, the actual deposition times need to be proportionally adjusted to the standard growth periods [4].

Table II. Proposed Standard Data on the Direct Pathway

Plant	Time of dep.		IF	T_w (d)	TLF
	DAP	DBH			
Rice	37	112	0.48	35.6	1.2E-02
	65	84	0.80	44.1	3.4E-02
	87	62	0.88	42.1	4.3E-02
	100	49	0.88	49.4	8.4E-02
	114	35	0.94	39.2	1.1E-01
	132	17	0.94	32.1	2.2E-02
Chinese cabbage	11	51	0.16	32.0	-
	23	39	0.59	34.5	-
	34	28	0.77	31.1	-
	45	17	0.83	22.4	-
	55	7	0.87	11.5	-
Radish	29	55	0.17	36.7	9.2E-02
	42	42	0.67	34.3	1.3E-01
	53	31	0.82	25.1	1.0E-01
	64	20	0.86	21.1	9.3E-02
	72	12	0.86	16.0	8.6E-02

DAP: days after planting
DBH: days before harvest.

Table III. Radiocesium TF Data for Brown Rice

TF value	Soil properties				Ref.
	pH (%)	OM (%)	Ex-K	Clay (%)	
1.6E-01	5.8	1.5	0.13	14.0	[5]
1.0E-02	8.8	0.6	0.99	10.6	[5]
1.0E-02	7.7	2.1	0.29	12.6	[5]
4.0E-02	5.5	1.8	0.21	29.8	[5]
1.0E-02	6.0	2.1	0.41	7.8	[5]
2.1E-02	6.4	0.42	0.36	4.7	[3]
6.1E-02	4.4	0.94	0.16	8.0	[6]
1.8E-02	6.1	0.68	0.18	2.8	[6]
3.0E-02	5.6	0.93	0.16	7.2	[6]
1.0E-01	4.6	2.43	0.11	6.0	[6]
1.5E-01	5.5	4.4	0.41	10.2	[10]
2.2E-02	5.4	3.3	0.79	19.9	[10]
8.1E-03	5.6	2.4	0.6	28.2	[8]

OM: Organic matter; Ex-K: Exchangeable K.

Table IV. Radiocesium TF Data for Vegetables

Food plant	TF value	Soil properties		Ref.
		pH (%)	Texture	
Ch. cabbage	1.1E-01	6.0	SL	[3]
Radish root	4.7E-02			

SL: Sandy loam.

Table V. Proposed Representative TF values for Staple Food Plants

Food plant [a]	GM	GSD
Brown rice (D)	2.9E-02	2.9
Ch. cabbage (F)	5.8E-02	3.0
Radish root (F)	2.6E-02	3.0

[a] D: dry; F: fresh
GM: Geometric mean as the representative TF value
GSD: Geometric standard deviation.

Based on the data in Tables III and IV and, additionally for the vegetables, some IAEA data, the standard TF data were proposed as shown in Table V. Because of the uncertainty in the TF value, the proposed representative values may need to be modified (usually increased) with reference to the GSDs.

Most of the transfer data are also applicable to a normal operation of the nuclear facilities. For the IF, T_w and TLF, existing steady-state food chain models generally use single values representative of the whole growth period instead of using deposition time-dependent values. Accordingly, the deposition time-dependent values in Table II need to be appropriately changed into single representative values so as to be usable in such steady-state models [3,4,11].

4. Conclusions

The transfer parameter values of radiocesium for rice, Chinese cabbage and radish varied considerably with soils and times of its deposition. The proposed representative values were mostly based on a limited amount of data so they cannot be considered to have a high representativeness. Accordingly, they are intended for provisional use and a continuous improvement should be made. It is necessary to produce a sufficient amount of additional domestic data on the indirect pathway by conducting root-uptake experiments with as many types of soil as possible. Also for the direct pathway, it is desirable to increase the amount of data through additional and supplementary experiments so as to reflect various kinds of growth conditions.

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REFERENCES

[1] International Atomic Energy Agency, Generic Models for Use in Assessing the Impact of Radioactive Substances to the Environment, IAEA Safety Reports Series No. 19, IAEA, Vienna, 2001.

[2] International Atomic Energy Agency, Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments, Technical Reports Series No. 472, IAEA, Vienna, 2010.

[3] Y. H. Choi, K. M. Lim et al., Parameters on the Radionuclide Transfer in Crop Plants for Korean Food Chain Dose Assessment, KAERI/TR-1993/2001, Korea Atomic Energy Research Institute, 2001.

[4] Y. H. Choi, K. M. Lim, I. Jun, B. H. Kim, D. K. Keum, Transfer Parameter Data of Radiocesium for Staple Food Crops in Assessing the Environmental Impact of a Nuclear Accident, KAERI/TR-6132/2015, Korea Atomic Energy Research Institute, 2015.

[5] J. H. Lee, J. Ryu, J. S. Kim et al., Environmental Impact Studies around Nuclear Facilities, KAERI/RR-386-1/82, 1983.

[6] Y. H. Choi, K. C. Kim, C. W. Lee, et al., Soil-to-plant transfer coefficients of Mn-54, Co-60, Zn-65 and Cs-137 for rice, soybean and vegetables, J. Korean Association for Radiation Protection 16, 55-65, 1991

[7] Y.H. Choi, K.M. Lim, D. Yu, H.G. Park, Y.G. Choi, C.M. Lee, Transfer pathways of ^{54}Mn, ^{57}Co, ^{85}Sr, ^{103}Ru and ^{134}Cs in rice and radish plants directly contaminated at different growth stages, Annals of Nuclear Energy 29, 429-446 (2002).

[8] K.M. Lim, Y.H. Choi, I. Jun, D.W. Park, D.K. Keum, Transfer factor of ^{85}Sr and ^{137}Cs for rice in three paddy soils from the Wolsung area, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, pp. 611-612, 2009.

[9] Y.H. Choi, K.M. Lim, I. Jun, D.W. Park, D.K. Keum DK, C.W. Lee, Root uptake of radionuclides following their acute soil deposition during the growth of selected food crops, J. Environmental Radioactivity 100, 746-751 (2009).

[10] Y.H. Choi, K.M. Lim, I. Jun, D.K. Keum, M.H. Han, I.G. Kim, Transport behavior and rice uptake of radiocesium and radiostrontium in flooded pady soils contaminated in two contrasting ways, Science of the Total Environment 412-413, 248-256, 2011

[11] Y.H. Choi, K.M. Lim, I. Jun, D.K. Keum, M.H. Han, Radioecological studies in Korea Atomic Energy Research Institute, KAERI, Radiation Protection Dosimetry 146, 287-290, 2011

[12] Y.H. Choi, K.M. Lim, I. Jun, D.K. Keum, C.W. Lee, Long-term predictions of the ^{90}Sr and ^{137}Cs concentrations in rice for their acute deposition at different times of the year, J. Nuclear Science and Technology Sup. 5, 650-653 (2008).