Domestic Data on the Radionuclide Transfer From Soils to Rice Plants

Yong-Ho Choi, Kwang-Muk Lim, In Jun, Dong-Kwon Keum, and Hyo-Joon Jeong
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea
yhchoi1@kaeri.re.kr

1. Introduction

Radionuclides in the radioactive waste disposed into an underground repository can enter a biosphere through the movement of underground water if natural and artificial barriers are damaged by certain causes. Rice fields in Korea are usually located in low places and submerged for about half a year. Considerable amount of underground water is used for irrigating them. The above-mentioned conditions make the paddy soils comparatively vulnerable to an invasion of the radioactivity originated from such radioactive wastes. Accordingly, it is very important to have a reliable tool for evaluating the radionuclide transfer from paddy soils to rice plants. Soil-to-plant transfer of radionuclides is generally estimated using the transfer factor (TF), which is a model parameter defined as the concentration ratio between soil and plant. This study was conducted for the purpose of collating TF values for rice which have been measured over last more than 30 years by KAERI.

2. Materials and methods

Most of the TF data was produced by means of pot experiments in greenhouses. Soils were thoroughly mixed with radioactive solutions for the top about 15-20 cm layers sometime before transplanting. Field studies were also conducted for fallout ^{137}Cs in mid 1990s. Tables 1 and 2 show physicochemical properties of the soils

Table 1. Soil properties in greenhouse (GH) experiments

Soil code	Physicochemical properties						
	pH	OM (%)	CEC [a]	K [a] exch.	Ca [a] exch.	Clay (%)	Sand (%)
A	5.8	1.5	7.1	0.13	6.83	14.0	39.3
B	8.8	0.6	8.4	0.99	3.55	10.6	24.8
C	7.7	2.1	12.2	0.29	17.2	12.6	48.8
D	5.5	1.8	10.9	0.21	5.3	29.8	6.0
E	6.0	2.1	9.0	0.41	4.3	7.8	60.5
F	6.4	0.42	7.5	0.36	4.5	4.7	78.9
G	4.4	0.94	6.7	0.16	1.8	8.0	71.4
H	6.1	0.68	4.7	0.18	3.3	2.8	81.9
I	5.6	0.93	5.4	0.16	3.9	7.2	71.9
J	4.6	2.43	7.2	0.11	3.2	6.0	67.3
K	5.5	4.4	8.2	0.41	6.1	10.2	46.2
L	5.4	3.3	16.3	0.79	14.9	19.9	10.6
M	5.6	2.4	12.8	0.63	6.2	28.2	21.5
N	5.5	3.7	14.4	0.29	4.5	11.0	-
O	5.1	4.2	27.7	0.48	10.9	15.4	-
P	5.6	3.0	17.0	0.49	6.1	26.9	-
Q	5.1	4.9	43.5	0.94	20.5	25.2	-

OM: organic matter, CEC: cation exchange capacity
[a] unit: cmol kg^{-1}.

Table 2. Soil properties in field studies

Soil code	Physicochemical properties					
	pH	OM (%)	CEC [a]	Clay (%)	Silt (%)	Sand (%)
S1	5.5	3.74	11.4	14.0	27.4	58.6
S2	5.8	3.24	10.2	14.0	21.0	65.0
S3	5.5	1.69	12.8	17.0	30.1	52.9
S4	5.6	2.24	7.5	20.0	40.7	39.3
S5	5.7	6.55	14.6	14.0	38.1	47.9
S6	5.5	1.94	9.5	20.1	29.6	50.3
S7	4.9	3.12	7.3	17.5	22.3	60.2
S8	5.8	2.14	8.6	20.4	19.9	59.7
S9	4.3	2.07	14.7	25.9	51.1	23.0
S10	5.0	1.95	6.5	17.3	17.1	65.6
S11	5.6	2.52	9.1	16.4	40.1	43.5
S12	6.4	1.83	9.3	21.3	36.7	42.0

OM: organic matter, CEC: cation exchange capacity
[a] unit: cmol kg^{-1}.

Radioactivity analysis was made by means of gamma spectrometry or total-beta counting. TF values (dimensionless) were calculated as follows;

$$TF = \frac{C_{plant}}{C_{soil}} \quad (1)$$

where C_{plant} (Bq kg^{-1}-dry) is the radionuclide concentration in the plant part of interest and C_{soil} (Bq kg^{-1}-dry) is that in the soil.

3. Results and discussions

3.1 Radiocesium (^{137}Cs)

The results on the radiocesium transfer are summarized in Tables 3 and 4.

Table 3. Summary for the Cs TF data from GH experiments

Plant part	Statistics on TF values				
	N (soils) [a]	AM	GM	Min.	Max.
BR	13 (A~M)	4.9E-02	2.9E-02	8.1E-03	1.6E-01
BR	3 (K~M)	6.0E-02	3.0E-02	8.1E-03	1.5E-01
Chaff	3 (K~M)	1.8E-01	8.1E-02	2.1E-02	4.5E-01
Straw	3 (K~M)	9.9E-02	5.0E-02	1.6E-02	2.5E-01

BR:brown rice, AM:arithmetic mean, GM:geometric mean
[a] number of soils tested (See table 1.).

Table 4. Summary for the Cs TF data from field studies

Plant part	Statistics on TF values				
	N [a]	AM	GM	Min.	Max.
BR	12	5.7E-03	4.5E-03	1.2E-03	1.1E-02

3.2 Radiostrontium (^{85}Sr, ^{90}Sr)

Table 5 summarizes the TF data of radiostrontium from greenhouse experiments. Straw had the highest TF value, followed by chaff, then brown rice.

Table 5. Summary for the Sr TF data from GH experiments

Plant part	Statistics on TF values				
	N (soils) [a]	AM	GM	Min.	Max.
BR	4(F,K~M)	4.4E-02	3.0E-02	1.6E-02	1.2E-01
BR	3 (K~M)	1.9E-02	1.9E-02	1.6E-02	2.5E-02
Chaff	3 (K~M)	1.7E-01	1.5E-01	9.7E-02	2.8E-01
Straw	3 (K~M)	7.1E-01	6.6E-01	4.2E-01	1.1E+00

3.3 Technetium (^{99}Tc)

TF data for ^{99}Tc is summarized in Table 6, showing its very low mobility to seeds.

Table 6. Summary for the Tc TF data from GH experiments

Plant part	Statistics on TF values				
	N (soils) [a]	AM	GM	Min.	Max.
BR	4 (N~Q)	1.3E-03	1.1E-03	5.4E-04	2.5E-03
Straw	4 (N~Q)	8.8E-01	8.3E-01	5.3E-01	1.3E+00

3.4 Radioiodine (^{125}I)

TF data for ^{125}I is summarized in Table 7.

Table 7. Summary for the I TF data from GH experiments

Plant part	Statistics on TF values				
	N (soils) [a]	AM	GM	Min.	Max.
BR	3 (K~M)	3.6E-03	2.9E-03	1.1E-03	6.4E-03

3.5 Others (^{54}Mn, ^{60}Co, ^{65}Zn)

The other TF data is summarized in Table 8.

Table 8. Summary for the BR TFs of other radionuclides

Nuc-lide	Statistics on TF values				
	N (soils) [a]	AM	GM	Min.	Max.
^{54}Mn	5 (F~J)	2.9E-01	2.6E-01	1.2E-01	5.2E-01
^{60}Co	4 (F,G,I,J)	4.7E-03	4.3E-03	2.2E-03	6.0E-03
^{65}Zn	4 (G~J)	1.9E+00	1.7E+00	5.8E-01	2.7E+00

4. Conclusions

For a reliable estimation of the ingestion dose, it is important to use site-specific transfer data. Much additional rice TF data needs to be domestically produced for a sufficiently reliable estimation of the dose due to a repository.

5. Acknowledgements

This work was supported by the MSIT, Korea.

REFERENCES

[1] Y.H. Choi, et al., KAERI/TR-1993/2001.
[2] Y.H. Choi, et al., KAERI/TR-6132/2015.