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KAERI's Contribution to the TRS-364 Working Group of the IAEA's EMRAS Program

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1. Introduction

The IAEA's EMRAS (Environmental Modeling for RAdiation Safety) program was initiated in 2003 to enhance the predictive capability of environmental models dealing with radionuclide releases. This program is composed of three themes – Theme 1: Radioactive Release Assessment, Theme 2: Remediation of Sites with Radioactive Residues and Theme 3: Protection of the Environment. Each theme has one or more working groups and the TRS-364 WG belongs to Theme 1. This WG aims at a revision of an IAEA handbook titled "Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments (Technical Reports Series No. 364) [1]." The KAERI has participated in this WG from the beginning and provided a lot of parameter values produced at the KAERI for the past about 20 years [2-4]. An IAEA TECDOC as a collection of participants' contributions is under preparation. The revised handbook shall be in a concise form of this TECDOC.

2. KAERI's Contribution to the TRS-364 WG

The TECDOC by the TRS-364 WG is structured to have 10 chapters. The KAERI contributed its data to the chapters of "Foliar Uptake (Chapter 3)" and "Agricultural Ecosystems – Root Uptake (Chapter 5)." For Chapter 3, experimental data on the interception faction, translocation factor and weathering half-life for major radionuclides and crop plants were provided. For Chapter 5, two different types of soil-to-plant transfer factors were presented. One is the traditional transfer factor (dimensionless, TF_{crop}) and the other is the areal transfer factor ($m^2\ kg^{-1}$, TF_{areal}).

2.1 Interception Fraction

Interception fraction is defined as the fraction of the total deposition that is intercepted and initially retained by the foliage. Table 1 is a summary of KAERI's contribution for the interception fraction. Biomass-normalized values are also given. The standing plants were exposed to spray of a solution containing ^{54}Mn, ^{57}Co, ^{85}Sr, ^{103}Ru and ^{134}Cs [2,3]. Therefore, the data are included in a section of "Wet deposition" in the TECDOC. Nevertheless, they could also be applied to a dry deposition of very fine and positively-charged radioactive particles because there was no run-off of the added solution from the foliage [3]. The interception fractions were not element-dependent, whereas they depended markedly on the times of deposition.

Table 1. KAERI's contribution for the interception fraction

Plant	Interception [a] fraction (IF)	Mass-normal. IF [b] ($m^2\ kg^{-1}$-dry)
Rice	0.48 ~ 0.94	0.49 ~ 6.0
Soybean	0.34 ~ 0.93	0.71 ~ 17
Chinese cabbage	0.16 ~ 0.87	3.0 ~ 30
Radish	0.18 ~ 0.86	5.2 ~ 16

[a, b] ranges by different times of deposition
[b] IF / standing-biomass density (kg-dry m^{-2}).

2.2 Weathering Half-Life

Weathering is a process of the activity loss from plants by the actions of wind and rain, tissue ageing, leaf fall and so on. Weathering rate constant (d^{-1}) is determined by dividing ln2 by a weathering half life (T_w, d). Table 2 summarizes KAERI's contribution for the weathering half life. The half lives were generally shorter for a later-stage deposition [2,3]. They also varied more or less with the radionuclide and plant species.

Table 2. KAERI's contribution for the weathering half life

Plant	Weathering half life (d) [a]				
	Mn	Co	Sr	Ru	Cs
Rice	16~47	14~43	14~47	24~53	32~49
Soybean	5~15	6~24	4~13	6~12	6~59
Ch. cabb.	9~20	10~16	9~22	17~32	12~35
Radish	11~25	9~29	9~21	20~26	16~37

[a] ranges by different times of deposition

2.3 Translocation Factor

Translocation factors quantify the movement of the radionuclides from the plant surface to the edible part. It is usually expressed as the fraction of the total plant activity that is contained in the edible part at harvest. Table 2 is a summary of KAERI's contribution for the translocation factor. For the seeds, depositions near their actively-developing stages produced the highest translocation factors in general. In contrast, the translocation factors for the radish roots were on the whole highest after an early-growth stage deposition. Of the five radionuclides, Cs or Co had the highest values, whereas Ru or Sr had generally the lowest values [2,3].

Table 3. KAERI's contribution for the translocation factor

Plant	Translocation factor [a]				
	Mn	Co	Sr	Ru	Cs
Rice [b] (seeds)	6.9E-04 3.8E-02	3.6E-03 1.6E-01	5.8E-04 3.2E-02	1.6E-04 7.6E-03	3.2E-02 2.0E-01

Soybean (seeds)	7.3E-04 6.5E-01	2.8E-02 8.6E-01	6.5E-04 2.8E-01	4.9E-04 4.2E-02	3.0E-02 7.2E-01
Radish (roots)	6.0E-03 1.7E-02	1.2E-01 4.7E-01	5.4E-03 2.2E-02	1.2E-03 2.8E-02	1.4E-01 3.1E-01

[a] minimums and maximums by different times of deposition
[b] for brown seeds (hulled but unpolished).

2.4 Soil-to-Plant Transfer Factor (TF_{crop})

TF_{crop} is defined as the ratio of the plant concentration (Bq kg^{-1}) to the soil concentration (Bq kg^{-1}). We provided the values of the TF_{crop} for several upper-land crop plants and rice for sections of "Root uptake - artificial radionuclides" and "Transfer to rice" in the TECDOC, respectively. The radionuclides tested by the KAERI were Mn, Co, Zn, Sr and Cs [2]. Table 4 summarizes KAERI's contribution for the TF_{crop} of Cs in various upper-land plants. Table 5 is a summary concerning these five radionuclides for rice. The TF_{crop} varied widely with the radionuclide and plant species. The values from field studies were an order of a magnitude lower than the others, all of which came from radio-tracer experiments. This is because the aged fallout ^{137}Cs was measured in the field studies.

Table 4. KAERI's contribution for the TF_{crop} of Cs in various upper-land plants

Plant	N	Expected value [a]
Barley (seeds)	1	5.5E-02
Soybean (seeds)	5	1.9E-01
Chinese cabbage (leaves)	1 12	2.2E+00 5.5E-02 [b]
Lettuce (leaves)	2	6.0E-01
Radish (roots)	1	7.1E-01
Carrot (roots)	2	1.6E-01
Squash (fruits)	2	6.2E-01

[a] geometric means for dry plant materials
[b] value from field studies.

Table 5. KAERI's contribution for the TF_{crop} of various radionuclides in rice

Nuclide	N	Expected value [a]	95% confide. Range
Mn	5	2.6E-01	8.8E-02~7.5E-01
Co	4	4.3E-03	1.7E-03~1.1E-02
Zn	4	1.7E+00	4.0E-01~6.8E+00
Sr	1	1.2E-01	-
Cs	7 12	3.1E-02 4.5E-03 [b]	6.6E-03~1.5E-01 9.9E-04~2.1E-02

[a] geometric means for dry brown seeds
[b] data from field studies.

2.5 Areal Transfer Factor (TF_{areal})

We presented our experimental data on the TF_{areal} (m^2 kg^{-1}), which is defined as the ratio of the plant concentration (Bq kg^{-1}) to the initial deposition onto soil (or water) in unit area of farmland (Bq m^{-2}) [2,4,5]. This parameter is to quantify the root uptake following an acute soil (or water) deposition during agricultural seasons. A section titled "Areal transfer factor" is being written by the KAERI for the TECDOC. Table 6 summarizes the KAERI's presentation on the TF_{areal} in the TRS-364 WG.

Table 6. KAERI's TF_{areal} values presented in the TRS-364 working group

Plant	Areal transfer factor (m^2 kg^{-1}-dry) [a]			
	Mn	Co	Sr	Cs
Rice (br. seeds)	1.2E-03 5.0E-03	1.6E-05 2.6E-04	1.1E-04 1.1E-03	2.3E-05 4.2E-03
Ch. cabb. (leaves)	1.3E-02 2.4E-02	6.4E-04 4.8E-03	4.4E-02 1.7E-01	6.6E-04 2.6E-03
Radish (roots)	1.4E-03 4.5E-03	1.7E-04 8.0E-04	6.2E-03 3.2E-02	1.1E-04 6.5E-04
Potato (tubers)	2.5E-04 9.5E-04	2.6E-04 9.0E-04	2.0E-04 2.0E-03	5.5E-05 1.1E-03

[a] minimums and maximums by different times of deposition.

3. Conclusion

KAERI's data on the parameters concerning radionuclide transfer in agricultural ecosystems have been presented in the TRS-364 WG of the IAEA's EMRAS program. These data are going to appear in an IAEA TECDOC in one form or another. Particularly for the areal transfer factor, the KAERI is the only institute to provide data and a section is being prepared by us to be included in the TECDOC. An IAEA handbook is planned to be published in a concise form of the TECDOC. Through our participation in the EMRAS program, KAERI's research capability for terrestrial radioecology was internationally recognized.

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