Soil- to-Whole Body Transfer Factors of Radionuclides for Terrestrial Wild Animals Living around the Gyeongju Nuclear Site

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1. Introduction

In the Gyeongju nuclear site, a low and medium level radioactive waste repository and five nuclear reactors are currently operating. The IAEA and ICRP consider it necessary to demonstrate that not only men but also wild organisms are protected from ionizing radiations. Therefore, it may not be long before the dose assessment for wildlife should be carried out in Korea. The transfer factor (TF) defined as the concentration ratio between an organism and an environmental medium is a key parameter in assessing the radiation dose to wildlife. The IAEA [1] recently published a handbook on the TF values of various radionuclides for different types of wildlife. However, it is recommended that they be used in cases in which there are no site-specific data. This is because TF values can vary greatly with wildlife species and environmental conditions. In the present study, the TF values of various radionuclides were measured for several terrestrial animal species living around the Gyeongju site.

2. Materials and Methods

TF values were calculated with the concentrations of stable elements in the soil and animal samples [2]

2.1 Soil and Animal Sampling

Samples of several animal species and associated soils were collected in two mountainous areas around the Gyeongju nuclear site in July, 2014. Fig. 1 shows the locations of the two sampling areas.

Fig. 1. Locations of the sampling areas (T-1: Sangra-ri, T-2: Hwanseo-ri).

Four types of animal samples, reptile, amphibian, annelid and arthropod, were collected. They were caught by hands or using some tools such as nets and rods. Soil samples were also collected near the animal-catching points. The soil-sampling depth was 10 cm.

2.2 Sample Treatment and Analysis

Animal samples as whole bodies were freeze-dried and then ground for homogenization. Soil samples were air-dried and sieved with a mesh size of 2 mm. Aliquots (1−3 g) of the homogenized animal and soil samples were chemically treated and changed into about 50 ml liquid samples. Measurements of the element concentrations were performed by means of the ICP-MS and ICP-AES in the KBIS (Korea Basic Science Institute). The results were reported as the means of triplicate measurements. The soil samples were also analyzed for their physicochemical properties.

2.3 Calculations of TF Values

TF values were calculated as follows;

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

where C_{animal} is the concentration of an element in the whole body of an animal species (g/kg-fresh) and C_{soil} is that in the dried soil (g/kg-dry).

3. Results and Discussion

3.1 Physicochemical Properties of Soils

Table I shows physicochemical properties of the soils collected in the two study areas.

Table I. Physicochemical properties of the soils

Soil No.	pH (1:5)	OM (%)	CEC (cmol/kg)	Sand (%)	Clay (%)	Tex-ture
S1	4.7	4.42	41.47	46.02	8.40	Loam
S2	5.1	4.46	31.99	34.41	8.56	SiL
S3	6.0	1.24	31.75	33.69	18.24	Loam
H1	5.3	2.61	21.17	39.98	8.08	SiL
H2	5.0	2.68	20.31	38.99	14.00	Loam

Note) S for Sangra-ri and H for Hwanseo-ri / OM: Organic matter, CEC: cation exchange capacity, SiL: Silt loam.

Acidic and loamy soils were dominant in both study areas. The organic matter contents were not very high as a whole, ranging from 1.2 to 4.5%. The cation exchange capacity was on an average about 30 cmol/kg, and was generally higher in S soils than in H soils.

3.2 TF Values

The TF values of 22 elements were measured for a total of eight different animal species. Table II shows the measured TF values.

Table II: TF Values for Terrestrial Animals

Area	Animal/ Soil	TF values (dimensionless)			
		Ca	K	Mg	Na
T-1	A1/S1,2	4.1E+00	1.8E−01	9.9E−02	1.0E−01
	A2/S1	2.6E+00	1.7E−01	9.6E−02	6.8E−02
	A3/S3	2.3E−01	3.8E−01	2.1E−01	1.7E−01
	A4/S3	1.4E−02	4.4E−01	2.9E−02	1.3E−02
T-2	A5/H2	1.5E+00	1.4E−01	1.0E−01	1.7E−01
	A2/H1	1.3E+00	1.1E−01	9.6E−02	1.1E−01
	A3/H1	4.0E−01	2.3E−01	4.0E−01	1.4E−01
	A4/H2	6.9E−02	1.3E−01	6.1E−02	3.4E−02
	A6/H2	5.1E−02	1.8E−01	1.1E−01	4.1E−02
	A7/H2	6.4E−02	2.3E−01	1.2E−01	3.2E−02
	A8/H1	6.0E−02	1.2E−01	6.3E−02	1.3E−01

(continued)

Area	Animal/ Soil	TF values (dimensionless)			
		P	S	Al	Sr
T-1	A1/S1,2	1.4E+01	8.9E+00	1.0E−02	1.3E−01
	A2/S1	1.2E+01	7.2E+00	1.9E−02	3.6E−01
	A3/S3	1.5E+00	8.9E+00	3.4E−01	2.3E−01
	A4/S3	2.6E+00	8.2E+00	4.7E−04	1.5E−02
T-2	A5/H2	1.8E+01	1.8E+01	6.0E−04	2.0E−01
	A2/H1	1.0E+01	8.3E+00	1.9E−02	3.9E−01
	A3/H1	3.1E+00	7.5E+00	5.2E−01	5.2E−01
	A4/H2	5.6E+00	5.8E+00	3.4E−04	8.0E−02
	A6/H2	8.2E+00	9.4E+00	9.4E−04	4.8E−02
	A7/H2	7.8E+00	9.3E+00	4.4E−04	3.7E−02
	A8/H1	4.8E+00	1.3E+01	1.4E−02	1.7E−01

(continued)

Area	Animal/ Soil	TF values (dimensionless)			
		Fe	Mn	Li	Ti
T-1	A1/S1,2	4.4E−03	1.1E−02	1.2E−02	1.7E−03
	A2/S1	9.9E−03	1.8E−02	2.0E−02	5.3E−03
	A3/S3	1.1E−01	1.6E−01	1.7E−01	1.1E−01
	A4/S3	3.4E−04	6.9E−03	9.0E−03	1.7E−04
T-2	A5/H2	1.0E−03	3.1E−03	1.5E−02	1.8E−04
	A2/H1	5.9E−03	1.2E−02	1.2E−02	3.1E−03
	A3/H1	1.3E−01	1.7E−01	1.1E−01	9.0E−02
	A4/H2	4.6E−04	2.1E−02	2.7E−02	9.2E−05
	A6/H2	8.3E−04	9.7E−03	8.9E−03	2.3E−04
	A7/H2	1.5E−03	1.3E−02	8.9E−02	2.6E−04
	A8/H1	4.2E−03	1.9E−02	5.8E−03	2.3E−03

(continued)

Area	Animal/ Soil	TF values (dimensionless)			
		Ba	V	Cr	Cu
T-1	A1/S1,2	1.8E−02	2.8E−03	2.1E−02	1.5E−01
	A2/S1	3.2E−02	9.7E−03	2.4E−02	8.8E−02
	A3/S3	1.8E−01	1.7E−01	5.9E−01	2.5E−01
	A4/S3	6.3E−03	9.1E−04	1.2E−03	3.6E−01
T-2	A5/H2	7.1E−03	1.9E−03	3.7E−03	9.6E−02
	A2/H1	3.9E−02	4.7E−03	1.2E−02	4.9E−02
	A3/H1	3.0E−01	1.4E−01	1.6E−01	1.2E−01
	A4/H2	7.0E−03	2.9E−03	5.3E−04	1.5E−01
	A6/H2	9.1E−03	1.4E−03	6.2E−04	4.2E−01
	A7/H2	7.0E−03	7.2E−03	2.5E−03	3.3E−01
	A8/H1	2.6E−02	4.2E−03	9.4E−03	3.3E−03

(continued)

Area	Animal/ Soil	TF values (dimensionless)			
		Zn	Pb	Th	U
T-1	A1/S1,2	4.2E−01	5.9E−02	2.3E−02	1.4E−02
	A2/S1	5.0E−01	1.8E−02	9.3E−03	8.1E−03
	A3/S3	3.1E−01	1.9E−01	4.3E−01	3.0E−01
	A4/S3	3.8E−01	1.4E−03	7.7E−04	7.7E−04
T-2	A5/H2	2.1E−01	5.6E−03	1.6E−04	1.7E−03
	A2/H1	1.3E−01	2.3E−02	5.7E−02	1.8E−02
	A3/H1	2.2E−01	1.5E−01	1.1E+00	2.2E−01
	A4/H2	1.1E−01	8.3E−04	4.8E−03	4.3E−04
	A6/H2	3.1E−01	2.6E−03	-	2.7E−03
	A7/H2	3.8E−01	3.6E−03	-	1.4E−03
	A8/H1	8.1E−01	1.7E−02	4.4E−02	1.2E−02

Note) A1: Mamushi, A2: Oriental fire-belled toad, A3: Earthworm, A4: Ussur brown katydid, A5: Wolter lizard, A6: Locust, A7: Grasshoper, A8: Centipede.

The TF values of most elements were lower than zero in all cases, whereas the opposite was true for P and S. The lowest and highest values observed were 9.2E−05 (Ti/A4) and 1.8E+01 (P&S/A5), respectively. The TF values of Ca, a main component of bone, were higher than zero only for all reptiles (A1and A5) and amphibians (A2). Animal species-dependent variations of the TF values were smallest in S (a factor of 3) and highest in Th (a factor of 7,000). Earthworms had markedly higher TF values of Al, Pb, Th and U than the other animal species.

As compared with the corresponding IAEA values (geometric means) [1], the present TF values of Mn for earthworms and those of Zn and Cu for reptiles were several- to several-ten-fold higher and those of U for reptiles were up to several-hundred-fold lower. The magnitude of the soil-to-animal transfer of an element is greatly dependent on its biological availability, which is mainly governed by the physicochemical properties of the soil. Accordingly, it is necessary to use as much site-specific data as possible.

3. Conclusions

For eight animal species inhabiting mountainous areas around the Gyeongju nuclear site, the TF values of 22 stable elements were measured. The acquired values varied considerably with the elements and animal species. Further TF data need to be produced for various Korean wild animal and plant species in preparation for future governmental regulations of wildlife exposure to ionizing radiations [3].

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REFERENCES

[1] IAEA, Handbook of Parameter Values for the Prediction of Radionuclide Transfer to Wildlife, Technical Reports Series 479, IAEA, Vienna, 2014

[2] A. Hosseini, H. Thørring, J. E. Brown, R. Saxén, E. Ilus, Transfer of radionuclides in aquatic ecosystems – Default concentration ratios for aquatic biota in the Erica Tool, Journal of Environmental Radioactivity 99, 2008.
et al., Journal of Environmental Radioactivity, 2008.
[3] D. K. Keum, Y. H. Choi, K. M. Lim, I. Jun et al., Development of Radiological Risk Assessment Technology of Ecosystem, KAERI/RR-3445/2011-0001883, 2012