Water-to-Wildlife Transfer of Radionuclides in Freshwater Ecosystems around the Gyeongju Nuclear Site

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1. Introduction

The IAEA and ICRP have recognized that not only humans but also wildlife needs to be protected from the impact of ionizing radiations. In many advanced countries, it is legally required to evaluate the radiological impact to wildlife. Therefore, it can be expected that the wildlife dose assessment will also soon become a legal requirement in Korea.

One of the key parameters in evaluating radiation doses to wildlife is the concentration ratio (CR), which is used for quantifying radionuclide transfer from an environmental medium such as soil and water to an organism[1]. CR values can vary greatly with environmental conditions and wildlife species. Accordingly, it is important for a reliable dose assessment that site-specific CR data be used.

In this study, CR values of various radionuclides were measured for several freshwater wildlife species living around the Gyeongju nuclear site.

2. Materials and Methods

CR values (L/kg) were determined as the ratio of the stable-element concentration in the whole body of wildlife species (g/kg-fresh) to that in water (g/L). Naturally occurring stable isotopes are well-established analogies to radioisotopes in equilibrium with an environmental medium[2].

Wildlife and associated water samples were collected in three streams (F1, F2, and F3) and a reservoir (F4) located within a radius of about 8 km of the nuclear site (Fig. 1). Three kinds of fish species (sweet fish, Chinese minnow and crucian carp) and three kinds of plant species (watery speedwell, undulate speedwell and water chestnut) were collected.

Fish were caught using fishing rods. Plants of watery speedwell and undulate speedwell were cut at around the shoot bases, which are usually submerged, whereas those of water chestnut were cut at somewhere of the stems, the whole parts of which are submerged. Water samples were collected near the wildlife sampling points using sampling bottles or a Van Dorn sampler. Their pH and temperature were immediately measured.

Animal and plant samples were freeze-dried and then ground for homogenization. Water samples were filtered with membrane filters (pore size 0.45 um).

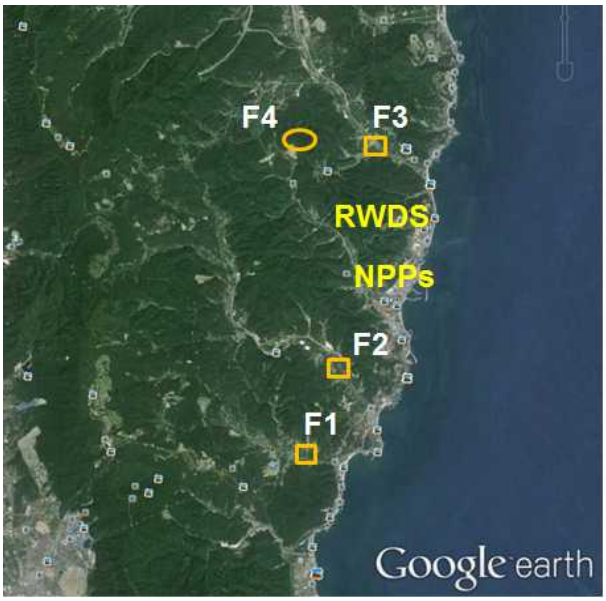

Fig. 1. Sampling points around the Geongju nuclear site. F1: Sooryeomcheon, F2: Haseocheon, F3: Daejongcheon, F4: Songjeon reservoir.

Aliquots of the homogenized wildlife samples were chemically treated and changed into liquid samples. Measurements of the concentrations of 21 elements were conducted by means of the ICP-MS and ICP-AES.

3. Results and Discussions

3.1 Physicochemical Properties of Freshwater

Table I shows the temperature and pH of the water samples. A little difference in water temperature occurred among the sampling points due to the samplings at different times during a day and at different months. There was also some difference in pH. The pH of the reservoir was slightly higher than those of the streams. The reason why is unknown.

Table I: Physicochemical Properties of Freshwater

Points	Temperature (^{o}C)	pH	Sampling Date
F1	17.1	7.4	May 24, '12
F2	19.2	7.6	May 24, '12
F3	20.5	8.0	May 24, '12
F4	24.2	8.1	June 20, '12

3.2 Concentrations of Elements in Freshwater

Table II presents the concentrations of several selected elements in the freshwater. The concentrations of K and Na were markedly higher than those of the other elements. The opposite was true for Cs, Th and U. Sr showed much higher concentrations than Cs as is generally found in soil.

Table II: Elemental Concentrations in Freshwater

Points	Concentration (mg L^{-1})			
	K	Na	Sr	Mn
F1	2.5E+00	1.9E+01	1.4E−01	6.4E−03
F2	1.5E+00	1.4E+01	1.1E−01	3.6E−03
F3	1.7E+00	1.3E+01	1.0E−01	3.3E−03
F4	1.2E+00	1.3E+01	1.1E−01	1.0E−01

(continued)

Points	Concentration (mg L^{-1})			
	Zn	Cs	Th	U
F1	3.4E−03	3.6E−05	1.7E−05	3.1E−05
F2	1.2E−03	2.8E−05	1.9E−05	2.9E−05
F3	9.2E−04	2.8E−05	1.8E−05	2.5E−05
F4	7.1E−03	4.0E−05	1.0E−05	6.9E−05

3.3 Concentration Ratios of Elements

Freshwater CR values were determined for a total of 20 elements. Table III shows the CR values of 16 elements for six different wildlife species.

Table III: CR Values for Freshwater Wildlife

Point	Species	CR values (L / kg-fresh)			
		K	Ca	Na	Mg
F1	A1	9.8E+02	3.3E+02	6.5E+01	5.6E+01
	P1	4.3E+02	3.4E+01	6.5E+00	3.0E+01
	P2	3.9E+02	7.5E+01	1.6E+01	4.1E+01
F2	A2	1.3E+03	4.8E+02	7.4E+01	7.3E+01
	P2	1.2E+03	1.1E+02	3.7E+01	6.0E+01
F3	A2	1.0E+03	4.0E+02	7.4E+01	7.4E+01
	P2	7.4E+02	1.1E+02	3.1E+01	4.7E+01
F4	A3	1.5E+03	9.3E+02	8.3E+01	1.4E+02
	P3	1.7E+03	8.4E+01	7.0E+01	1.9E+02

(continued)

Point	Species	CR values (L / kg-fresh)			
		Al	Fe	Ti	Sr
F1	A1	4.4E+04	4.3E+03	9.1E+03	1.0E+02
	P1	2.5E+03	1.4E+03	2.0E+03	3.1E+01
	P2	2.0E+03	1.1E+03	1.6E+03	6.3E+01
F2	A2	8.6E+02	1.8E+02	5.8E+02	1.4E+02
	P2	7.7E+02	5.4E+02	6.3E+02	1.1E+02
F3	A2	3.7E+03	6.4E+02	1.1E+03	1.1E+02
	P2	4.9E+02	4.6E+02	3.5E+02	9.9E+01
F4	A3	7.8E+03	5.8E+02	3.9E+03	2.7E+02
	P3	2.5E+03	3.5E+02	1.9E+03	9.9E+01

(continued)

Point	Species	CR values (L / kg-fresh)			
		Mn	Cr	Cu	Zn
F1	A1	1.3E+03	-	3.4E+02	2.2E+03
	P1	8.0E+02	-	2.9E+02	1.2E+03
	P2	6.5E+02	-	3.7E+02	2.1E+03
F2	A2	1.2E+03	-	7.5E+02	1.3E+04
	P2	1.2E+03	-	6.0E+02	1.0E+04
F3	A2	1.9E+03	-	7.5E+02	1.6E+04
	P2	1.1E+03	-	7.3E+02	7.5E+03
F4	A3	2.3E+02	3.3E+03	2.3E+02	2.2E+03
	P3	4.3E+02	6.9E+02	4.1E+02	2.8E+02

(continued)

Point	Species	CR values (L / kg-fresh)			
		Cs	Ba	Th	U
F1	A1	2.7E+03	3.2E+02	7.0E+03	1.1E+03
	P1	6.0E+02	1.6E+02	1.0E+02	7.0E+01
	P2	5.9E+02	8.6E+01	1.4E+02	4.0E+01
F2	A2	5.2E+02	2.5E+02	4.4E+02	1.0E+02
	P2	1.9E+02	1.9E+02	2.3E+02	5.3E+01
F3	A2	6.9E+02	2.0E+02	7.4E+02	1.9E+02
	P2	1.6E+02	1.5E+02	4.7E+01	1.8E+01
F4	A3	1.6E+03	5.5E+02	7.4E+03	3.6E+02
	P3	5.7E+02	6.5E+02	1.8E+02	6.5E+01

Note) A1: sweet fish, A2: Chinese minnow, A3: crucian carp, P1: watery speedwell, P2: undulate speedwell, P3: water chestnut.

All of the CR values were higher than 1.0, indicating bioaccumulation of the elements. Of the16 elements, Al or Zn had the highest values, whereas Na had the lowest values in general.

The CR values for fish were generally higher than those for aquatic plants. Particularly in Ca and U, fish values were higher than plant values at every point by factors of up to 10 and 30, respectively. Some differences between the sampling points may be attributable to the differences in species composition and in environmental conditions.

Variation in the CR value with the wildlife species was greatest in Th, and smallest in Cu. Within the same wildlife species and the same elements, CR values varied with the sampling points by factors of up to only 5.

Many of the present values differ considerably from the corresponding IAEA values[1], emphasizing the importance of using site-specific CR data.

3. Conclusions

CR values of a total of 20 elements were determined for three fish species and three plant species living in freshwater ecosystems around the Gyeongju nuclear site. The CR values showed considerable variations with the elements and with wildlife species.

For the establishment of a reliable input data file of K-BIOTA[3], a Korean wildlife dose assessment model, data on CR values needs to be increased to cover a wider range of domestic wildlife.

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REFERENCES

[1] IAEA, Handbook of Parameter Values for the Prediction of Radionuclide Transfer to Wildlife, Technical Reports Series No. 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.