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Concentration Ratios of Various Elements for Wildlife in Freshwaters around the Younggwang Nuclear Site

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1. Introduction

Radionuclides released from nuclear facilities can enter adjacent freshwaters via direct deposition and run-off from contaminated land, leading to exposures of aquatic wildlife to ionizing radiations. The necessity of demonstrating that wild animals and plants are protected from ionizing radiations is internationally increasing. It is expected that the dose assessment for wildlife shall become a legal requirement in Korea sometime in the future. The concentration ratios (CRs) of radionuclides between an organism and a relevant environmental medium are a key parameter in assessing the radiation dose to wildlife. The IAEA [1] recently published a handbook on the CR values of various radionuclides for different types of wild organisms. However, the agency recommends that they be used in the case there are no site-specific data. This is because CR values can vary greatly with wildlife species and environmental conditions. For the reason mentioned above, site-specific CR values of various radionuclides were measured for wildlife species living in freshwater ecosystems around the Younggwang nuclear site.

2. Methods and Results

Stable elements in collected environmental samples were analyzed to measure the CR values of their radioactive isotopes [2]. It is well known that stable isotopes are very close analogies to radioactive isotopes in the transfer behavior in equilibrium [3].

2.1 Collection of Environmental Samples

Aquatic organisms and associated water samples were collected in two streams around the Hanbit NPP site twice in 2015. Sampling points in Zaryong and Watan streams were located within radii of about 3 and 8 km of the NPP site (Fig. 1). A total of nine fish species, two crustacean species, one amphibian species and four macrophyte species were collected. Table I summarizes the collections at each sampling point.

Aquatic animals were caught using nets and traps. Plants were cut at around the shoot bases or somewhere on the stems. Water samples were collected at a depth of about 0.5 m or near the bottoms at the same points for the wildlife samples using sampling bottles. The pH and temperature of the water samples were measured on-site immediately after they were collected.

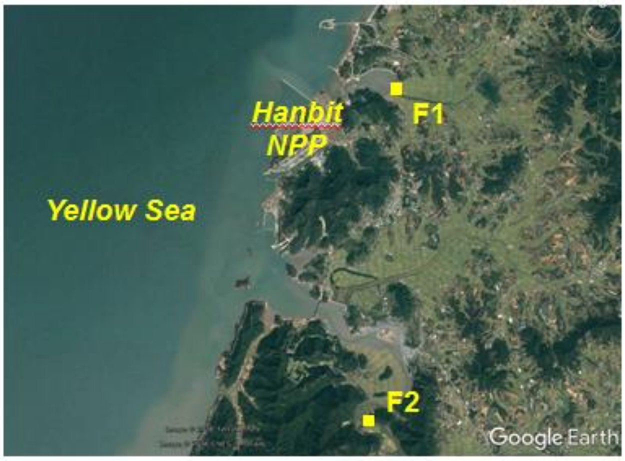

Fig. 1. Locations of the sampling points for freshwater ecosystems (F1: Zaryong stream, F2: Watan stream)

Table I: Summary of Collected Wildlife Species

Sampling point [a]	Wildlife type	No. of collected species
F1-A	Fish	5 (carp, crucian carp, et al.)
	Amphibian	1 (American bullfrog [b])
	Macrophyte	2 (common reed, et al.)
F1-B	Fish	2 (Korean bullhead, et al.)
	Macrophyte	2 (water chestnut, eelgrass)
F2-A	Fish	6 (crucian carp, et al.)
	Crustacean	1 (a kind of crab)
	Macrophyte	1 (common reed)
F2-B	Crustacean	1 (freshwater shrimp)

[a] A: collected on May 14 (plants) or June 17 (animals)
B: collected in November 5.
[b] tadpole

2.2 Sample Treatment and Analysis

Wildlife samples were freeze-dried and homogenized using a grinder. Aliquots (0.7~1.0 g) of the homogenized samples were changed into about 50 g liquid samples as a result of a series of chemical treatments. Water samples were filtered using a membrane filter of 0.45 um in pore size. Measurements of elemental concentrations were performed by means of the ICP-MS and ICP-AES in the Chungnam National University.

2.3 Calculation of CR Values

In accordance with the definition adopted by the IAEA [1], CR values (Lkg^{-1}-fresh) were calculated as follows;

$$CR = \frac{C_{wo\text{-}biota}}{C_{water}} \qquad (1)$$

where $C_{wo\text{-}biota}$ is the whole-body concentration of an element in an organism (mg kg^{-1}-fresh) and C_{water} is the water concentration of the element (mg L$^{-1)}$

3. Results and Discussions

3.1 Physicochemical Properties of Freshwaters

Table II shows the temperature and pH of the water samples. There were great differences in the water temperature between the two sampling dates (May and November) with little difference between the two points (F1 and F2) on the same date.

Three measurements of the pH indicate comparatively high alkalinity. The reason why such high pHs occurred is unknown. The other three shows an almost neutral or weak alkaline pH.

Table II: Physicochemical Properties of Freshwaters

Points	Temperature (°C)	pH	Sampling Date
F1-A*	26.3	9.3	May 14, ’15
F1-A	-	7.2	June 17, ‘15
F1-B	13.7	7.7	Nov. 5, ’15
F2-A*	25.0	9.3	May 14, ’15
F2-A	-	7.3	June 17, ‘15
F2-B	13.1	9.4	Nov. 5, ’15

3.2 Elemental Concentrations in Freshwaters

The concentrations of several selected elements in the freshwaters are given in Table III. The concentrations of K and Na were markedly higher than those of the other elements. The opposite was true for Co, Cs and U. Sr showed much higher concentrations than Cs as is generally found in soil.

Table III: Elemental Concentrations in Freshwater

Points	Concentration (mg L^{-1})							
	K	Na	Sr	Mn	Zn	Co	Cs	U
F1-A*	1.3E+01	1.8E+02	2.1E-01	1.4E-03	1.3E-03	<0.001	<0.001	<0.001
F1-A	1.5E+01	1.3E+02	1.8E-01	9.9E-03	3.0E-03	5.2E-04	<0.001	<0.001
F1-B	2.0E+01	1.8E+02	3.7E-01	2.5E-01	1.3E-02	< 0.01	< 0.01	< 0.01
F2-A*	1.7E+01	2.7E+02	3.2E-01	1.3E-03	5.9E-03	5.1E-04	3.0E-05	2.5E-04
F2-A	1.3E+01	7.1E+01	1.8E-01	4.3E-03	3.5E-03	<0.001	<0.001	<0.001
F2-B	5.6E+01	1.4E+03	9.5E-01	2.4E-01	2.4E-01	< 0.01	< 0.01	< 0.01

(continued)

3.3 CR Values of Elements for Aquatic Wildlife

Freshwater CR values were determined for a total of 21 elements. Table IV shows the CR values of 12 selected nuclides for 16 different wildlife species. The CR values of Cs and U were obtained only for common reed at F2-A, because most of the Cs concentrations were below the MDA (Table III).

Almost all of the CR values were higher than 1.0, indicating bioaccumulation of the elements. Some differences in the CR value among the sampling points may be attributable to the differences in species composition and in environmental conditions.

Of the 12 elements, Mn or Zn mostly had the highest values, whereas Al or Mg had the lowest values in general. The CR values of Ca, Sr and Zn were generally higher for aquatic animals than for plants. However, the opposite was true for Al and Mn.

Table IV: CR Values for Freshwater Wildlife

Point	Species	CR values (L kg^{-1}-fresh)			
		Al	Fe	Ca	Mg
F1-A	A1	2.4E+00	1.9E+02	4.8E+02	2.4E+01
	A2	2.0E+01	5.7E+01	4.2E+02	2.0E+01
	A3	9.7E+01	1.6E+02	5.7E+02	2.5E+01
	A4	3.3E+01	6.2E+01	6.0E+02	2.4E+01
	A5	8.5E+00	3.8E+01	3.9E+02	1.7E+01
	A6	1.7E+03	3.4E+03	8.4E+01	2.4E+01
	P1	3.7E+03	9.2E+02	4.5E+00	7.5E+00
	P2	2.2E+04	4.2E+03	1.7E+01	2.3E+01
F2-A	A3	4.4E+00	5.1E+01	8.0E+02	5.6E+01
	A5	2.0E+01	1.3E+01	6.6E+02	3.7E+01
	A7	2.1E+00	4.3E+00	4.6E+02	4.8E+01
	A8	7.7E–01	7.7E+00	5.8E+02	4.6E+01
	A9	8.0E+00	1.3E+01	4.4E+02	4.2E+01
	A10	1.1E+00	6.4E+00	3.1E+02	3.4E+01
	A11	6.7E+01	1.8E+02	2.6E+03	3.6E+02
	P1	8.2E+02	4.2E+02	5.5E+00	5.6E+00
F1-B	A4	6.0E+01	6.1E+01	4.2E+02	1.8E+01
	A7	3.7E+02	2.3E+02	6.1E+02	2.6E+01
	P3	7.8E+02	5.2E+02	3.0E+01	3.2E+01
	P4	5.6E+02	5.5E+02	5.2E+00	1.8E+01
F2-B	A12	3.4E+01	4.8E+01	1.1E+02	3.0E+00

Note) A1: bass, A2: carp, A3: crucian carp, A4: Korean bullhead, A5: stripe mullet, A6: American bullfrog’s tadpole, A7: false dace, A8, A9 and A10: unidentified, A11: a kind of ghost crab, A12: freshwater shrimp, P1: common reed, P2: water chestnut, P3: eel grass, P4: unidentified

(continued)

Point	Species	CR values (L kg^{-1}-fresh)			
		Sr	Mn	Cu	Zn
F1-A	A1	1.8E+02	2.5E+02	6.3E+01	5.3E+03
	A2	2.5E+02	6.8E+02	1.5E+02	1.6E+04
	A3	2.5E+02	1.6E+03	2.0E+02	1.2E+04
	A4	2.3E+02	4.8E+02	2.6E+02	6.0E+03
	A5	1.9E+02	9.2E+02	8.1E+01	3.3E+03
	A6	2.7E+01	8.2E+03	7.4E+02	4.2E+03
	P1	8.3E+00	3.1E+04	2.8E+02	2.9E+03
	P2	2.1E+01	2.7E+05	5.2E+02	5.4E+03
F2-A	A3	2.5E+02	1.3E+03	2.7E+02	1.2E+04
	A5	3.2E+02	6.6E+02	1.2E+02	2.8E+03
	A7	2.7E+02	1.3E+03	2.9E+02	1.3E+04
	A8	2.0E+02	9.3E+02	2.4E+02	8.7E+03
	A9	2.0E+02	8.1E+02	2.7E+02	8.0E+03
	A10	1.1E+02	2.8E+03	5.1E+02	4.0E+03
	A11	2.2E+03	2.3E+04	6.2E+03	6.3E+03
	P1	1.2E+01	2.0E+04	1.5E+02	8.9E+02
F1-B	A4	1.1E+02	3.1E+01	2.4E+02	1.2E+03
	A7	1.4E+02	6.5E+01	1.6E+02	2.3E+03
	P3	4.5E+01	5.2E+03	1.8E+02	1.9E+02
	P4	8.5E+00	2.1E+03	2.4E+02	3.1E+02
F2-B	A12	6.9E+01	1.3E+01	9.1E+02	-

(continued)

Point	Species	CR values (L kg^{-1}-fresh)			
		Rb	Cs	Ba	U
F1-A	A1	2.8E+02	-	1.8E+01	-
	A2	1.9E+02	-	7.8E+01	-
	A3	2.2E+02	-	1.2E+02	-
	A4	2.3E+02	-	5.4E+01	-
	A5	2.8E+02	-	3.6E+02	-
	A6	6.5E+02	-	4.2E+02	-
	P1	4.0E+02	-	1.1E+02	-
	P2	5.5E+02	-	5.9E+02	-
F2-A	A3	1.5E+02	-	1.2E+02	-
	A5	2.2E+02	-	4.8E+01	-
	A7	1.6E+02	-	1.3E+02	-
	A8	2.4E+02	-	5.8E+01	-
	A9	2.2E+02	-	4.3E+01	-
	A10	3.0E+02	-	7.3E+01	-
	A11	1.2E+02	-	2.5E+03	-
	P1	1.7E+02	4.5E+02	5.6E+01	3.5E+01
F1-B	A4	5.4E+01	-	7.0E+01	-
	A7	9.4E+01	-	1.3E+02	-
	P3	7.8E+01	-	6.8E+02	-
	P4	8.3E+01	-	3.3E+02	-
F2-B	A12	1.4E+02	-	7.6E+01	-

The observed CR values ranged from 7.7×10^{-1} (Al / a fish species / F2-A) to 2.7×10^{5} (Mn / water chestnut / F1-A). The variation in the CR value with the wildlife species and sampling points was greatest in Al (a factor of 29,000), and smallest in Rb (a factor of 12).

In the same wildlife species and the same elements, CR values varied with the sampling points by factors of lower than 10 in most cases. The greatest variation of this kind occurred between F2-A and F1-B for the combination of false dace (A7) and Al.

Many of the present values are greatly different from the corresponding IAEA values [1]. This fact emphasizes the necessity of using as much site-specific CR data as possible in the wildlife dose assessment.

4. Conclusions

As the result of field works in 2015, CR values of a total of 21 elements were produced for 12 animal species and four plant species living in freshwaters around the Hanbit NPP site. The CR values showed considerable variations with the elements and with the wildlife species.

The produced CR data is planned to be used in establishing the CR data file of K-BIOTA [4], a Korean wildlife dose assessment model. The use of site-specific CR data can increase the reliability of the wildlife dose assessment, which might become a legal requirement in the near future.

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