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Elemental Concentration Ratios for Benthic Animals in the Seas around the Gyeongju Nuclear Site

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1. Introduction

The necessity of demonstrating that wildlife is, or will be, reasonably protected from ionizing radiations has been internationally increasing for last two decades. In accordance with such necessity, several computerized tools for estimating the exposure of wildlife to ionizing radiations have been developed.

The world most famous tools may be RESRAD-Biota [1] and ERICA [2]. There is also a Korean version named K-Biota. All of these three assessment tools use concentration ratios (CRs) for the estimation of the internal radiation dose to wild organisms.

The CR is one of the most important model parameters in the wildlife dose assessment in general, and defined as the ratio of the radionuclide concentration in an organism to that in a medium (soil or water) [3,4]. The IAEA [4] recently published a handbook of CR values for generic use.

CR values can vary greatly with environmental conditions and wildlife species. Accordingly, it is better to use site-specific CR data if available, as emphasized by the IAEA [4]. In this study, CR values of different nuclides were measured for various benthic wild animal species living in the seas around the Gyeongju nuclear site.

2. Materials and Methods

Wild animal and associated seawater samples were collected near or on the bottoms under three marine points (M1, M2 and M3) (Fig. 1) in early summer, 2015. The numbers of species collected were three, three, two, one and one for fish, crustaceans, echinoderms, gastropods and urochorda, respectively.

Fish and crustaceans were collected using nets, which had been fixed near the bottoms overnight. Samples of the other organisms and seawater were collected by an employed scuba diver, who dived down to the sea beds with a Van Dorn water sampler. The pH, salinity and temperature of the water samples were immediately measured on the sampling boat.

Animal samples were freeze-dried and then ground for homogenization. Water samples were filtered with 0.45 um membrane filters. Aliquots of the homogenized wildlife samples were acid-digested and changed into liquid forms. The concentrations of various elements were measured by means of the ICP-MS and ICP-AES.

CR values (L kg^{-1}-fresh) were determined as the ratios of the elemental concentrations in the whole bodies of organisms (g kg^{-1}-fresh) to those in waters (g L^{-1}). In terms of the transport behavior in the environment, naturally occurring isotopes are well-established analogies to artificial radioisotopes being in equilibrium with an environmental medium [3].

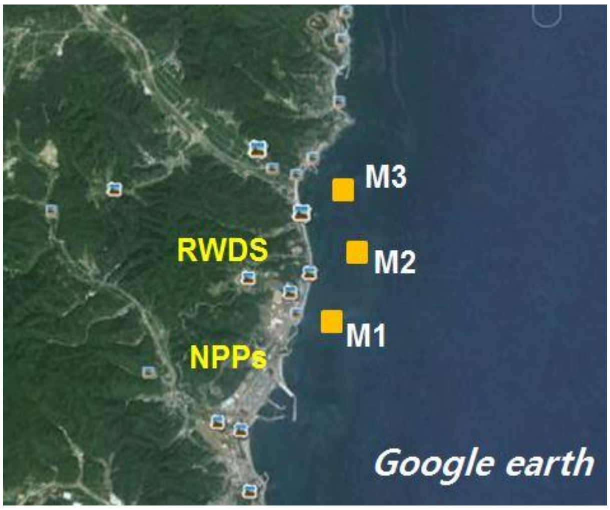

Fig. 1. Marine Sampling Points(M1~M3) around the Geongju nuclear site. RWDS: Radioactive Waste Disposal Site, NPPs: Nuclear Power Plants.

3. Results and Discussions

3.1 Physicochemical Properties of Seawaters

Table I shows the temperature, pH and salinity of the water samples. The depths of sampling were around 15~20 m and the water temperatures were slightly lower than 10 ^{o}C. The temperature of seawater may depend on such factors as the depth, time, season and weather. The pH and salinity were in the ranges of 7.8~8.2 and 34.0~34.7 ‰, respectively, which can be considered normal for the seas.

Table I: Physicochemical Properties of the Seawaters

Points	Depth (m)	Temp (^{o}C)	Salinity (‰)	pH	Sampling Time

M1	15.0	-	34.3	8.2	June 4, 08:20
M2	21.0	9.3	34.7	7.8	June 4, 09:30
M3	20.0	9.5	34.0	7.9	June 4, 10:30

Table II: Elemental Concentrations in the Seawaters

Points	Concentration (mg L^{-1})			
	K	Na	Sr	Mn
M1	4.4E+02	1.1E+04	5.4E+00	3.9E−02
M2	4.6E+02	8.8E+03	5.5E+00	3.3E−02
M3	4.2E+02	9.9E+03	5.5E+00	4.9E−02

(continued)

Points	Concentration (mg L^{-1})			
	Zn	Co	Cs	U
M1	1.0E−01	3.4E−02	6.5E−03	1.7E−02
M2	6.1E−02	1.3E−02	3.0E−03	8.4E−03
M3	5.6E−02	8.9E−03	2.1E−03	5.8E−03

3.2 Elemental Concentrations in Seawater

Table II shows the concentrations of several selected elements in the seawaters. The concentrations of Na and, to a lesser degree, K were markedly higher than those of the others as is characteristic of seawater. Sr has comparatively high concentrations, followed by Zn, Mn, and then Co. The concentration of Cs was lower than that of Sr by a factor of about 1,000. The greatest variation depending on the sampling points occurred in Co. In contrast, little or inconsiderable variations occurred in Sr, K and Na.

3.3 Elemental Concentration Ratios for Organisms

Table III shows the CR values of 16 elements for a total of ten different marine benthic animal species.

Table III: CR Values for Marine Benthic Organisms

Point	Species	CR values (L kg^{-1}-fresh)			
		Al	Fe	Mg	Na
M1	A1	9.0E+00	4.3E+00	2.3E−01	2.4E−01
	A2	5.3E+00	6.7E+00	3.1E−01	1.3E−01
	A4	1.2E+02	4.3E+01	5.4E−01	2.3E−01
	A5	1.8E+02	4.0E+01	1.7E+00	4.4E−01
	A8	5.8E+02	1.3E+02	3.0E+00	2.5E−01
	A9	9.1E+00	5.4E+00	6.3E+00	5.5E−01
M2	A1	4.0E+00	2.8E+00	1.4E−01	2.3E−01
	A3	1.3E+01	5.3E+00	2.2E−01	1.6E−01
	A4	8.5E+01	3.3E+01	6.0E−01	3.2E−01
	A6	1.7E+03	2.2E+02	1.6E+00	3.9E−01
	A10	6.9E+02	6.3E+01	6.7E−01	8.2E−01
M3	A1	3.5E+00	2.6E+00	1.4E−01	1.9E−01
	A3	4.7E+00	7.4E+00	2.6E−01	2.0E−01
	A6	8.1E+02	1.4E+02	1.7E+00	3.1E−01
	A7	6.1E+01	1.7E+01	1.4E+00	3.8E−01

(continued)

Point	Species	CR values (L kg^{-1}-fresh)			
		K	Sr	Cr	Mn
M1	A1	4.4E+00	2.5E+00	1.5E+00	2.2E+01
	A2	6.8E+00	1.3E+01	2.5E+00	7.6E+00
	A4	4.0E+00	2.5E+00	1.0E+01	1.6E+02
	A5	5.3E+00	8.5E+01	2.4E+00	5.3E+01
	A8	8.6E−01	1.0E+02	1.2E+01	1.7E+02
	A9	3.6E+00	9.8E+01	9.3E−01	2.1E+02
M2	A1	4.2E+00	2.3E+00	9.1E−01	2.4E+01
	A3	7.2E+00	5.9E+00	2.8E+00	5.5E+01
	A4	3.6E+00	2.4E−02	2.3E+02	4.5E+00
	A6	1.9E+00	5.8E+01	2.6E+01	6.5E+03
	A10	1.5E+00	2.7E+00	1.3E+01	4.9E+02
M3	A1	4.1E+00	1.5E+00	1.5E+00	1.3E+01
	A3	6.7E+00	5.6E+00	1.7E+00	2.4E+01
	A6	4.7E+00	7.4E+01	5.6E+00	5.4E+02
	A7	5.1E+00	8.8E+01	2.4E+00	3.1E+02

(continued)

Point	Species	CR values (L kg^{-1}-fresh)			
		Co	Ni	Cu	Zn
M1	A1	3.0E−01	1.8E+00	4.3E+00	1.2E+02
	A2	9.1E−01	7.9E+00	2.6E+00	1.6E+02
	A4	2.4E+00	7.5E+00	2.1E+02	6.9E+02
	A5	1.5E+00	1.2E+01	3.8E+01	2.0E+02
	A8	4.7E+00	3.6E+01	1.7E+00	7.7E+01
	A9	3.0E+00	2.6E+01	1.7E+01	8.1E+01
M2	A1	6.6E−01	2.1E+00	3.4E+00	1.8E+02
	A3	1.0E+00	5.6E+00	3.5E+00	1.9E+02
	A4	1.1E+02	6.2E+02	4.2E+02	1.7E+02
	A6	2.2E+01	2.4E+01	2.6E+02	3.9E+02
	A10	7.5E+00	1.9E+01	7.6E+00	7.7E+01
M3	A1	7.4E−01	1.9E+00	2.7E+00	2.0E+02
	A3	1.5E+00	6.1E+00	1.7E+00	1.8E+02
	A6	9.7E+00	1.5E+01	1.2E+02	4.4E+02
	A7	5.5E+00	1.4E+01	5.5E+01	3.8E+02

(continued)

Point	Species	CR values (L kg^{-1}-fresh)			
		As	Cs	Ba	U
M1	A1	3.8E+01	8.8E−01	6.5E−01	1.3E−01
	A2	4.2E+01	2.3E+00	3.0E+00	2.3E−01
	A4	1.5E+02	1.5E+00	4.0E+00	2.5E+00
	A5	7.3E+01	1.2E+00	1.1E+01	2.0E−01
	A8	7.3E+00	4.0E+00	1.3E+01	1.7E+00
	A9	4.1E+01	−	1.3E+01	6.8E+00
M2	A1	1.5E+01	1.1E+00	9.1E−01	1.9E−01
	A3	7.4E+01	2.8E+00	1.8E+00	−
	A4	2.4E+01	3.4E+00	1.6E+01	4.2E+00
	A6	1.5E+02	3.7E+01	2.8E+02	4.4E+00
	A10	2.8E+01	1.2E+01	1.6E+02	2.4E+00
M3	A1	2.6E+01	2.0E+00	1.4E+00	2.1E−01
	A3	5.6E+01	3.9E+00	2.0E+00	−
	A6	4.2E+01	1.5E+01	1.3E+02	2.2E+00
	A7	9.7E+01	1.7E+00	3.2E+01	−

Note) A1: blackmouth angler, A2: blass bloched rockfish, A3: bluefin searobin, A4: Lischke's top shell, A5: a kind of crab, A6: hermit crab, A7: swimming crab, A8: sea urchin, A9: starfish, A10: Warty sea squirt.

Most of the CR values were higher than 1, indicating bioaccumulation of the involved elements. In contrast, all of the Na values were lower than 1. This may be associated with the fact that the seawater concentration of Na is very high. Al, Mn or Zn usually had higher CR values than the others.

Of the present CR values, the highest one was 6.5E+03, which occurred for Mn in hermit crabs of M2, whereas the lowest was 2.4E−02, which occurred for Sr in Lischke's top shells of M2. The CR-value variation with animal species and sampling points was comparatively large in Mn and Al. In contrast, Na showed the smallest variation, varying only by a factor of 6. The CR values for fish were generally lower than those for crustaceans. There were some differences among the sampling points for the same animal species, which may be attributable to different environmental conditions.

Most of the present CR values for Mn, Co, Ni, Cu, Zn, Cs and U are considerably lower than the corresponding generic IAEA values [4], indicating the importance of using site-specific CR data. The IAEA [4] also recommended that their generic values be used when site-specific data are not available.

3. Conclusions

As the result of field studies, CR values of 16 elements were measured for ten different animal species living near or on the bottoms of seas around the Gyeongju nuclear site. The CR values varied considerably with elements, wildlife species and sampling points.

For the enhancement in accuracy and reliability of the estimation with the K-BIOTA, a computerized tool for Korean wildlife dose assessment, CR data needs to be extended to many other species of domestic wildlife.

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