Study on concentration of nuclides in aquatic organisms*

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Abstract Accumulation contents and concentration factors (CF) for ^{54}Mn, ^{60}Co, ^{58}Co, ^{124}Sb occurring simultaneously in aquatic organisms were determined. The results show that CF correlates to nuclides, the species of organisms, the culture time and the specific activity (SA) of nuclides in water, and their relationship can be expressed by regression equations. Among shrimp, snail, ophiocephalus argus and carassius auratus, the shrimp has the highest CF particularly for ^{54}Mn, the CF reaches 291.5, the ophiocephalus argus has the lowest. The distribution of nuclides in fish has the magnitude order: gill>viscera>epidermis>bone>flesh.
Keywords Concentration factor, Aquatic organism, ^{54}Mn, ^{60}Co, ^{58}Co, ^{124}Sb

1 Introduction

Many studies[1,2] have shown that the fish, shrimp, and other aquatic organisms inhabited in radioactive contaminated area can be contaminated. In the days that the nuclear power is being developed day by day it has significant meaning to undertake the study on accumulation of nuclides by aquatic organisms. In order to predict the dose to human consumers and provide the useful data for environment science, it is necessary to understand the uptake and accumulation of nuclides by organisms.

Among various aquatic organisms the fish are the primary source of food from freshwater ecosystem for men. However, studies on accumulation of radionuclides by ophiocephalus argus (predatory) are little. Therefore, studies on accumulation contents and concentration factors (CF) for ^{54}Mn, ^{60}Co, ^{58}Co, ^{124}Sb occurring simultaneously are undertaken. Besides that, the snail, shrimp and carassius auratus (omnivorous) were also used in this study.

The environment factors much influence the accumulation of nuclides, hence the CF in aquatic organisms. The CF calculated from laboratory data may be one to four orders of magnitude lower than that calculated from field data[3].

2 Experimental methods

The organisms used in this study are ophiocephalus argus, carassius auratus, shrimp and snail. The experiments were conducted in laboratory. The temperature of room was maintained at 20~25°C, humidity at 38~50%. The laboratory was equiped with two glass aquaria (No.1, No.2) filled with 52 L well water. While the organisms were in aquarium the water was continuously aerated. After purchased from market the organisms used in experiments were kept in aquarium No.1 for at least a week to acclimate them circumstances. Then removed to aquarium No.2 in which the water was contaminated with nuclear industry waste liquid containing ^{54}Mn, ^{60}Co, ^{58}Co and ^{124}Sb. At stipulated culture time the organisms were taken out of the aquarium No.2, washed with tap water to remove the adhering materials, blotted with filter paper and weighed. Then the whole fish dissoluted in aqua-regia and diluted to 500 ml. In the experiment on accumulation content for given nuclides in tissues of organisms the sample was steamed at electric stove for 15 min for the sake of sampling convenience prior to dissolution. Consequently, the organism was dissected and the divided parts were processed in the way mentioned above. The dissoluted and diluted samples were placed in polyethylene bottles for analysis.

Approximately 500 ml of the experimental water was drawn and analyzed while the organisms were removed out. And the water was filtered prior to analysis to get rid of precipitate and solid particles in it. The CF was calculated

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using the following formula:

$$CF = \frac{\text{SA of nuclide in organism (Bq/kg)}}{\text{SA of nuclide in water (Bq/kg)}}$$

where SA stands for specific activity of nuclide.

Samples were analyzed in multichannel analyzer with a PGe detector, the resolution of which was 1.95 keV, relative efficiency was 40%. The samples were counted for 21600-57600s.

2.1 Accumulation contents and CF of ophiocephalus argus for ^{54}Mn, ^{60}Co, ^{58}Co, ^{124}Sb

12 fish with nearly the same weight amount to 240 g and 374 g snails were cultivated in aquarium. The snails kept in water were used as food for the fish. The SA of nuclides in water was 2.580×10^{2}Bq/kg for ^{58}Co, 5.676×10Bq/kg for ^{54}Mn, 2.847×10^{4}Bq/kg for ^{124}Sb, 6.851×10Bq/kg for ^{60}Co at the beginning. The sampling was conducted on days of 1, 3, 7, 10, 15, 23, 37, 44, respectively. Every time 1-2 fish and 500 ml water were collected from the culture aquarium, sampled, and analyzed in the way mentioned above. Then calculated the CF according to formula (1). Based on these data, the regression equations were got by accumulation contents vs culture time and concentration factors vs culture time.

2.2 CF in tissues of fish

The fish were cultivated in contaminated water. After 7 d they were removed out and steamed. Then, dissected and divided into 5 parts: epidermis (containing scale of fish), gill, bone (containing head and tail), flesh, viscera. After sampling, measuring and calculating the CF of tissues for given nuclides were obtained.

2.3 CF vs SA of nuclides in water

The ophiocephalus argus were kept in contaminated water for 7 d. The steamed fish was divided into edible part and remains. The edible part was sampled and analyzed. According to these data regression equations were performed on CF for given nuclides vs the SA of nuclides in water.

2.4 CF for other organisms

The shrimp, snail, carassius auratus were cultivated together in contaminated water for 7 d. The ophiocephalus argus was cultivated alone for 7 d. The edible parts of them were sampled and analyzed.

3 Results and discussion

3.1 Results

3.1.1 The accumulation contents and CF for ^{54}Mn, ^{60}Co, ^{58}Co, ^{124}Sb in ophiocephalus argus at different culture time are shown in Figs.1,2, respectively.

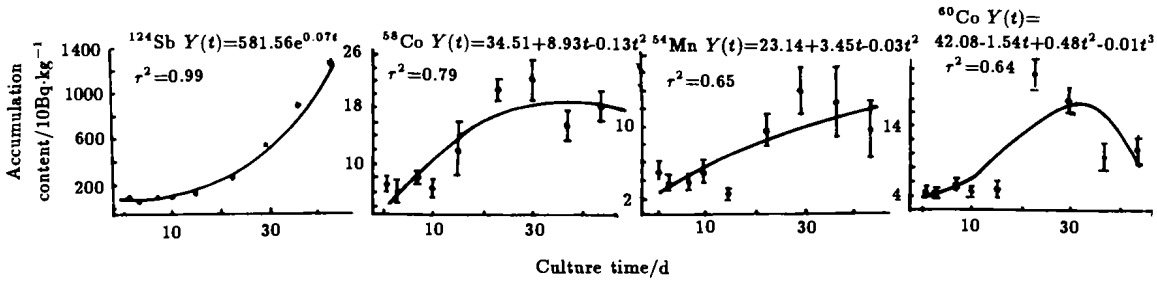

Fig.1 Accumulation of nuclides in whole body of ophiocephalus argus as a function of culture time

3.1.2 The accumulation contents and CF of given nuclides in ophiocephalus argus varying with the SA of nuclides in water are summarized in Table 1. The regression equations are also shown in Table 1.

3.1.3 The tissues distribution of given nuclides in ophiocephalus argus is summarized in Table 2. The concentration capability of tissues for given nuclides had the magnitude order: gill>viscera>epidermis>bone>flesh.

3.1.4 The concentration factors in fleshes of shrimp, snail, carassius auratus, ophiocephalus

argus cultivated for 7 d for given nuclides are summarized in Table 3.

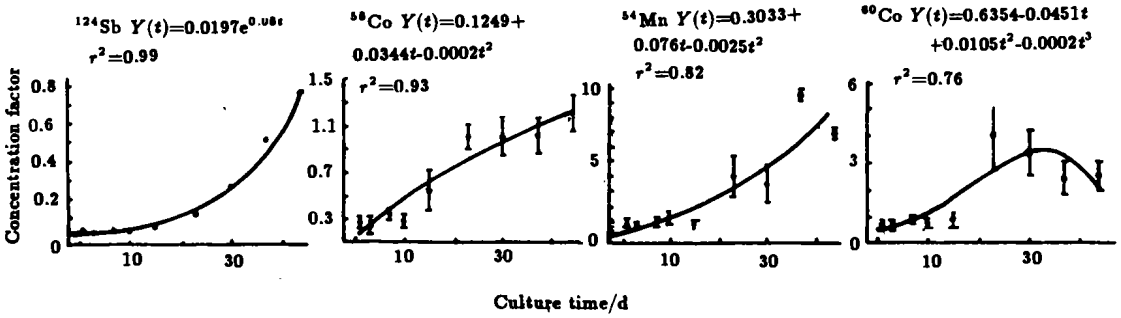

Fig.2 CF of nuclides in whole body of ophiocephalus argus as a function of culture time

Table 1 Accumulation contents and concentration factors for nuclides in flesh of ophiocephalus argus as a function of SA in water

	^{124}Sb			^{58}Co	
SA in water/Bq·kg^{-1}	Content in flesh/Bq·kg^{-1}	CF	SA in water/Bq·kg^{-1}	Content in flesh/Bq·kg^{-1}	CF
$(2.618\pm0.004)\times10^4$	$(2.056\pm0.034)\times10^2$	0.008±0.001	$(3.524\pm0.171)\times10^2$	$(1.157\pm0.203)\times10$	0.033 ±0.006
$(1.198\pm0.003)\times10^4$	$(1.415\pm0.060)\times10^2$	0.012±0.001	$(1.592\pm0.080)\times10^2$	(6.438±2.060)	0.040±0.013
$(6.210\pm0.034)\times10^3$	$(1.682\pm0.039)\times10^2$	0.027×0.001	(6.596±0.625)×10	(3.410±1.091)	0.052±0.017
$(2.967\pm0.010)\times10^3$	(7.306±0.305)×10	0.025±0.001	(1.041±0.263)×10	(1.031±0.330)	0.099±0.040
$(9.129\pm0.208)\times10^2$	(2.545±0.182)×10	0.028±0.002	(7.940±0.579)	(1.519±0.486)	0.191±0.063
$(5.531\pm0.354)\times10^2$	(1.248±0.184)×10	0.023±0.004	–	–	–
Regression equation	$y(x)=0.17x^{0.73}$	$y(x)=0.0559$ -0.0099 lg$x$		$y(x)=0.34x^{0.59}$	$y(x)=0.34x^{-0.41}$
	r^2=0.79	r^2=0.57		r^2=0.99	r^2=0.83
	^{54}Mn			^{60}Co	
SA in water /Bq·kg^{-1}	Content in flesh/Bq·kg	CF	SA in water /Bq·kg^{-1}	Content in flesh/Bq·kg^{-1}	CF
$(6.542\pm0.098)\times10^2$	(2.364±0.350)×10	0.036±0.005	$(1.717\pm0.086)\times10^2$	(4.684±0.400)×10	0.273 ±0.028
$(1.651\pm0.075)\times10^2$	(2.046±0.212)×10	0.124±0.014	(5.675±0.223)×10	(3.155±0.231)×10	0.556±0.046
(9.932±1.829)×10	(1.126±0.180)×10	0.113×0.056	(3.041±0.930)×10	(1.933±0.149)×10	0.636±0.201
(5.228±0.459)×10	(1.214±0.476)×10	0.232±0.093	(1.279±0.238)×10	5.527±0.629	0.432±0.094
(1.372±0.330)×10	(2.626±0.840)	0.191±0.076	6.910±0.036	2.989±0.649	0.433±0.097
2.740±0.644	1.076±0.344	0.393±0.156	–	–	–
Regression equation	$y(x)=0.66x^{0.62}$	$y(x)=0.419$ -0.138 lg$x$		$y(x)=0.63x^{0.90}$	$y(x)=0.5727-$ 0.0721lg$x$
	r^2=0.78	r^2=0.87		r^2=0.88	r^2=0.08

Table 2 Concentration factors of nuclides in tissues of ophiocephalus argus

Tissue	^{124}Sb(9.129×10^2)	^{58}Co (5.596×10)	^{54}Mn (5.228×10)	^{60}Co(3.041×10)
Flesh	0.028±0.002	0.052±0.017	0.232±0.093	0.636±0.149
Bone	0.042±0.017	0.512±0.062	0.761±0.233	1.567±0.489
Epidermis	0.271±0.011	0.567±0.190	0.862±0.232	2.512±0.832
Viscera	0.260±0.027	0.990±0.316	1.690±0.440	4.512±1.463
Gill	0.550±0.030	4.866±1.628	9.918±1.755	16.450±5.296

In Tables 2 and 3, the values in brackets are the specific activity of nuclides in water, Bq/kg

Table 3 The CF for nuclides in flesh of organisms

Organism	$^{54}Mn(1.0076\times10^2)$	^{60}Co (6.6260×10)	$^{58}Co(2.3234\times10)$	$^{124}Sb(2.0912\times10^2)$*
Shrimp	$(2.915\pm0.031)\times10^2$	$(6.890\pm0.071)\times10$	$(7.321\pm0.341)\times10$	7.535 ± 0.114
Snail	$(1.273\pm0.015)\times10^2$	$(7.412\pm0.122)\times10$	$(5.484\pm0.189)\times10$	8.134 ± 0.196
Carassius auratus	7.361 ± 0.102	4.732 ± 0.260	3.950 ± 0.199	0.963 ± 0.029
Ophiocephalus argus**	0.124 ± 0.014	0.556 ± 0.046	0.099 ± 0.040	0.023 ± 0.004

**The ophiocephalus argus was cultivated in water containing 1.651×10^2 Bq/kg ^{54}Mn, 5.675×10 Bq/kg ^{60}Co, 1.041×10Bq/kg ^{58}Co, 5.531×10^2Bq/kg ^{124}Sb

3.2 Discussion

3.2.1 The CF in the same species of organisms varied from nuclides to nuclides

The data in this study indicate that the CF for ^{54}Mn, ^{58}Co, ^{60}Co were much higher than that for ^{124}Sb. Tracing the reason from the biological function can aid in understanding it. The stable elements Co, Mn are biologically active elements. Cobalt is an essential component of vitamin B_{12} and is nutritional for fish health. The manganese functions as an inorganic moiety for several metabolic enzymes, while antimony has no known biological function.

3.2.2 The CF of organisms for the same nuclide varied from species to species of organisms

This study indicates that the CF magnitude of given organisms for the nuclides used had the order: shrimp, snail>fish; carassius auratus> ophiocephalus argus. The ophiocephalus argus is a predatory species. The carassius auratus is omnivorous fish species. Many studies [1,2] have shown that the predatory species attain lower muscle concentration of nuclides than planktivorous and omnivorous fish species do. The results in this study are in coincidence with it. The shrimp and snail are benthic feeders.[2] The adsorption of particulate material on the surface can significantly influence the whole-body accumulation. These factors may be the cause that the concentration capability of the fish for the nuclides used in this study is lower than those of the shrimp and snail.

3.2.3 The nuclides in whole body of fish are uneven

The results show that the nuclides used in this study have higher concentration in epidermis, gill, viscera than in flesh. The biological function of Co is to regulate the formation of red blood cells in fish. It much concentrates in kidney and spleen. The Mn is absorbed primarily through the GI tract. By the way, the radionuclides that trend to absorb suspended materials may also be accumulated to relatively high level on epidermis, gill and in the GI tract.

4 Conclusions

The CF for nuclides varied from species to species of organisms and from nuclides to nuclides. The shrimp has the highest concentration capability for the nuclides used in this study, particularly for ^{54}Mn. Its CF reaches 291.5. So the shrimp may be taken as the indicator for contamination in freshwater. The concentration capability of organisms in this study for the nuclides used in experiments has the order of: shrimp>snail>carassius auratus>ophiocephalus argus.

The tissue distribution of nuclides in fish are uneven because the tissues have different metabolic requirements for certain elements. The concentration capability of them have the order of: gill>viscera>epidermis>bone>flesh.

The accumulation contents of nuclides in organisms have a possitive correlation to the SA of those, while CF has a negative correlation to SA in water.

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