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Effects of Temperature on the Uptake and Retention of Cesium-137 by the Clam *Cyclina sinensis*

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가무락조개에 의한 세슘-137의 濃縮과 殘留에 미치는 溫度의 영향

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Abstract

The effects of temperature on the uptake of ^{137}Cs from seawater and on the retention after its uptake by the clam *Cyclina sinensis* was investigated under laboratory conditions. The clams exhibited a greater bioaccumulation of ^{137}Cs in 25°C-acclimated animals than those acclimated at 15°C. The viscera of the clams reached the highest bioconcentration factor after 14 days uptake from seawater, but the tissue distribution pattern of ^{137}Cs was little influenced, if any, by the uptake temperature. The uptake rate slightly decreased with an increase of temperature in order of 10°C. The radionuclide accumulated in clams was released again in a radionuclide-free seawater according to a two-exponential compartment model. A temperature increase of 10°C reduced the biological half-life of the long-lived component with a factor of about two, whereas it caused no change in the short-lived component.

Introduction

The release of radionuclides from nuclear power plants causes the dispersion and bioaccumulation of certain radionuclides in the environment and ecosystem. Cesium-137 is one of the major fission products in the liquid effluent released from nuclear power plants and it has the long physical half-life and high fission yield.[1,2] This radionuclide released into the marine environment may reach man via several routes, of which the group of bivalvular shellfishes used as food is one of the importent routes of entry. Marine bivalves are widely distributed and dominant species in estuarine and shallow coastal area which are being used for disposal of liquid waste effluent

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from nuclear power plants. In addition, marine bivalves are widely used as a biological indicator species in studies on the contamination of radionuclides and chemical pollutants in coastal and estuarine environments as their sessile behavior facilitates the sampling.[3-6]

In order to evaluate the potential radiation hazard to man and to ensure the safety of nuclear facilities, much information on the bioaccumulation of radionuclides in the food chains of local interest is keenly needed. Laboratory studies on the uptake of cesium-137 from seawater and foods by some marine bivalves have been reported by a few workers.[7,8] However, experimental data with the marine clam *Cyclina sinensis* which is commonly used as food in Korea have not been reported as yet.

This study was, therefore, undertaken to investigate the accumulation of cesium-137 directly from seawater and subsequent elimination in the clam *Cyclina sinensis*. In addition the effects of temperature on the uptake and the retention of the radionuclide were observed in detail. This paper describes the results thus obtained.

Materials and Methods

Clams(*Cyclina sinensis*), weighing about 20-30 g, were collected from the West coast of Korean Penninsula and maintained in aquarium at 15-17°C until needed. The animals were acclimated to the experimental temperature for at least one week before use. The salinity of natural seawater used in this study ranged from 29 to 31‰.

In the experiments on the direct uptake of radionuclide from seawater, two groups of 50 animals each were placed in separate acryl aquaria(30×20×30 cm) with 10 liters of seawater and kept at two constant temperatures of 15 and 25±1°C. After the elapse of appropriate acclimation period, ^{137}Cs as chloride form was added to each aquarium in a concentration of 2 μCi/liter. ^{137}Cs with a specific activity of 27.5 μCi/μg and dissolved in 1 M HCl was obtained from the Radiochemical Centre, Amersham, UK. The uptake media were renewed several times during the experiments and 1 ml aliquots were regularly taken for the measurement of radioactivity. The variation of ^{137}Cs concentration did not exceed ±10% of the average concentration. At proper time intervals, five animals each were removed from the aquarium and briefly rinsed with non-radioactive seawater. After the soft tissues were removed from the shell, the samples were measured separately for radioactivity after dry ashing at 480°C for 12 hrs by a G.M. counter (Aloka G.M. tube, window thickness 1.5 mg/cm^2, operating voltage 1,100 V). Counts per minute were corrected for background.

To investigate the tissue distribution of ^{137}Cs in the clam after uptake, five animals were taken from each group. The soft tissues were removed from the shell and dissected into the following parts of mantle, gills, adductor muscle, foot and viscera. After the dissected tissue was separately combined and weighed, the radioactivity of the samples were measured as in the uptake experiments. Bioaccumulation of radionuclide was expressed in terms of bioconcentration factor, that is, the ratio of the activity in g of fresh tissue weight to the activity in ml of aqueous medium. The radioactivity of medium was obtained from the measured values during the experimental period.

For the purpose of retention experiments, clams were placed in seawater containing ^{137}Cs(2 μCi/liter) and allowed to bioaccumulate the radionuclide for 14 days at 15°C in the same manner as in the uptake experiments. Following the uptake, two groups of animals were replaced in non-radioactive seawater maintained at 15 and 25±1°C.

Results and Discussion

1. Temperature-acclimation effect on ^{137}Cs uptake

The results of temperature-acclimation studies as shown in Table 1 indicated that acclimation temperature had great influence on ^{137}Cs uptake by *Cyclina sinensis*. That is, the clams exhibited a greater bioconcentration factor at 25°C-acclimated animals than those acclimated at 15°C. Clams acclimated at 25°C for 14 days and transferred to 15°C exhibited the highest bioconcentration factor among the experiments. Jackim *et al.*[9] found that acclimation within 10 to 20°C had little, if any, influence on Cd uptake

Table 1. Uptake of ^{137}Cs by *Cyclina sinensis* at 15 and 25°C with and without temperature acclimation[a)]

Acclimation temperature (°C)	Uptake temperature (°C)	Bioconcentration factor[b) c)] After 7days	After 14days
15	15	1.81±0.20	2.44±0.12
25	15	2.44±0.15*	3.05±0.08**
15	25	1.39±0.07	1.93±0.10
25	25	1.80±0.07*	2.55±0.10**

a) Test animals were acclimated for 2 weeks at the specified temperature, and then placed in test seawater containing 2 μCi of ^{137}Cs/liter.
b) Mean of 5 replicates (animals) and standard deviation
c) Asterisks indicate statistically significant difference at $p<0.05$ for* and at $p<0.01$ for ** by the student's t-test for the two means at the same uptake temperature and period.

by *Mya arenaria* and *Mulinia lateralis*, whereas *Mytilus edulus* initially exhibited a greater accumulation rate at 10°C in 10°C-acclimated animals than those acclimated at 20°C. It, therefore, appears that species of marine bivalves may exhibit widely varying temperature-acclimation responses toward the uptake of radionuclides.

2. Relative distribution of ^{137}Cs in tissues

The data on the relative distribution of ^{137}Cs in different tissues of the clam are shown in Tables 2 and 3. The results after 7 days uptake show that the tissue distribution pattern of ^{137}Cs was slightly-influenced by the uptake temperature. In the case of adductor muscle, the amount of ^{137}Cs in that tissue increased according to the extension of uptake period, as compared with other tissues. The results after 14 days uptake show that the highest amount of ^{137}Cs was found in viscera with decreasing amounts in the order of mantle, gills, adductor muscle, and foot. However, the order of the bioconcentration factor in different tissues was somewhat different from above order as shown Fig. 1. That is, the highest bioconcentration factor was located in the viscera followed by gills, mantle, foot, and adductor

Table 2. Distribution of ^{137}Cs in different tissues of *Cyclina sinensis* after 7 days uptake period at two temperaures

Tissue*	Uptake at 15°C		Uptake at 25°C	
	% of fresh body weight	% of total radioactivity	% of fresht body weigh	% of total radioactivity
Foot	5.7	4.9	6.6	7.1
Adductor muscle	13.0	5.0	11.8	6.6
Mantle	27.6	25.1	32.4	29.7
Gills	10.9	16.6	11.6	11.9
Viscera	42.7	48.4	37.6	44.7

* Collected from 5 animals

Table 3. Distribution of ^{137}Cs in different tissues of *Cyclina sinensis* after 14 days uptake at two temperatures

Tissue*	Uptake at 15°C		Uptake at 25°C	
	% of fresh body weight	% of total radioactivity	% of fresh body weight	% of total radioactivity
Foot	6.2	4.5	4.2	3.4
Adductor muscle	22.0	13.1	19.2	13.3
Mantle	24.7	23.5	24.6	23.8
Gills	13.6	14.2	18.1	19.7
Viscera	33.2	44.6	33.9	39.8

*Collected from 5 animals

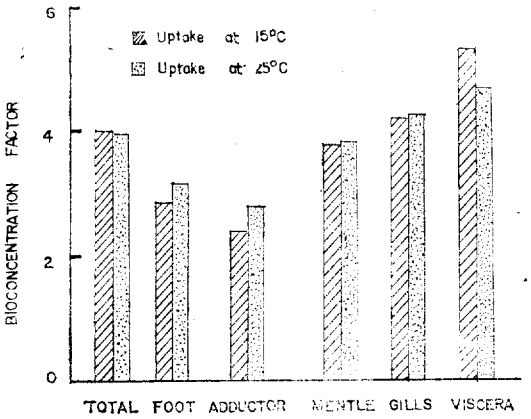

Fig. 1. Bioconcentration of ^{137}Cs in different tissues of *Cyclina sinensis* after 14 days uptake at two temperatures

muscle.

In a long-term uptake study using ^{109}Cd, Fowler and Benagoun[10] found that the viscera showed the highest bioconcentration factor in *Mytilus galloprovincialis*. Although the viscera displayed higher concentration factor than other tissues, differential tissue affinity for heavy metals such as Zn, Co, Fe, and Mn by various tissues of *Mytilus* was also reported by other workers[11, 12].

3. Uptake of ^{137}Cs from seawater

The results of the uptake experiments at two different temperatures(15 and 25°C) for the period of 5 weeks are presented in Fig. 2. The accumulation of ^{137}Cs from seawater was expressed in terms of bioconcentration factor for the whole soft tissues of clams. The bioconcentration factor is defined as the ratio of ^{137}Cs activity in clams(cpm/g fresh weight) to the average radioactivity of the seawater (cpm/ml). The bioconcentration factor of ^{137}Cs as obtained from mean of 5 animals increased slowly to the value of 5.5 at 15°C and 4.8 at 25°C at the end of experiment. The clams accumulated more ^{137}Cs at lower temperature than at higher temperature, the difference being small. It is, however, said that the bioconcentration factors determined in the edible tissues of the clam *Cyclina sinensis* are within the range of those reported for other clams by Harrison, and others[7,8].

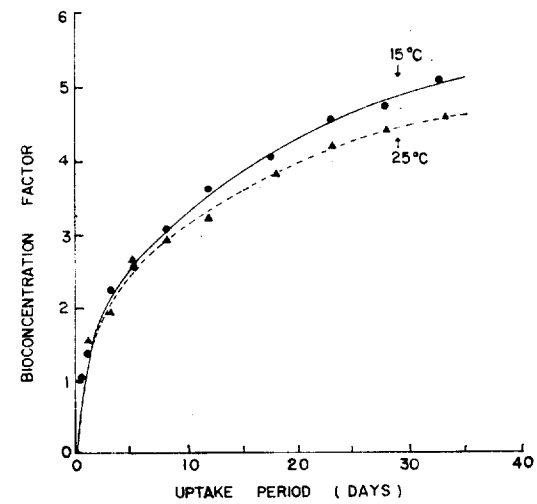

Fig. 2. Uptake of ^{137}Cs from seawater by *Cyclina sinensis* at 15°C and 25°C

4. Retention of ^{137}Cs after uptake

The retention of ^{137}Cs in clams after its uptake for 14 days was measured at different temperatures of 15 and 25°C for 5 weeks period. The loss of ^{137}Cs can be described by two exponential function, as the loss from two compartments with different rates. The equation is expressed as follows:

$$A_t = A_1 e^{-\lambda_1 t} + A_2 e^{-\lambda_2 t}$$

where:

A_t = retained fraction of initial activity at time t

A_1 and A_2 = fractions of initial activity present in the two compartments at t=0

λ_1 and λ_2 = rate constant for loss from both compartments

Fig. 3 shows the retention curves of ^{137}Cs in the clam tissues with the biological half-lives(Tb) derived from the rate constants for loss. After 14 days, the turnover continued at an exponential rate and it was, therefore, treated as loss from a single long-lived compartment. This portion of the curve was subjected to a least square analysis, and biological half-lives of 33 and 17 days at 15 and 25°C, respectively, were computed. The retention curves indicate that a higher fraction of the initial activity is accounted for by the long-lived component at 15°C than at 25°C.

The data for the parameters derived from the retention curves are summarized in Table 4. The long-lived component accounts for ratio of initial activity ranging from 47 to 38% at the temperature

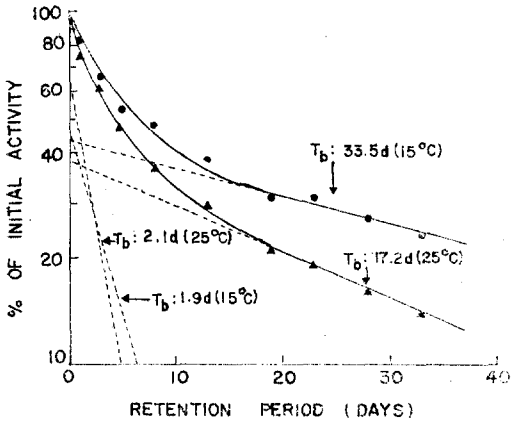

Fig. 3. Retention of ^{137}Cs by *Cyclina sinensis* at 15°C and 25°C after 14 days uptake from seawater containing 2 μCi of ^{137}Cs/liter

Solid line : retention curves obtained from 4 animals replication

Broken line : separately obtained for short and long-lived components

of 15 and 25°C, respectively. The effect of temperature on the retention of ^{137}Cs can be seen in the difference in the biological half-life of the long-lived components. Table 4 shows that the Tb of this component is about two times shorter at the higher temperature than at the lower. For *Mya arenaria* and *Crassostrea gigas* long-lived compartments of radiocesium have been demonstrated[7, 13]. It is estimated that about 60% of the activity was in the short-lived component. Turnover was rapid in the short-lived component, which had Tb of approximately 2 days at both temperatures.

要 約

가무락조개 (*Cyclina sinensis*)에 의한 放射性核種 ^{137}Cs의 吸收와 殘留에 미치는 溫度의 영향을 알기 위하여 실험실 조건하에서 調査한 결과는 다음과 같다.

1) 가무락조개는 15°C에서 適應시킨 것보다 25°C에서 적응시킨 경우에 더 높은 生物濃縮係數를 나타냈다.

2) 가무락조개를 14일간 ^{137}Cs에 노출시킨 후의 生物濃縮係數는 여러 組織중에서 內臟이 가장 높았으나 組織間 ^{137}Cs의 分布相은 노출온도에 의하여 큰 영향을 받지 않았다.

3) 가무락조개에 의한 ^{137}Cs의 吸收速度는 노출온도 25°C에서 보다는 15°C에서 약간 높이 나타났으며 5주간 노출후의 生物濃縮係數는 최고 5.5에 도달하였다.

4) 가무락조개에 의하여 吸收된 ^{137}Cs은 放射性核種이 없는 바다물에 노출시 二段階 모델에 의하여 다시 放出되었다. 吸收된 ^{137}Cs중 長壽命成分의 生物學的 半減期는 노출온도가 10°C 상승함에 따라 1/2로 감소되었으나 短壽命成分의 그것은 변화되지 않았다.

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Table 4. Parameters for the retention equation* of ^{137}Cs by *Cyclina sinensis* after 14 days uptake

Retention temperature(°C)	A_1/A_2 ratio	Biological half-life (days)**	
		Short-lived	Long-lived
15	1.14	2.1	33.5
25	1.65	1.9	17.2

*Retention equation : $A_t = A_1 e^{-\lambda_1 t} + A_2 e^{-\lambda_2 t}$

**Obtained from 4 animals replication

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