BIOKINETICS OF ^{137}Cs IN THE MUSSEL *Mytilus galloprovincialis* LAMARCK MEASURED UNDER CONTROLLED ENVIRONMENTAL CONDITIONS

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Abstract. The rate of uptake and loss, and the quantity of retained ^{137}Cs in mussels were studied under controlled environmental conditions. The following results were obtained: (a) increased concentrations of stable cesium (0.22 and 2.20 µmol l^{-1}, respectively) increased the rate of uptake of ^{137}Cs up to 15 %. The same concentrations of stable cesium decreased the rate of ^{137}Cs loss from the mussel; (b) during loss, the percentage of whole body ^{137}Cs retained was positively correlated with the length of exposure time to ^{137}Cs; (c) EDTA concentrations of 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} mol l^{-1} did not affect the rate of uptake nor the quantity of ^{137}Cs retained by mussels.

Résumé. Accumulation, perte, et rétention de ^{137}Cs ont été étudiées chez Mytilus galloprovincialis dans des conditions environnementales. Les résultats suivants ont été obtenus : (a) L'augmentation des concentrations en Césium stable (respectivement : 0.22 et 2.20 µmol l^{-1}) entraîne une augmentation de 15 % du taux d'accumulation. Ces mêmes concentrations diminuent le taux de perte de ^{137}Cs chez les Moules. (b) Pendant la perte, le pourcentage de ^{137}Cs retenu dans le corps de l'animal est proportionnel au temps d'exposition à ce même ^{137}Cs. (c) Des concentrations en EDTA (10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} mol l^{-1}) n'ont pas affecté les taux d'accumulation, ni les quantités de ^{137}Cs retenues par les Moules.

INTRODUCTION

Radioactive cesium (^{137}Cs) enters the northern Adriatic primarily as stratosphaeric fallout but also in effluent from some nuclear power plants. Radiocesium is a potentially dangerous contaminant because of its long half-lie and relatively strong biochemical binding in marine organisms. Mussels are widespread and are a very suitable test organism for the evaluation of radioactive pollution. Mussels are also very important in the fisheries industry. If mussels accumulate radiocesium above the allowed concentrations, they could become dangerous to man through food chain contamination.

The role of cesium in the physiology of marine organisms is largely unknown. It is probably concentrated by animals because of its chemical similarity to potassium (Bryan, 1962, 1963). Bivalve molluscs accumulate most of the radioactive and stable cesium in soft tissues (99.7 %) with only a small amount being incorporated in the shell (0.3 %) (Jelisavčić, unpublished data).

MATERIALS AND METHODS

Mussels (*Mytilus galloprovincialis* Lamarck) for all experiments were taken from commercial areas at Pomer, near Pula. Before the experiments the mussels were acclimated to laboratory conditions (temperature, aeration, salinity). Twenty specimens were used for each experiment, including one control group. The size of mussel varied between 4 and 4.27 g wet.

Cesium ions in the chloride form ($CsCl_2$, Chemapol-Praha, Czehoslovakia), and EDTA (disodium ethylene diamine tetraacetic dehydrate, Geigy Industrial Chemicals) were used.

TABLE I The effect of stable cesium on the uptake of ^{137}Cs by the mussel *Mytilus galloprovincialis* Lam. ^{137}Cs concentration is presented as relative radioactivity (RA in % of standard) and standard deviations (± s.d.).

Controlled parameters	Days	Control	GROUP S 0.22 µmol l^{-1}	2.20 µmol l^{-1}
MUSSELS				
RA (in % RT-1) ± s.d.	1	1.59±0.14	1.82±0.55	1.73±0.47
	2	1.94±0.76	2.26±0.68	2.27±0.61
	3	2.31±0.77	2.58±0.83	2.60±0.78
	5	2.57±0.97	3.02±0.87	2.76±0.94
	7	2.68±0.90	3.09±0.92	2.98±0.93
	10	2.99±1.01	3.30±1.11	3.11±0.92
	15	3.08±1.00	3.51±1.03	3.35±0.96
BASIN				
Salinity		$37.6x10^{-3}$	$37.6x10^{-3}$	$37.6x10^{-3}$
Temperature (°C)		20	20	20
pH		7.88	7.93	7.93
A/ml (in % RT-1)		1.75	1.73	1.72
A bound to particles > than 0.45 µm (in % RT-1)	f_1	0.5	0.5	0.4
	f_2	0.3	0.3	0.2

High specific activity ^{137}Cs was obtained from Amersham (0.0060 to 0.074 Bq l^{-1} seawater, carrier free in 1 N HCl). In the uptake and loss experiments ^{137}Cs was followed in individual organisms. Radiometric determination of ^{137}Cs was made with a Nuclear Chicago scintillation counter, attached to an automatic sample changer, scaler and printer. Radioactivity is reported as specific activity in percentage of a standard (^{137}Cs RT-1 model, Nuclear Chicago Corporation, 0.13 Bq activity).

TABLE II The effect of stable cesium on the loss of ^{137}Cs from the m
galloprovincialis Lam. The concentration of ^{137}Cs is prese
activity (RA in % of standard) with standard deviations (±
retention (%) related to the point of reference (100 %).

Measured parameters	Days	G R O U P S			
		Control	Rel.Ret.	0.22 µmol l^{-1}	Rel.Ret.
MUSSELS					
RA (in % RT-1)	0	3.08±1.00	100 %	3.51±1.03	100 %
± s.d.	1	1.56±0.74	50.6	2.04±0.89	58.1
	2	1.33±0.63	43.2	1.64±0.71	46.7
	3	1.06±0.49	34.4	1.36±0.64	38.7
	5	0.84±0.37	27.3	1.09±0.44	31.0
	7	0.66±0.28	21.4	0.87±0.34	23.1
	10	0.55±0.21	17.8	0.66±0.30	18.8
	15	0.38±0.15	12.3	0.48±0.20	13.7
	20	0.29±0.11	9.4	0.34±0.16	9.7
	25	0.24±0.09	7.8	0.27±0.12	7.7
	30	0.19±0.09	6.2	0.21±0.10	6.0
BASIN					
Salinity		$37.6x10^{-3}$		$37.6x10^{-3}$	
Temperature		21 °C		21 °C	
pH		8.02		8.04	

TABLE III The loss of ^{137}Cs in the mussel *Mytilus galloprovincialis* Lam. after and longer periods of uptake. The concentration of ^{137}Cs is present relative activity (RA in % of standard) with standard deviations (± with the retention (%) related to the reference point (100 %).

Measured parameters	Days	GROUPS 16 days uptake of ^{137}Cs		5 days uptake of ^{137}Cs		1 day uptake ^{137}Cs	
MUSSELS	0	4.94±0.60	100 %	3.73±0.67	100 %	2.36±0.16	10
RA (in % RT-1)	1	2.70±0.51	54.6	1.58±0.38	42.4	0.62±0.12	2
± s.d.	2	2.15±0.41	43.5	1.18±0.32	31.6	0.42±0.08	1
	3	1.78±0.44	36.0	0.96±0.24	25.7	0.32±0.06	1
	5	1.42±0.27	28.7	0.63±0.13	16.9	0.20±0.05	
	7	1.15±0.23	23.3	0.49±0.10	13.1	0.16±0.04	
	10	0.92±0.19	18.6	0.37±0.05	9.9	0.10±0.03	
	15	0.73±0.16	14.8	0.28±0.04	7.5		
	20	0.59±0.14	11.9	0.21±0.03	5.6		
	25	0.49±0.13	9.9	0.17±0.03	4.6		
	30	0.42±0.11	8.5				
BASIN							
Salinity		$36.4x10^{-3}$		$36.4x10^{-3}$		$36.4x10^{-3}$	
Temperature		16-20 °C		16-20 °C		16-20 °C	
pH		7.85-8.06		7.85-8.06		7.85-8.06	

TABLE IV The effect of EDTA on the uptake of ^{137}Cs in the mussel *Myt*
vincialis Lam. The concentration of ^{137}Cs is presented as
vity (RA in % of standard) with standard deviation (± s.d.)

Measured parameters	Days	Control	E 10^{-3} M/l	D 10^{-4} M/l	T A 10^{-5} M/
MUSSELS					
RA (in % RT-1)	1	1.99±0.18	1.91±0.18	1.99±0.12	2.03±0.
± s.d.	2	2.64±0.17	2.45±0.25	2.49±0.10	2.46±0.
	3	2.96±0.20	2.81±0.36	2.77±0.12	2.80±0.
	5	3.29±0.18	2.94±0.27	3.05±0.17	3.10±0.
	7	3.78±0.27	3.35±0.41	3.42±0.17	3.34±0.
	10	3.85±0.33	3.36±0.28	3.64±0.21	3.57±0.
	15	4.19±0.28	3.42±0.30	3.83±0.31	3.80±0.
BASIN					
Salinity		$36.7x10^{-3}$	$36.7x10^{-3}$	$36.7x10^{-3}$	36.7x10
Temperature		26 °C	26 °C	26 °C	26 °C
pH		8.03	7.93	7.99	8.02
A/ml		1.43	1.40	1.43	1.39
A bound to particles > than 0.45 µm (in % RT-1)	f_1	0.6	0.6	0.5	0.6
	f_2	0.6	0.4	0.5	0.6

RESULTS

The concentration of stable cesium in northern Adriatic seawater varies from 0.0018 to 0.0022 μmol l^{-1} (Marsel and Popović, pers. comm.). Two concentrations of stable cesium were used in the experiments: 100 and 1000 times higher than those found in seawater (0.22 and 2.20 μmol l^{-1} respectively). The effect of these concentrations on the rate of uptake and loss of ^{137}Cs in the mussel *Mytilus galloprovincialis* Lam. was followed (Table I and II). These concentrations of stable cesium induced higher rates of radiocesium uptake as well as the quantity of retained radiocesium in the mussel. This was most pronounced at the lower stable cesium concentrations.

The loss of ^{137}Cs in running seawater was correlated with the length of exposure time to radiocesium (Table III). The group of mussels exposed for just one day to radiocesium in running seawater was decontaminated in about ten days. Retention in this group after 10 days of the experiment was 4.24 %. In the group of mussels which was exposed to ^{137}Cs for 5 days, the retention of ^{137}Cs after 10 days was 9.92 %. In the group of mussels exposed for 16 days to radiocesium, retention after 10 days was 18.6 %.

The EDTA complex in the concentration range of 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} mol l^{-1} did not seem to affect the uptake of ^{137}Cs by mussels. There was no statistically ($0.90<P<0.80$; $0.80<P<0.70$; $0.80<P<0.70$; $0.70<P<0.60$) significant differences between the concentrations of ^{137}Cs in control groups and in groups treated with EDTA (Table IV).

REFERENCES

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