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EXPERIMENTAL DATA ON ^{59}Fe, ^{65}Zn AND ^{89}Sr UPTAKE BY *Enteromorpha linza* AND *Cystoseira barbata* FROM THE ROMANIAN BLACK SEA SHORE

Al.S.Bologa[1] *and I.Chiosilă*[2]

[1] Romanian Marine Research Institute - Constanţa

[2] Clinical Hospital Fundeni, Section of Radiobiology - Bucureşti

ABSTRACT:

The following maximum concentration factors for the green alga Enteromorpha linza L. and the brown alga Cystoseira barbata (Good.et Wood.)Ag. from the Romanian Black Sea shore were experimentally determined: for ^{59}Fe = 3,227 and 453 (August), respectively; for ^{65}Zn = 7,147 and 2,444 (August), respectively; for ^{89}Sr = 65 and 120 (June), respectively.

INTRODUCTION

The relationship between the concentration of a chemical element in organisms and environment (e.g.water) depends on both the element and the organism. It is known that only some organisms, like e.g. seaweeds, exhibit a metabolic adjustment for trace elements. Thus, the extent to which an alga adjusts the uptake of a trace element is very important when a pollution of the environment with metals or their radionuclides is possible.

Nowadays it is accepted that among marine organisms,the algae show a strong concentration ability of radionuclides(3).The benthic algoflora from the Romanian Black Sea shore, though decreased at present both quantitatively and qualitatively (7,8), is interesting also from the mentioned viewpoint. Among the main algal species along the Romanian shore, with known chemical composition (5,10,11,18,19) the concentration factors of ^{131}I, ^{134}Cs and ^{89}Sr in *Cystoseira barbata* have been already determined under experimental conditions (4).

As to reference data concerning the concentration factor of other radionuclides, like ^{59}Fe and ^{65}Zn, in benthic marine algae, for ^{59}Fe there are less information (e.g. 14, 20).

The concentration factor of ^{65}Zn in benthic algae is better known. Thus, this concentration factor was higher in the green alga *Enteromorpha linza* as compared to the brown alga *Sargassum*; the concentration factor varied with salinity, and the photosynthetic rate rather than surface area of the alga influenced the uptake of ^{65}Zn during the first three hours (9). The uptake of ^{65}Zn by 6 species of algae, which occured only in the light and proportional to gross oxygen production, varied with species; consequently, ^{65}Zn has possibilities as a tool for the measurement of primary productivity (2). Or, the uptake of ^{65}Zn by *Ulva rigida* decreased with 12-36% as compared to the control by adding 1 ml DDT l^{-1} (1).

In an other brown alga, *Laminaria digitata*, the concentration factor decreased as the sea water concentration of Zn increased, initially at least; it was found that the uptake of this radionuclide is a gradual process of accumulation and is not accompanied by the exchange of Zn ("net uptake process"); once it has been absorbed, ^{65}Zn, like Zn, shows little tendency to be lost from the plant (6). The transfer of ^{65}Zn was studied also along food chains, e.g. *Fucus serratus* → *Littorina obtusata* (20).

Experiments carried out on Black Sea algae evinced that H_2S inhibits initially the uptake of ^{65}Zn by *Ulva lactuca* and *Cystoseira barbata*; also that the constant presence of H_2S in the environment caused the death of algae and favoured the more intense uptake of ^{65}Zn by them (17). Also, a dependence between ^{65}Zn uptake and growth in *Ulva rigida* occured (12).

Concerning the Sr, from the study of ^{90}Sr distribution in the *Cystoseira* community, it resulted that among algae this radionuclide is most concentrated by the brown algae *Cystoseira*

(CF=6o) and *Padina*(CF=26o) and by the red alga *Corallina* (CF=26o) (13). For *Cystoseira barbata* the decisive rôle of fucoidan, laminarine and algulose concerning the extraction of ^{90}Sr from sea water was specified (16);also that fucoidan concentrates ^{90}Sr and that it stimulates the fixation on alginic acid (15).

The aim of the present paper consists in the determination of the concentration factors of ^{59}Fe, ^{65}Zn and ^{89}Sr in *Enteromorpha linza* and *Cystoseira barbata* from the Romanian Black Sea shore.

MATERIAL AND METHOD

Specimens of *Enteromorpha linza* (Chlorophyta) and *Cystoseira barbata* (Phaeophyta) collected at Jupiter (Mangalia) in June and August 1981 were used; *C.barbata* was cleared of epibiosis (*Ceramium* sp., *Dermatolithon cystoseirae*).

Laboratory experiments were performed during the periods June-July and August-September, in continuously aerated aquaria, containing 7 l previously filtered sea water (pH=8.1 and S‰=12.45, and pH=8.1 and S‰=14.98,respectively).The algal material was kept 24 hours in the aquaria for accomodation before the adding of radionuclides. ^{59}Fe, ^{65}Zn and ^{89}Sr were used as water-soluble salts ($^{59}FeCl_3$, $^{65}ZnCl_2$ and $^{89}SrCl_2$). Duration of experiments was 21 days for *E.linza* and 15 days for *C.barbata*. Radioassays were carried out after 2, 4, 7, 14 and 21 days for *E.linza* and after 2, 4, 7, 11 and 15 days for *C.barbata*. Because of the difficulty of maintaining the algal material longer alive under experimental conditions,it is possible that the equilibrium concentration factors were not always reached. The control showed values near the natural background.

Light intensity and temperature during the experiments (a.m.) ranged in June-July between 24o-37,888 lx and between 22-25.5°C and in August-September between 23o-4,655 lx and 22 - 25°C.

The activity of radionuclides was assayed both in the water and in the alga. Water samples were obtained by evaporation of 2oo ml (salt).Algal samples,previously weighed (fresh weight), were obtained by carbonization at 210°C and calcination at 480°C (ash). Aliquots of the samples were radioassayed on targits using a low background Nuclear Enterprises beta counter with an efficiency of 14%, for 1,ooo s,at least 5 times each. The results were expressed in fresh weight.

Concentration factors (CF) were calculated for each radionuclide:

$$CF = \frac{\text{cpm g}^{-1}\text{ wet alga}}{\text{cpm ml}^{-1}\text{ water}}.$$

RESULTS AND DISCUSSION

Concerning the experiments with ^{59}Fe, in Enteromorpha linza between 578 - 3,467 cpm/loo g fresh weight were found during June-July and between 2,578-9,325 cpm during August-September. The maximum activity for both seasons occured after 2 days. The concentration factors were higher in August, with the maximum value 3,227 (Table 1); comparatively,for E.intestinalis a concentration factor of 3oo is known (14), which means an order of magnitude less than for E.linza from the Romanian Black Sea shore.

Table 1

Variation of concentration factor (CF) of ^{59}Fe in Enteromorpha linza under experimental conditions (June-July and August-September, 1981)

Month	Time (days)	Residue from loo ml water (g)	Residue from loo g alga (fresh weight)	Residue cpm.g	Ash cpm.g	Water/ loo ml cpm	Alga/ loo g f.w. cpm	CF
.VI-VII	2	1.27	4.85	3.06	638.2o	3.9o	3o95.27	794
	4	1.27	7.51	1.65	461.65	2.11	3466.99	1643
	7	1.23	11.71	2.17	158.24	2.66	1852.99	697
	14	1.31	1o.oo	2.o3	57.82	2.66	578.2o	217
	21	1.4o	5.53	1.47	236.29	2.o5	1,3o6.66	637
VIII-IX	2	1.7o	2.92	3.39	2376.77	7.83	9o91.62	1161
	4	1.6o	4.27	1.33	16o5.73	2.89	9324.79	3227
	7	1.67	3.75	2.72	3215.26	6.93	8o54.27	1162
	14	1.84	6.62	2.7o	344.24	7.55	3418.3o	453
	21	2.o7	8.39	5.35	2o4.84	16.87	2577.9o	153

In Cystoseira barbata between 49o - 632 cpm were found during June-July and between 934-1,899 cpm during August-September. The maximum activity occured after 7 and 12 days, respectively. Similar concentration factors in both seasons were determined, with the highest value of 453 in August (Table 2). Earlier data indicate for this species a higher concentration factor, of 1,060 (14). Also for ^{59}Fe, in an other brown alga, Fucus serratus, after a longer period (70 days), higher equilibrium concentration factors, ranging between 2,000 - 2,500, were found (20).

Table 2

Variation of concentration factor (CF) of ^{59}Fe in Cystoseira barbata under experimental conditions (June-July and August-September, 1981)

Month	Time (days)	Residue from 100 ml water (g)	Residue from 100 g alga (fresh weight)	Residue cpm.g	Ash cpm.g	Water/ 100 ml cpm	Alga/ 100 g f.w. cpm	CF
VI-VII	2	1.28	7.86	2.67	72.03	3.43	566.15	165
	4	1.15	8.42	1.88	68.32	2.16	575.25	266
	7	1.33	7.40	2.15	85.46	2.87	632.40	220
	11	1.40	8.50	2.95	72.89	4.15	619.99	149
	15	1.42	5.00	1.88	97.94	2.68	489.70	183
VIII-IX	2	1.65	3.90	2.09	182.84	4.69	934.13	199
	4	1.62	4.55	1.72	219.92	3.80	1310.83	345
	7	1.50	4.50	2.89	217.71	6.58	1485.87	226
	12	1.82	3.90	3.13	324.59	8.67	1898.85	219
	15	1.78	3.90	1.30	272.76	3.52	1595.64	453

It follows that regarding the two algal species from the Romanian shore, a higher concentration ability of ^{59}Fe was determined in the green alga E.linza as compared to C.barbata.

As concerns ^{65}Zn, in E.linza between 267 - 339 cpm were found during June-July and between 7,119-13,021 cpm during August-September. In both seasons the maximum activity was registered after 7 days. As for ^{59}Fe, the concentration factors were higher in August, with the highest values 7,147 (Table 3). In E.linza the concentration factors were much higher during August-September. Comparatively, concentration factors of 127 and 290, respectively, for the green algae Ulva rigida and U.pertusa are also known (14).

Table 3

Variation of concentration factor (CF) of ^{65}Zn in _Enteromorpha linza_ under experimental conditions (June-July and August-September, 1981)

Month	Time (days)	Residue from 1oo ml water (g)	Residue from 1oo g alga (fresh weight)	Residue cpm.g	Ash cpm.g	Water/ 1oo ml cpm	Alga/ 1oo g f.w. cpm	CF
VI - VII	2	1.3o	5.32	4.oo	59.78	5.2o	318.o2	61
	4	1.27	4.58	1.51	58.3o	1.91	267.o1	14o
	7	1.25	7.97	2.oo	42.58	2.5o	338.51	135
	14	1.4o	5.88	2.96	48.15	4.14	283.12	68
	21	1.36	6.71	2.67	39.99	3.63	268.33	74
VIII-IX	2	1.64	13.92	1.32	39o.41	2.74	7,119.19	2598
	4	1.67	7.81	4.8o	967.8o	3:16	1o,o7o.o6	3,187
	7	1.71	12.5o	1.3o	694.45	3.57	13,o2o.93	3,647
	14	1.71	1o.23		5o7.72	2.34	7,79o.95	3,329
	21	2.oo	1o.74	o.43	576.71	1.3o	9,29o.79	7,147

However, more recent data indicate for _U.rigida_ too higher concentration factors of ^{65}Zn, of 1,08o (January) and 1,28o (July) (17), or the highest concentration factor of 2,9o5 (12).

In _C.barbata_ too, after the uptake of ^{65}Zn, lower activities, between 57 - 248 cpm during June-July, are found compared to those between 1,43o - 7,5o4 cpm during August-September. The highest activities occured at the beginning of experiments, after the 4th and the 2nd day, respectively. The concentration factor, also much higher during the second experiment, showed the highest value of 2,444 (Table 4). Previous data indicate for _C.barbata_ a lower concentration factor, of 186 (14). For the same species, recent data emphasize similar concentration factors to those determined in the algal material originating from the Romanian shore, namely of 87o (January) and 2,o7o (July) (17); in these experiments the concentration factor in the brown alga _C.barbata_ was higher than in _Ulva rigida_ during the summer season.

Very similar concentration factors are known for other brown algae too, e.g. from the Atlantic Ocean, like _Laminaria digitata_ - 2,455 (6), or even much higher, like _Fucus serratus_ - 1o,768 (2o).

Table 4

Variation of concentration factor (CF) of ^{65}Zn in Cystoseira barbata under experimental conditions (June-July and August-September, 1981)

Month	Time (days)	Residue from loo ml water (g)	Residue from loo g alga (fresh weight)	Residue cpm.g	Ash cpm.g	Water/ loo ml cpm	Alga/ loo g f.w. cpm	CF
VI - VII	2	1.32	3.5o	3.49	16.31	4.6o	57.08	12
	4	1.3o	5.6o	3.99	44.31	5.18	248.13	48
	7	1.31	6.4o	2.72	34.88	3.56	223.23	63
	11	1.32	4.37	2.82	42.49	3.72	185.68	5o
	15	1.38	4.95	3.17	34.98	4.37	173.15	4o
VIII-IX	2	1.55	4.6o	1.46	1,245.24	3.o7	7,5o3.81	2,444
	4	1.55	4.o5	3.73	176.46	2.19	4,515.82	2,o62
	7	1.72	4.25	o.5o	239.66	1.3o	1,527.82	1,175
	12	1.74	4.3o	o.68	23o.68	1.79	1,487.88	831
	15	1.93	4.1o	o.74	232.57	2.15	1,43o.29	665

Higher values of the concentration factor of ^{65}Zn in the green algae as compared to the brown ones, like for E.linza and C.barbata from the Romanian shore, were observed for other species too, e.g. in E.linza compared to Sargassum (9).

Table 5

Variation of concentration factor (CF) of ^{89}Sr in Enteromorpha linza under experimental conditions (June-July and August-September, 1981)

Month	Time (days)	Residue from loo ml water (g)	Residue from loo g alga (fresh weight)	Residue cpm.g	Ash cpm.g	Water/ loo ml cpm	Alga/ loo g f.w. cpm	CF
VI - VII	2	1.28	5.15	34.3o	1o9.61	44.o7	564.49	12
	4	1.18	11.o6	22.o5	156.83	26.61	1734.53	65
	7	1.33	4.66	28.12	492.39	37.54	2294.53	61
	14	1.39	5.27	23.13	31o.72	32.15	1637.49	51
	21	1.4o	3.84	18.59	372.22	26.o3	1429.32	55
VIII-IX	2	1.55	2.64	35.76	197.75	187.14	621.12	3
	4	1.66	3.1o	118.3o	427,47	265.72	1,673.18	6
	7	1.61	3.39	65.72	1,o81.66	158.o5	5,437.46	34
	14	1.72	3.35	94.98	1,38o.15	245.75	6,872.47	28
	21	1.9o	3.3o	66.57	1,o87.16	188.97	5,318.66	28

As concerns ^{89}Sr, though both for E.linza and C.barbata high activities were radioassayed in the two periods, ranging between 565 - 2,295 cpm and between 1,268-1,843 cpm, respectively, the concentration factors are much lower than those for ^{59}Fe and ^{65}Zn. The maximum concentration factor of ^{89}Sr, obtained for both species in June, were in E.linza 65 (Table 5) and in C.barbata 12o (Table 6).

Table 6

Variation of concentration factor (CF) of ^{89}Sr in Cystoseira barbata under experimental conditions (June-July and August-September, 1981)

Month	Time (days)	Residue from loo ml water (g)	Residue from loo g alga (fresh weight)	Residue cpm.g	Ash cpm.g	Water/ loo ml cpm	Alga/ loo g f.w. cpm	CF
VI - VII	2	1.36	4.73	19.o1	368.89	25.85	1,745.32	68
	4	1.25	4.9o	12.25	376.o5	15.31	1,842.69	12o
	7	1.34	4.8o	14.99	36o.54	2o.o8	1,73o.59	86
	11	1.36	4.6o	13.22	387.93	17.97	1,784.47	99
	15	1.38	3.9o	14.68	325.1o	2o.25	1,267.87	63
VIII-IX	2	1.51	4.oo	73.48	125.58	147.61	426.47	3
	4	1.6o	4.6o	64.3o	1,47o.54	139.92	8,629.9o	62
	7	1.67	4.6o	54.17	1,492.62	134.63	10,087.5o	75
	12	1.55	4.1o	43.7o	1,5o9.93	99.67	9,o54.5o	91
	15	1.71	4.5o	42.48	1,321.93	1o7.13	8,691.4o	81

The present data are considerably higher as compared to the concentration factor 1 known for E.compressa (14), to the concentration factor lo found for C.barbata from the Romanian Black Sea shore by indirect radioassays (4) and to the concentration factor 4o obtained previously also for C.barbata from the Black Sea (14).

CONCLUSIONS

1. The following relation was established between the concentration factors of the investigated radionuclides in Enteromorpha linza and Cystoseira barbata: FC ^{65}Zn > FC ^{59}Fe > FC ^{89}Sr.

2. The following maximum concentration factors were

experimentally determined in E.linza: for ^{59}Fe = 3,227 (August), for ^{65}Zn = 7,147 (August) and for ^{89}Sr = 65 (June).

3. The following maximum concentration factors were experimentally determined in C.barbata: for ^{59}Fe = 453 (August), for ^{65}Zn = 2,444 (August) and for ^{89}Sr = 12o (June).

4. Generally, maximum values of the concentration factors were recorded for both species after 4 days from radionuclide addition.

5. The data obtained suggest the algae E.linza and C.barbata as possible bioindicators for the contamination of the coastal marine ecosystem with ^{59}Fe and ^{65}Zn and with ^{59}Fe, ^{65}Zn and ^{89}Sr, respectively.

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