Selenium Assimilation in a Marine Copepod

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A new method was developed for determining the assimilation efficiency of Selenium in marine animals feeding on Selenium-containing food. The experiments, which employed two gamma-emitting radiotracers--^{75}Se and ^{241}Am-- to study the assimilation of Selenium ingested by the marine Copepod Acartia tonsa, indicated that 97% of the ingested Selenium was retained by this animal after gut evacuation. Selenium showed a higher assimilation efficiency in Copepods than any other element, including Sulfur and Carbon.

The assimilation of an element ingested by marine Zooplankton will determine the extent to which that element is biologically usable or toxic and well as the residence time of that element in surface waters. Those elements which show negligible assimilation by marine Zooplankton (e.g., the Lanthanides and Actinides) would not accumulate in biological tissue, the oceanic food web, or the organic cycle in general. They would be efficiently "packaged" by the zooplankton into rapidly sinking materials, generally in fecal pellets or exoskeletons which are periodically released during molting, and the Zooplankton would therefore serve to depurate the surface waters of these elements (FOWLER and KNAUER, 1986; FISHER and FOWLER, 1987). The oceanic residence times for these elements is characteristically short (WHITFIELD and TURNER, 1987). In contrast, elements which show pronounced assimilation in the Zooplankton would enter into the organic cycle in surface waters and have much longer oceanic residence times than the unassimilated elements. These elements would therefore have lower concentrations in fecal pellets or exoskeletons than in body tissue or in the food upon which the animals had fed. Polonium has been well studied in this regard and has been shown to assimilate in the hepatopancreas of marine crustaceans (CHERRY *et al.*, 1983) and to associate in general with proteins in marine organisms (FISHER *et al.*, 1983b; HEYRAUD *et al.*, 1987). We have examined the assimilation of another group VIA element, Selenium, which may act as a Sulfur analog in aquatic organisms and which associates with seleno-amino acids in Algae and higher plants (BROWN and SHRIFT, 1982).

In a series of experiments, the small centric diatom Thalassiosira pseudonana was labeled with two gamma-emitting radiotracers, ^{75}Se, added as selenite (37-660 kBq l^{-1}, 0.136-2.42 nM)) and ^{241}Am (18.5-37.0 kBq l^{-1}, 0.6-1.2 nM), cells were harvested from their radioactive medium and resuspended into 200 ml unlabeled seawater to give cell densities of 1.3 to 2.1 x 10^5 ml^{-1}. These feeding suspensions then received 20 individuals of the adult copepod Acartia tonsa and the animals were allowed to feed for 6 hours. During the feeding, the radioactivity of the cells, the ambient water (ie., in the dissolved phase), and the fecal pellets and eggs produced by the animals was monitored using a gamma counter with a NaI (Tl) crystal as described in FISHER *et al.* (1983a).

The assimilation efficiency of the Selenium was determined by relating the radioactivity in the food and fecal pellets as described by the equation :

$$\text{Assimilation efficiency} = \frac{^{75}Se/^{241}Am\ (\text{food}) - ^{75}Se/^{241}Am\ (\text{feces})}{^{75}Se/^{241}Am\ (\text{food})}$$

The results indicated that the concentration of ^{75}Se in the fecal pellets was always reduced by over an order of magnitude in the fecal pellets relative to the levels in the food. The mean assimilation efficiency from four different experiments, conducted months apart from each other with different batches of phytoplankton and animals, was 97.1± 1.5% (Table 1). Mass balance assessments of Se assimilation efficiency gave comparable values. Further mass balance calculations indicated that only about 1% of the ingested ^{241}Am was assimilated.

The results suggest that Se should readily enter the organic cycle in the ocean, perhaps acting as a S analog in marine organisms. The high assimilation in animals and association with amino acids in Algae are consistent with the observation that most of the Selenium in surface waters is in organic form (CUTTER and BRULAND, 1984). Its biogeochemical behavior is therefore similar to that of Po.The organic cycling of Se is probably responsible for its relatively long residence time --2.6 x 10^4 years--in the oceans (BROECKER and PENG, 1982).

Table 1. Radioactivity of ingested and excreted material and assimilation efficiencies of Se calculated using the ratio method.

Experiment	Radioactivity (Bq µg^{-1} dry wt) Food			Feces			Assimilation efficiency
	Se	Am	Se/Am	Se	Am	Se/Am	
1	2.99	1.53	1.95	0.11	2.63	0.04	98%
2	2.74	1.19	2.30	0.05	0.55	0.09	96.1%
3	12.65	1.44	8.79	0.33	0.84	0.39	95.5%
4	6.14	0.65	9.45	0.26	2.12	0.12	98.7%
						mean :	97.1+1.5%

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Radium and its Daughters in *Bryopsis plumosa*

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Among the species of marine biota from the Rumanian sector of the Black Sea, the radioactivity of which has been systematically monitored since 1984 (DOVLETE 1984, 1985, 1986 and OSVATH 1987, 1988, 1989), the Bryopsis plumosa green alga stands out due to the great values of its alfa and beta radioactivity. High resolution gamma spectrometrical analysis shows that these are to be attributed to Ra-226, Ra-228 (radionuclides belonging to the uranium-radium, respectively thorium radioactive series) and their daughters (GUSEV and DIMITRIEV, 1978). An average radionuclidic composision of Bryopsis plumosa is presented in Table 1 (natural radionuclides only).

Table 1. Natural gamma emmitting radionuclide concentrations (Bq kg^{-1} fresh weight) at 320 days after sampling

Ra-226	Pb-214	Bi-214	Pb-210	Ac-228	Pb-212	Tl-208	K-40
642±6	437±2	400±2	9±2	250±3	67±1	24±4	75±3

Regarding the members of natural radioactive series identified in Bryopsis plumosa, the following relevant activity ratios were studied: Ra-226/Pb-214, Pb-214/Pb-210 for the U-Ra series and Ac-228/Pb-212 for thorium series. The activity of the i-th radionuclide in a radioactive series at time t is given by:

$$A_i(t) = \lambda_i N_0 \sum_{J=i}^{1} e^{-\lambda j t} \prod_{K=1}^{i-1} \lambda_K \Big/ \prod_{K=1,K\neq J}^{1} (\lambda_K - \lambda_J) \qquad \text{Eq. (1)}$$

where: λ_i = decay constant coresponding to i-th nuclide
N_o = number of parent nuclei at t=0

Values of the Pb-214/Pb-210 and Ac-228/Pb-212 activity ratios, computed using Eq. (1) and from radionuclide concentration data obtained directly by gamma spectrometrical analysis of the samples are presented in Tables 2 & 3 for various values of time T elapsed after sampling. In computing ratio values by applying Eq. (1) the hypothesis was made that Ra-226 and Ra-228 were the parent radionuclides of the series in the sample, which indicates that Bryopsis plumosa assimilates only the radium isotopes from its environment. The good agreement between calculated and measurement derived values (Table 2, for higher values of T, and Table 3) confirms the hypothesis, leading to the conclusion that the alga does not concentrate uranium or thorium isotopes but only radium isotopes from the environment. This conclusion is validated by the discrepancy between experimental values of the Ac-228/Pb-212 activity ratio and the theoretical ones according to which Th-232 is assimilated by the alga (Table 3). The discrepancy between theoretical and measurement-derived Pb-214/Pb-210 ratio values given in Table 2 is due to the difficulties for measuring Pb-210 by applying gamma spectrometry because its concentration is near the detection limit for lower values of T. The discrepancy obviously decreases with time, as Pb-210 concentration increases through the usual ingrowth process characterising radionuclides in a radioactive series. From this it can also be concluded that the alga does not assimilate Pb-210 from its environment, but all the Pb-210 in the sample are the decay products of Ra-226 assimilated by the living plant.

Table 2. Pb-214/Pb-210 activity ratio

T (days)	240	320	1000
experimental	81	48.7	13.5
theoretical parent Ra-226	45	34.0	11.0

Table 3. Ac-228/Pb-212 activity ratio

T (days)	240	320	1000
experimental	5	3.7	1.3
theoretical parent Ra-226	4.6	3.6	1.4
theoretical parent Th-232	9.4	7.1	2.6

The measurement-derived value of the Ra-226/Ra-228 ratio ranges between 2 and 3 in Bryopsis plumosa and between 1.5 and 3 in marine sediment (OSVATH, 1989), hence in sea water. This confirms that the alga conserves the environmental relative abundance of radium isotopes. It can be concluded that Ra-223 is also assimilated in much lower quantities, according to its relative abundance, but due to their short half-lives, its descendents cannot be identified in samples.

Radioactive equilibrium is achieved between Rn-220 and Po-216, Rn-220 exhalation from the sample being negligible. The situation is different for Rn-222, where a disequilibrium factor of 1.4 exists between Rn-222 and Po-218 (assessed through the Ra-226/Pb-214 ratio). The value of the radium concentration factor (CF) for Bryopsis plumosa calculated using the typical value of Ra-226 concentration in sea water given in (PENTREATH, 1988), is of the order of 10^5, three orders of magnitude above the average value recomended in IAEA, 1985. The computation of CFs for members of radioactive series (e.g Pb-210) is a delicate problem, and often requires supplementary measurements.

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