

Biokinetics of americium in marine plankton

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Abstract

Concentration factors for ^{241}Am in marine phytoplankton, euphausiids, and appendicularians were experimentally determined to be around 10^5 , 10^2 , and 10, respectively. The biological half-life of ^{241}Am in these organisms and their debris (i.e., fecal pellets, molts, larvacean houses) ranged from 3 days (euphausiid molts) to 51 days (euphausiid fecal pellets). Combining Am retention data in biogenic debris with known sinking rates, it is predicted that crustacean debris would effectively transport most of its Am to sediments while sinking phytoplankton and marine snow would enrich intermediate depth waters.

Résumé

Des facteurs de concentration de ^{241}Am par du phytoplancton marin, des Euphausiacés et des Appendiculaires ont été déterminés par voie expérimentale et sont respectivement de l'ordre de 10^5 , 10^2 et 10. des demi-vies biologiques de ^{241}Am dans ces organismes et leurs déchets (i.e., boulettes fécales, mues, logettes) s'échelonnent entre 3 jours (mues des Euphausiacés) et 51 jours (boulettes fécales des Euphausiacés). En combinant les données sur la rétention de Am dans les débris biogéniques avec les taux connus de sédimentation, on peut prédire que les débris de Crustacés transporteront la plus grande part de leur Am vers les sédiments, tandis que le phytoplancton et la neige marine enrichiront les eaux à des profondeurs intermédiaires.

The uptake and retention of four transuranic elements by seven species of marine phytoplankton, belonging to six different algal classes, was examined using isotope tracer methodology. Neptunium showed no detectable accumulation in any cells, while plutonium, americium, and californium were rapidly concentrated so that volume/volume concentration factors at equilibrium generally exceeded 10^5 . The results for ^{241}Am , comparable to those for ^{237}Pu and ^{252}Cf , are given in Table 1. Uptake of radionuclide proceeded by passive adsorption onto cell surfaces and was directly proportional to the number of particles and radioisotope concentration, with equilibrium being achieved within 3 - 4 days (Fisher *et al.*, 1983 a). Generally, diatoms had the most reactive surfaces and green and blue-green algae the least reactive. The biological half-time ($T_{b1/2}$) for loss of ^{241}Am from algae was 10-12 days (Table 1). Dissolved humic and fulvic acids, even at elevated

concentrations, had no appreciable influence on bioaccumulation of these elements; the rate of ^{241}Am accumulation in a diatom was inversely related to concentrations of ASV-labile transition metals, suggesting competition for bindings sites on the cell (Fisher et al., 1983 b).

Table 1. Volume/volume concentration factors and biological half-lives ($\text{Tb}_{1/2}$) of ^{241}Am in marine plankton. Estimates for sinking rates of different components also given.

Type of Organism	No of species examined	Vol/vol concentration factor for ^{241}Am (range)	^{241}Am $\text{Tb}_{1/2}$ (days)	Sinking rate (m day^{-1})
phytoplankton	6	$(0.3 - 6.9) \times 10^5$	10-12	< 2
euphausiid (whole animal)	3	$(1.4 - 7.9) \times 10^2$	-	-
(fecal pellets)	1	-	41-51	100-900
(molts)	1	-	3	500-1500
appendicularian (whole animal)	1	10	-	-
(fecal pellets)	1	-	6-10	20-170
(houses)	1	-	9	20-160

Euphausiids (Meganyctiphanes norvegica) accumulated ^{241}Am from filtered seawater so that concentration factors were about 10^3 lower than in phytoplankton (Table 1). Concentration factors varied inversely with the size of the animals. Virtually all isotope (96%) accumulated from filtered seawater deposited on the exoskeletons and was lost upon molting. Am-241 was released from cast molts with a $\text{Tb}_{1/2}$ of 3 days (Table 1). Virtually all ^{241}Am ingested in labelled algal food was defecated, with a $\text{Tb}_{1/2}$ for release from fecal pellets of 41 days at 13°C and 51 days at 5°C (Table 1).

Appendicularians (Oikopleura dioica), gelatinous zooplankton, accumulated ^{241}Am from filtered seawater so that volume/volume concentration factors were about 10 (Table 1). When animals grazed on ^{241}Am -labelled diatoms, there was no detectable assimilation of the nuclide in the animal. Fecal pellets contained about 2/3 of the filtered ^{241}Am and the $\text{Tb}_{1/2}$ for ^{241}Am loss from the fecal pellets was 6 - 10 days, depending on the food source (Table 1). About 1/3 of the filtered ^{241}Am was retained in the mucopolysaccharide houses of the animals, which are expended about 8 times per day. The $\text{Tb}_{1/2}$ of ^{241}Am in expended houses was 9 days (Table 1).

There was negligible assimilation of ^{241}Am in animals; instead it appears that zooplankters act as effective "packagers" of this element and mediate its vertical transport via biogenic debris. Considering the $\text{Tb}_{1/2}$ remineralisation values and the sinking rates of marine phytoplankton and of biogenic debris from the zooplankters (Table 1), it is predicted that fecal pellets and molts from euphausiids and other crustaceans would carry ^{241}Am (and similarly reacting elements) to very deep water and to sediments. Marine snow, rich in phytoplankton and appendicularian houses (Silver & Alldredge, 1981) sinks slower and would, by contrast, lose half its ^{241}Am in intermediate depth waters (less than 1000 m). This may help explain the observed peaks of soluble Pu and Am at 500 and 750 m, respectively (Bowen *et al.*, 1980; Bowen; in press) in ocean waters.

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Paper presented by N.S. Fisher (IAEA)

Discussion

M. BRANICA: Can you comment on the most probable dissolved species of ^{241}Am in your experimental system?

N. FISHER: The Am was added as americium nitrate. It is thought to exist in the III oxidation state, though we did not specifically examine this ourselves. I have heard that it may combine with hydroxyl groups to form $\text{Am}(\text{OH})_3$ in seawater, but again this was not examined in the present study.

V. ZUTIC: 1. How do you explain the apparently contradictory experimental findings on the effect of dissolved organics and ASV-labile transition metals ?

2. Did you find that the concentration factors in phytoplankton were constant over a large range of radionuclide concentration ?

N. FISHER: 1. We think that the humic and fulvic substances preferentially complex Cu and Zn over Am. Thus, when these substances are present in high concentrations, they complex the transition metals, thereby reducing the number of ions ambient in the seawater that may compete with Am for binding sites on the cells. Why the Am is not complexed by the humic acids is a matter of speculation at this point; if it exists in an unchanged state in a stable inorganic complex, then it may be less available for complexation than some of the transition metals. But, in any case, we consistently find that the presence of DOC at natural or elevated levels does not reduce the bioavailability of Am.

2. Yes. With axenic cultures of diatoms and green algae, the concentration factors were constant over a 16 fold range in Am concentration (from 83 to 1330 pM). In experiments with natural particle assemblages from the Mediterranean we found

that 9% of the Am became associated with particles, comparable to the 10% value measured by Holm *et al.* However, in the experimental flasks, the Am concentration was $\sim 10^9$ greater than in the surface waters of the Mediterranean, suggesting that the concentration factors are pretty constant over a very large range of Am levels.

R. BOJANOWSKI: 1. Couldn't the enhanced uptake of ^{241}Am by phytoplankton in the presence of humic substances have resulted from surface adsorption of an Am-humic acid complex?

2. Does the presence of inorganic suspended particles affect the uptake and the CF of ^{241}Am by phytoplankton?

N. FISHER: 1. It is possible, but we think unlikely for two reasons. First, we checked adsorption of Am with and without humic acids onto blank Nuclepore filters (that is, without cells) and there were no apparent differences -- adsorption was very low incidentally. Second, when humic acids complex Cu, for example (or other transition metals), they reduce the bio-availability of the metals rather than enhance it.

2. The wet weight concentration factors for Am in two natural particle assemblages from the Mediterranean tested experimentally were comparable to the diatom concentration factors. The particle assemblages were composed of diatoms and what appeared under the light microscope as inorganic debris. Further, these Am concentration factors are nearly identical to those measured in natural particles in the Irish Sea, according to Pentreath, where the preponderance of particles is non-living.

