*Americium adsorption on macroalgal surfaces

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Abstract

Macrophytic algae display very high concentration factors for americium accumulated from ambient water. Data is presented on rates at which americium deposits upon blade surfaces of three algal species. Transport rates for Am are quite similar to that reported for polonium and both are one order of magnitude lower than a plutonium transport rate reported in literature. Evidence is presented that the high concentration factors result from the adsorption of Am on the thin outer organic coating of these seaweeds.

Resume

Les algues benthiques présentent des facteurs de concentration pour l'américium très élevés. Les taux de dépôt de l'Am sur les surfaces de trois espèces d'algues ont été déterminés. Ces taux de transfert calculés pour l'Am sont identiques au taux trouvé pour le polonium et tous les deux sont d'un ordre de grandeur plus bas que celui trouvé pour le plutonium. L'Am accumulé par les algues se dépose surtout sur la mince couche organique extérieure par adsorption et on estime qu'il s'agit du mécanisme responsable des facteurs de concentration élevés que l'on trouve chez les algues.

Americium is a manmade transuranium element which enters the marine environment mainly through fallout from nuclear weapon tests and controlled releases of industrial nuclear wastes. In the near future americium levels are expected to increase in marine ecosystems both by further inputs as well as in situ decay from Pu-241. From field measurements and laboratory experiments data are accruing which show that seaweeds are extremely efficient in taking up Am and other transuranics. Hence, laboratory experiments have been designed to help clarify several aspects of Am accumulation by seaweeds.

In a former experiment Am-241 ($T_{pl/2}$ = 433 a) was used to label sea water (specific radioactivity 7.1 Bq ml^{-1}) in which several thalli of the

*to be published in extenso elsewhere.

Mediterranean macrophyte seaweeds Bryopsis balbesiana (Chlorophyceales, green) and Dilophus spiralis (Phaeophyceales, brown) were allowed to accumulate the radiotracer. Throughout the experiment Am-241 was regularly measured by standard NaI(Tl) scintillation techniques in thoroughly rinsed thalli and in sea water samples in order to compute concentration factors. After 17 days' exposure concentration factors were 1625 and 750 in the brown and green algae, respectively. Am-241 depuration was characterized by an initial rapid phase in which 15% and 24% of the radionuclide was lost from brown and green algae during the first 24 hours. This phase was followed by a much slower period of loss with biological half-times of 14 and 36 days for the brown and green algae, respectively. The pool of Am which turns over slowly represented roughly 80% of the radionuclide initially accumulated by both species (Carvalho and Fowler, 1984). These sorts of data underscore the potential importance of seaweeds in the biogeochemical cycle of this radionuclide in coastal zones.

To supplement previous experiments and to delineate the mechanisms involved in Am biokinetics we selected three Atlantic species of seaweeds to measure the Am deposition rate. Entire thalli of actively growing Ulva sp. (Chlorophyceales), Fucus vesiculosus (Phaeophyceales) and Gigartina stellata (Rhodophyceales, red) were collected from the infralitoral rocky shore off Portugal. Am-243 ($T_{p1/2}$ = 7950 a; 5.27 MeV α-emission) was used as radioactive tracer to label sea water. In a first experiment, several thalli from each algal species were allowed to accumulate Am-243 from spiked sea water (specific radioactivity 0.46 Bq ml^{-1} = 27.7 dpm ml^{-1}) contained in beakers. Two groups of algae were run at the same time, one group exposed to artificial fluorescent light and the other kept in the dark. In a second experiment thalli of Ulva were exposed in separate beakers in the light to different Am concentrations (11.1, 27.7 and 55.4 dpm ml^{-1}). Temperature in all experiments was a constant 12°C. Periodically, during a 7 hour period, entire thalli of each species were removed, rinsed in clean sea water, and small disks of known surface area were excised and dried on steel planchets. These samples were measured for radioactivity directly in an ion grid chamber connected to a pulse height analyzer.

The three algal species rapidly accumulated Am from water although at distinctly different rates. The green alga (Ulva) took up approximately 3 times more Am than the brown alga (Fucus) and 5 times more radionuclide than the red species (Gigartina). No difference in uptake rate was observed between algae held under light or in the dark, an observation which suggests that the uptake process is a passive one. Exposure of Ulva to different Am-243 concentrations resulted in different Am deposition rates on algal surface. Normalization of these rates to the three ambient Am concentrations (i.e., transport rates) indicated that uptake was proportional to the ambient Am concentration.

Deposition and transport rates were calculated for each species. Deposition rates were a function of the ambient Am concentrations for the same algal species and varied from species to species for the ambient Am concentration. Computed transport rates were similar for the same species (e.g. 3.6-3.9 x 10^{-5} for Ulva) at variable external Am concentrations, but differed for all the species tested (1.1 x 10^{-5} for Fucus, 0.7 x 10^{-5} for

Gigartina). These values were similar to the Po-210 transport rate (2×10^{-5} pCi cm^{-2} s^{-1}/pCi cm^{-3} sea water) computed by Folson et al. (1975) for the giant kelp Macrocystis pyrifera. However, the Po-210 results and ours for Am are an order of magnitude lower than the mean Pu transport rate (2×10^{-6} pCi cm^{-2} s^{-1}/pCi cm^{-3} sea water) from water to Macrocystis also reported by Folsom et al. (1975). The uptake rates are likely to more dependent upon different reactivities of the organic coatings of a given species than upon the transuranic radionuclide. This hypothesis is supported by field studies which have demonstrated no preference for either Pu or Am in seaweeds (Aarkgor et al., 1984).

The Am-243 alpha spectra obtained from directly counting dried seaweed samples are similar to spectra originating from sources prepared by evaporating solutions of Am-243 on steel planchets. The same samples were radioanalyzed with a Ge(Li) detector using the 75 KeV γ-emission of Am-243. Radioactivity computed from α measurements was never less than 70% of the total activity computed from γ measurements. These observations support the hypothesis that surface adsorption is primarily responsible for the high Am accumulation by seaweeds.

If americium accumulated from sea water by seaweeds is in fact adsorbed on the organic coating of the external surface, the known release of algal extracellular products could explain the rapid Am loss found for marine zooplankton and thus Am could conceivably enter lower trophic level food chains through this transfer pathway.

REFERENCES

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Discussion

P. MIRAMAND: N'avez-vous pas eu de problèmes pour maintenir en vie des algues en aquarium pendant une période de temps relativement longue?

F. CARVALHO: Les algues sont restées vivantes pendant toute la durée de l'expérience, l'eau renouvelée pendant la première expérience y a beaucoup contribué.

I. GEORGESCU: In what form was the Am incorporated? Were the alpha measurements made by silicon detectors?

F. CARVALHO: Am was added to sea water in the nitrate form and is probably present in the +3 oxidation state. The alpha measurements were made in a grill ionization chamber purged with methane-argon gas, and counted on a multichannel analyzer.