*Observations on americium biokinetics in benthic invertebrates and its relation to feeding mode

SCOTT W. FOWLER and [1]FERNANDO P. CARVALHO

International Laboratory of Marine Radioactivity, IAEA
Musée Océanographique, Principality of Monaco, MC 98000

Abstract

Am-241 bioaccumulation from sea water was tested using the suspensivorous crinoid Antedon mediterranea and the filter-feeding tunicate Halocynthia papillosa. Both species readily accumulated Am reaching high concentration factors. Experimental evidence indicated that the external mucous cover used as a feeding guild by the crinoid is not an efficient trap for particulate Am but the particulate fraction is available to tunicates through their filtering activities. The principal mode of uptake in both species is by adsorption of soluble Am onto the mucous layer and body wall. Ingestion of labelled food results in high assimilation efficiencies in both the brittlestar Ophiura textura (87%) and the squat lobster Galathea strigosa (58%); however retention of the assimilated fractions was significantly different as evidenced by biological half-lives of 78 days and 14 days respectively. This large difference is attributable to different feeding-digestion physiologies of the two species.

Résumé

L'accumulation de l'Am-241 à partir de l'eau a été mesurée chez le crinoïde suspensivore Antedon mediterranea et chez le tunicier filtreur Halocynthia papillosa. Ces deux espèces accumulent l'Am jusqu'à des facteurs de concentration élevés. Les résultats indiquent que la couche extérieure du mucus, dont les crinoïdes se servent pour attraper les particules en suspension, n'a pas d'efficacité pour prélever la fraction de l'Am associée à ces particules, tandis qu'elle est à même d'être retenue par les tuniciers filtreurs. Cependant, c'est l'adsorption de l'Am soluble sur la couche de mucus et sur les parois extérieures du corps qui est la voie principale d'accumulation de l'Am chez ces deux espèces. Par ingestion de nourriture contaminée avec de l'Am, Ophiura texturata et le crustacé Galathea strigosa présentent des taux d'assimilation élevés. Pourtant, la rétention des fractions assimilées est différente comme le montrent les demi-vies biologiques de 78 et 14 jours respectivement. Cette différence s'explique par la physiologie différente des deux espèces.

---

1 Present address: LNETI/DPSR, Estrada Nacional 10, P-2685 Sacavem, Portugal

Recent reviews stress that the relatively small amount of data on americium in aquatic biota does not provide a sufficient basis for comparison with the corresponding plutonium data base. We therefore undertook to delineate, experimentally, the biokinetics of ^{241}Am in some marine benthic species with very different feeding-digestion strategies, which hitherto have not been studies in any detail in a radioecological context. Since significant amounts of transuranics entering the sea become associated with particulate matter, we considered the effect of particulate-bound Am on bioavailability to benthic organisms with different feeding modes.

Several specimens of the crinoid Antedon mediterranea ($\bar{X}$ = 0.76 g wet weight) and the tunicate Halocynthia papillosa ($\bar{X}$ = 2.6 g wet) were allowed to accumulate ^{241}Am ($T_{1/2}$ = 433 a) from labelled sea water with a specific radioactivity of 9 Bq ml^{-1} (0.24 nCi ml^{-1}). In a separate experiment the polychaete Nereis diversicolor was used to follow the production of particulate ^{241}Am in labelled sea water. Throughout the experiments ^{241}Am was measured in each individual and 20 ml of radioactive sea water in order to compute concentration factors (C.F.). Before introduction and after removal of the animals, the particulate and soluble ^{241}Am fractions in sea water were measured by filtering aliquots through double layered 0.45 µm Millipore filters. After exposure in radioactive sea water certain individuals were transferred to flowing sea water and radionuclide retention was measured during several weeks. Several specimens of the ophiuroid Ophiura texturata ($\bar{X}$ = 2.9 g wet) and the decapod crustacean Galathea strigosa ($\bar{X}$ = 2.3 g wet) were fed a single ration of ^{241}Am labelled mussel soft parts and Artemia carcasses, respectively. Radionuclide retention was measured in each individual and assimilation efficiencies computed. Whole body measurement techniques for radioanalyzing ^{241}Am and methods used to compute biological half-lives ($T_{b1/2}$) and assimiliation efficiencies have been described elsewhere (Fowler and Guary, 1977; Grillo et al., 1981; Carvalho et al., 1983; Carvalho and Fowler, 1984).

In freshly labelled sea water without animals, the fraction of particulate-associated ^{241}Am increased quickly and stabilized after 1 day at about 15%. When the polychaete Nereis or the crinoid Antedon was added to the water, the particulate-associated ^{241}Am fraction increased rapidly to ∿40% on day 1 and ∿77% on day 5. In contrast, in water containing the filter-feeding Halocynthia, the particulate Am fraction remained low. For example on day 2 it was 5.7% ± 1.7% (n = 4) and for several days thereafter remained below the normal value for the blank, i.e. < 15%. The low value indicates that the tunicates were removing the particulate-associated Am fraction from water via their filtration activities.

Antedon and Halocynthia both displayed relatively high whole body ^{241}Am uptake rates; after a 2-week exposure period, near equilibrium C.F.s of 173 and 193, respectively were reached. The crinoid Antedon has a calcified body wall, the surface of which is covered by a mucous layer. In general, the largest transuranic fraction in echinoderms is found associated with the body wall. Comparing data on body wall $CaCO_3$ content and Am C.F.s, quoted from literature for crinoids and other echinoderms classes, a positive correlation is apparent suggesting that Am accumulated by echinoderms increases with the

degree of calcification of body wall. Radioanalyses of the tunicate tissues showed that the body wall contained about 90% of the ^{241}Am body burden, whereas the atrial water contained the same Am concentration as that of the surrounding water (i.e. C.F. $\sim$1) indicating a lack of Am concentration in this fluid. Regardless of the tunicate's ability to filter labelled food particles from water, the incorporation of Am into internal tissues is low ($\sim$7% of the Am total body burden).

Am-241 depuration by Halocynthia displayed a triphasic pattern; the long-lived compartment representing 41% of the initial radioactivity content (A_o) turned over slowly with $T_{bl/2}$ of 83 days, while the two short-lived compartments lost Am much more rapidly ($T_{bl/2}$ of 1 and 7 days). Am loss by Antedon followed biphasic kinetics with a $T_{bl/2}$ of 0.4 days for the short-lived compartment (15% of A_o) and 51 days for the long-lived retention compartment (85% of A_o).

Following the ingestion of labelled food, ^{241}Am elimination by Ophiura and Galathea displayed very different kinetics. A large fraction (87%) of the Am ingested by the brittlestar was assimiliated into internal tissues and was subsequently excreted very slowly ($T_{bl/2}$ = 78 days). At 113 days post-ingestion of radioactive food, brittlestars still retained 31% of the initial dose despite repeated feedings with non-labelled mussel. At this time the gut held 78% of the remaining Am with lesser amounts located in the other organs. The crustacean Galathea eliminated ingested Am faster than the ophiuroid. The assimilated fraction, 58% of the ingested Am, turned over rapidly ($T_{bl/2}$ = 14 days) with most of the transuranic being eliminated with the faeces. After a 26 day depuration period the remaining fraction of the ingested Am in individuals ranged from 1.4 to 33%. At this time small but variable amounts of the tracer were located in the digestive tract (up to 23% of the total body burden), hepatopancreas (up to 4%) and muscle (up to 10%), indicating that absorption had taken place through gut walls.

Food chain experiments with Ophiura demonstrated both a high assimilation efficiency for Am and a long retention time; these features, which appear to be a function of the general digestion physiology of these organisms, may be widespread among echinoderms. Results obtained with Galathea clearly showed that ingested Am is efficiently assimilated from food and that it is quickly eliminated from tissues via the faeces. Nevertheless the high Am assimilation efficiency noted with Galathea is not a general rule among crustaceans (Fisher et al., 1983).

Some general trends emerge from comparisons of the above results. Filter-feeders such as tunicates are able to clear Am-labelled particles from sea water by filtration through the branchial basket, and accumulate small amounts of the Am in internal tissues. On the other hand the same particulate fraction of Am is not efficiently trapped by the mucous feeding guilds of suspension-feeders like crinoids. Here uptake takes place by complexation and/or adsorption of dissolved Am to mucus and body wall. Echinoderms, such as ophiuroids and asteroids, and certain large crustaceans efficiently assimilate Am ingested with their prey; however the large differences found

between the biological half-lives for Am excretion in these two taxonomic groups argue for basing the behaviour of incorporated Am on different feeding/ digestion physiologies rather than on general taxonomic distinctions.

REFERENCES

CARVALHO, F.P. and S.W. FOWLER. Experimental studies on biokinetics of americium in benthic marine organisms. In: International Symposium on the Behaviour of Long-Lived Radionuclides in the Marine Environment (A. Cigna and C. Myttenaere, eds.), EUR 9214, pp. 297-315, CEC, Luxembourg (1984).

CARVALHO, F.P., S.W. FOWLER and J. LA ROSA. Assimilation, interorgan transfer and excretion of americium in two teleost fish. Mar. Biol., 77: 59-66 (1983).

FISHER, N.S., P. BJERREGAARD and S.W. FOWLER. Interactions of marine plankton with transuranic elements. 3. Biokinetics of americium in euphausiids. Mar. Biol. 75: 261-268 (1983).

FOWLER, S.W. and J.C. GUARY. High adsorption efficiency for ingested plutonium in crabs. Nature 266 (5605): 827-828 (1977).

GRILLO, M.C., J.C. GUARY and S.W. FOWLER. Comparative studies on transuranium nuclide biokinetics in sediment dwelling invertebrates. In: Impacts of Radionuclide Releases into the Marine Environemnt, IAEA, Vienna, pp. 273-291 (1981).

GUARY, J.C., S.W. FOWLER and T.M. BEASLEY. Routes of plutonium uptake and their relation to biomagnification in starfish. Mar. Pollut. Bull., 13 (3): 21-28 (1982).