Am-241 Assimilation and Excretion in Marine Fish

- An Experimental Approach

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Abstract

Experiments with two species of teleost fish fed with Am-241 labelled food, showed that the radioelement is assimilated through the gastro-intestinal walls with accumulation and retention mainly occurring in the skeleton, skin and muscle. Gut transfer coefficients (≈0.67% of the initial ingested radioactivity) were similar in both species. Results from an intramuscular injection experiment indicate a low accumulation by muscle tissue, a short biological half-life for the liver and long retention in the bone. Principal excreted routes involved in americium depuration appear to be via gills, kidneys and faeces; bile is implicated as an excretion route from liver.

Résumé

Deux espèces de Téleostéens nourries avec une nourriture marquée par l'Am-241 ont assimilé le radionucléide à travers la paroi du tube digestif et l'accumulation et rétention ont lieu surtout dans le squelette, la peau et le muscle. Les coefficents de transfert digestif (≈0.67% de la radioactivité ingérée) chez les deux espéces sont identiques. Les résultats d'une expérience d'injection intramusculaire du radionucléide indiquent que l'accumulation par le tissu musculaire est faible, que la demi-vie de l'Am dans le foie est courte et que le squelette le retient beaucoup. Les voies d'excrétion principales par lesquelles l'élimination de l'Am a lieu semblent être les branchies, les reins et les feces, la bile jouant une rôle dans l'excrétion de l'Am par le foie.

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Americium-241 enters the marine environment by way of fallout from nuclear testing and controlled releases of radioactive wastes from reprocessing plants. 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. The fact that this transuranic element has been found to accumulate in marine fish (Pentreath and Lovett, 1978a) indicates the potential for a direct transfer to man via sea food. Hence, laboratory experiments have been designed to help clarify several aspects of americium metabolism in marine fish.

The α- emitter Am-241 (Tpl/2 = 458y) was used in this study. The 60-KeV gamma emission of this radionuclide allows whole body radioactivity measurements to be made by standard NaI(Tl) scintillation techniques.

Several individuals of the pelagic fish Serranus scriba and of the benthic fish Scorpaena notata, were fed a single ration with Am-241 (nitrate form, neutral pH) labelled polychaetes (Nereis diversicolor). Fish were subsequently held in plastic aquariums supplied with flowing sea water and radionuclide retention and excretion were monitored regularly for several weeks.

After 7 days the bulk of the ingested americium (≃ 99%) was lost via faeces. The absorbed fraction of the Am initially ingested averaged 0.46% for Serranus and 0.87% in the case of Scorpaena and was slowly excreted with biological half-lives for the different individuals ranging between 49-61 days and 12-117 days, respectively, for each species. The pattern of loss, the fraction absorbed and the calculated biological half-lives were not significantly different between species. Whereas the mean gut transfer coefficient of ingested Am (≃ 0.67%) is lower than that reported for marine invertebrates (Guary, 1980; Carvalho and Fowler, unpublished data), it is at least one order of magnitude higher than typical values reported for mammals (Nenot and Stather, 1979). Comparable studies on plutonium assimilation by marine teleosts have indicated that plutonium retention following ingestion of the radionuclide is extremely low with transfer coefficients probably less than 0.01% (Pentreath, 1978b).

Following 65 days loss for Serranus and 34 days for Scorpaena, fish were dissected and their organs radioanalysed separately. In the case of Scorpaena, among the internal organs the major fraction of Am-241 was detected in the skeleton (21.8 - 74.0%) with most of the remainder located in skin (10.2 - 11.1%) and muscle (3.3 - 9.0%). Lesser fractions were contained in spleen, liver, kidneys, brain, eyes, gall bladder, gills and intestine. In Serranus following a single ingestion of contaminated food, because of low initial radioactivity, Am-241 was detectable only in spleen and gut walls. In order to confirm Am assimilation through the gastro-intestinal tract, another group of Serranus was repeatedly fed different types of labelled food during a three week period. Twelve days after the last labelled meal, fish were dissected and similar organs from the fish

bulked to obtain higher Am-241 levels. As with Scorpaena measurable quantities of the radionuclide were found in the internal organs, indicating that Am-241 was assimilated from food through the gut wall. Similarly, the main pool of incorporated radionuclide was located in skeleton (51.6% of the total body burden), followed by the muscle (10.3%) and skin (6.5%) Lesser amounts of radioactivity were also measurable in blood, heart, spleen, liver, kidneys, gut walls, gills and eyes. The main loci of Am-241 deposition in these fish agreed well with in situ measurements of Am-241 in marine flat fish which had been contaminated by reprocessing plant wastes (Pentreath and Lovett, 1978a).

To obtain preliminary data on americium transfer between internal organs, a third group of Serranus was injected with radioisotope in the lateral muscle of the tail region. Periodic whole body counting over several weeks revealed a whole body biological half-life of 139-161 days, somewhat longer than that for Am absorbed from food. Two fish were dissected on the 8th, 15th and 31st day after injection and their organs radioanalysed. High residual amounts of the radionuclide (75-96% of the injected activity) were found at the injection site probably because americium rapidly undergoes polymerization, binds to cell surfaces and is strongly retained (Nenot and Stather, 1979). If the injection site is disregarded, we find that of the remaining tissues, skeleton, skin and the liver are again the main sites of radionuclide deposition.

Trends in transfer processes were evident by examining temporal changes in levels of Am among the various tissues. For example, a decrease in radioactivity associated with blood and a concomitant increase in the Am fraction found in bone suggests a temporal transfer from blood to bone. In addition liver radioactivity decreased between day 15 and 31; the estimated biological half-time for Am removal from this tissue was about 24 days. In some fish Am-241 was detected in gall bladder and gut contents which strongly suggests that one excretion route for americium accumulated in the liver is via the bile. Furthermore, the gills and kidneys, which are primarily involved with ionic regulatory functions in marine fish, show markedly high Am retention.

Americium behaviour in muscle was very different from that in bone. The Am-241 activity associated with muscle decreased considerably over 31 days. This was presumably due to clearance of contaminated blood from the muscle tissue. If we assume that radioactivity in tissues results from transfer from the blood, comparison of tissue/blood concentration ratios (C.R.) at the termination of the experiment show that greatest relative uptake occurred in the spleen (C.R. = 399-637) followed by lesser accumulations in the liver (52-83), kidneys (37-50) and skeleton (19-46).

We conclude that marine teleosts can accumulate Am-241 through ingestion of contaminated food, although the degree of tissue assimilation is very low. Once accumulated Am-241 is rapidly transferred to bone where it is probably retained with a relatively long biological half-life. Two consequences of the low degree of assimilation become apparent: 1) Food chain biomagnification of Am-241 along the fish food chain is unlikely to occur and 2) Faeces from fish ingesting prey contaminated with Am-241 are likely to be instrumental in the biogeochemical cycle and vertical transport of this radionuclide in the marine environment.

In extenso version of this communication will be issued elsewhere.

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"*Am-241 assimilation and excretion in marine fish*"

Paper presented by F.P. Carvalho (Portugal)

Discussion

C. PAPADOPOULOU: Did you count ^{241}Am in fish otoliths and do you have any idea of the age of the experimental fish?

F. CARVALHO: No, we did not radioanalyze the otoliths. The exact fish ages are not known, but the fish weighed between 20.6 - 45.3 g wet (*Serranus scriba*) and 5.1 - 18.2 g wet (*Scorpaena notata*).

H. FLOROU-GAZI: Do teleosts only accumulate ^{241}Am through ingestion or can they take it up directly from water?

F. CARVALHO: Probably marine teleosts also can accumulate Am directly from sea water, at least through the gut walls, as they do from food. It is a well established fact that marine teleosts deliberately swallow water to replace the water lost osmotically across the body surface. Other possible uptake routes, gills for example, were not addressed in our study.