^{137}CS AS A TOOL FOR INVESTIGATING THE MIGRATION OF POLLUTANTS VIA WATER MASS MOVEMENT BETWEEN TWO DIFFERENT BASINS

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The northeastern Aegean Sea is an area where the Black Sea (B.S.) water mass interacts with Aegean Sea waters through the Dardanelles (Fig. 1). As the B.S. waters enter the Aegean Sea (A.S.), they are diluted in the northern and the western part of the A.S. The upper layer of the B.S. water mass is characterized by low salinitiy values, which produce high stability of buoyancy conditions. Thus, the upper layer (0 50 m) of the entire water column comes out to the A.S. through the Dardanelles, a narrow channel of 90 m maximum depth (NITTIS *et al.*,1990).

The situation outside of the mouth of Dardanelles in the A.S. is completely different, characterized by higher salinity values, deeper depths and strong currents during the cold period. The volume of water coming from B.S. is insignificant (300-700 km^3 annually) as compared with the total water volume of the eastern A.S. (90000 km^3)° however, the upper layer of the northern and western part of the A.S. is greatly affected by the B.S. water flux (Fig. 1).

The Chernobyl nuclear accident on 26 April 1986 resulted in a deposition of about 530 TBq of ^{137}Cs in the A.S. (KRITIDIS and FLOROU, 1990). The respective amount for the B.S. is about 2400 TBq. Since ^{137}Cs is re-suspended from the B.S. sediments and the river outflows deliver contaminated terrestrial material to the B.S., an amount of about 250 TBq is estimated to remain in the 0-50 m water layer based on data for the period 1986-1991 (EGOROV *et al.*, 1994). This amount is expected to be discharged from the B.S. into the Sea of Marmara and consequently to the northeastern A.S. through the Dardanelles channel.

According to our ^{137}Cs measurements of surface sea water during 1993, it was shown that approximately 48 TBq of ^{137}Cs was the 1993 discharge to the A.S. due to the purification process of the B.S. (FLOROU and KRITIDIS, 1994). Thus, we assume that the mouth of Dardanelles is a definite "point source of pollution" for the eastern Mediterranean with a more or less predictable amount of ^{137}Cs discharge. Considering the generic inventory of ^{137}Cs in the A.S. during 1993, the average concentration of ^{137}Cs in the mouth of Dardanelles close to the A.S. is 118 ± 8 Bq m^{-3}, whereas the mean estimated value for the A.S. is 20.7 ± 14.7 Bq m^{-3} (FLOROU *et al.*, 1994). This value is quite high if compared with the pre-accident levels (2.6 ± 0.3 Bq m^{-3} for the period 1984-85 reported by FLOROU (1992), or with the respective value for the Ionian Sea, 9.2 ± 2.5 Bq m^{-3} (FLOROU, 1994). If we look at the dispersion of ^{137}Cs, we note that this can reflect the surface current circulation pattern in this area, since the B.S. waters may be traced periodically from north to south in the A.S. region (Fig. 1).

The above considerations are being studied further and a model of ^{137}Cs dispersion based on meteorological and oceanographic data is now under evaluation. Since ^{137}Cs is a soluble tracer with a slow removal time from the water column, it could be used for the prediction not only of the dispersion of radioactive substances, but also of conventional pollutants.

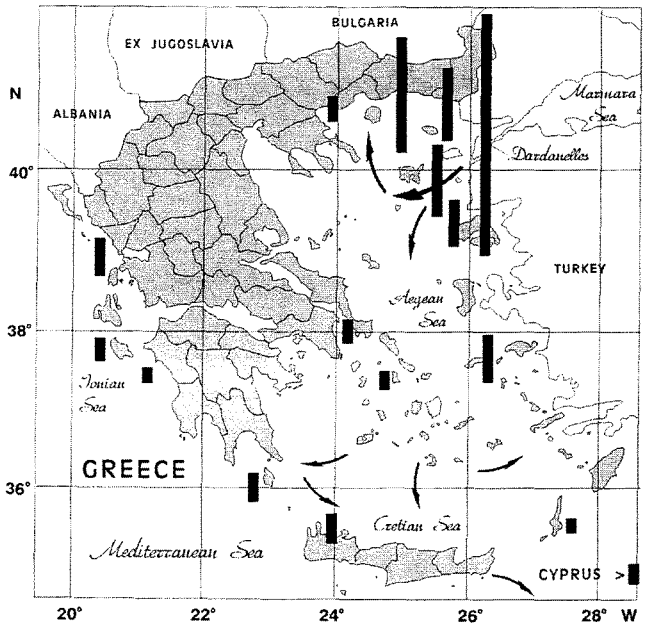

Fig. 1 : Concentrations of ^{137}CS and main directions of surface currents in the Aegean Sea (Florou and Kritidis, 1994; Zodiatis, 1993)

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ASSIMILATION AND RETENTION OF HEAVY METALS AND RADIONUCLIDES IN SEASTARS

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From both ecological and toxicological viewpoints, it is important to understand the transfer and cycling of trace elements and contaminant heavy metals and radionuclides through marine food chains. Studying these aspects in the natural system or using elevated concentrations of the target elements under simulated conditions usually entails greatly perturbing the elemental composition of the water, subsampling from a large population of organisms, and carrying out lengthy chemical separations for eventual elemental and/or radionuclide analyses. The use of high specific activity or carrier-free gamma-emitting radiotracers of these elements circumvents these problems and allows rapid radioanalyses of live organisms or tissues which have been exposed to the contaminants at concentrations more likely to be present in the surrounding waters.

For our studies, we have developed a multi-isotope analytical technique which allows measuring simultaneously seven gamma-emitting radiotracers in the same experimental organisms. Use of this multi-tracer technique reduces inter-experimental variation which occurs between separate treatments labelled with single radioisotopes. This report summarizes results from laboratory radiotracer experiments aimed at quantifying the assimilation and retention of some key heavy metals and radionuclides in carnivorous seastars following contaminant transfer via a typical three-step food chain (phytoplankton - bivalve - seastar).

Carrier-free or high specific activity solutions of the gamma emitters ^{109}Cd, ^{65}Zn, ^{110m}Ag, ^{60}Co (inorganic) and ^{57}Co (cobalamine) were employed in all experiments. In addition, two radionuclides of current interest, ^{241}Am and ^{134}Cs, were also used in the multi-isotope mixture. Mussels (*Mytilus edulis*) were labelled for 96 hours in sea water containing a suspension of phytoplankton cells (*Isochrysis galbana*, 5x10^3 cells/ml) and radiotracers of the selected elements. During this period, the labelling medium was changed every 24 hours. Following the contamination period, the mussels were rinsed and their soft parts removed and counted for radionuclide content. The mussel soft parts were then fed to asteroids (*Marthasterias glacialis*) which promptly ingested the food ration. After radio-labelled feeding, the seastars were periodically whole body counted live over the next several weeks in order to assess excretion rates for the different elements. General experimental protocols, radio-labelling techniques and whole body gamma spectrometric analyses (GeLi detector) of the radiotracers in marine organisms are described elsewhere (GUARY *et al.*, 1982; FISHER *et al.*, 1991; NOLAN *et al.*, 1992).

Assimilation efficiencies of all the elements tested were very high often ranging between 60 and 100% retention of the ingested dose several days after feeding. This was particularly evident for the organic form of cobalt of which 80-100% was retained by the asteroids during the first month of the excretion period. At different times during the experiment, mean percent activity retained was calculated for each radionuclide using 3 to 5 individual seastars, and the resultant excretion patterns examined. In all cases, it appeared that excretion kinetics could be fit to a single exponential model. Therefore, as a first estimation of excretion rates linear regression analysis was applied to the loss curves which extended over a period of nearly 4.5 months. Biological half-lives for radiotracer loss are given in Table 1. In all cases the computed half-times were relatively long ranging from approximately 4 to 100 days. Of particular interest is the long biological half-life of zinc, a biologically essential element active in co-enzyme systems. Although measurements were made for several months, there was some indication toward the end of the experiment that certain elements (e.g. Co org., Zn and Ag) were entering into a much slower loss phase.

Element/ RN	Ag	Cd	Co(in.)	Co(org.)	Zn	^{134,137}C s	^{241}Am
Tb½ (days)	57	47	40	53	101	78	44

Table 1. Biological half-lives (Tb1/2) of selected elements and radionuclides in the seastar *Marthasterias glacialis* following a single ingestion of radiolabelled food.

Other noteworthy features were the enhanced retention of organic Co over the inorganic form (Fig. 1) and the stronger retention of the monovalent radiocaesium compared to trivalent ^{241}Am. This latter observation merits further investigation particularly in view of the many studies which report longer biological half-lives for ^{241}Am than radiocaesium in marine organisms.

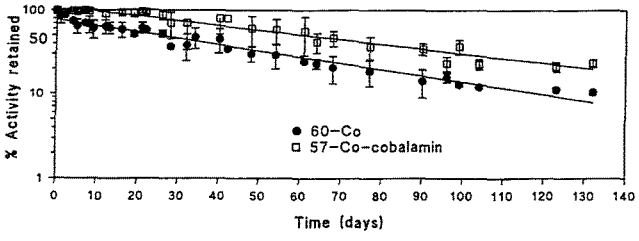

Fig. 1.Long-term excretion of inorganic ^{60}Co and ^{57}Co-cobalamine in seastars following a single ingestion of radiolabelled food. T = 15±1°C; S = 37‰; Bars =±1σ.

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