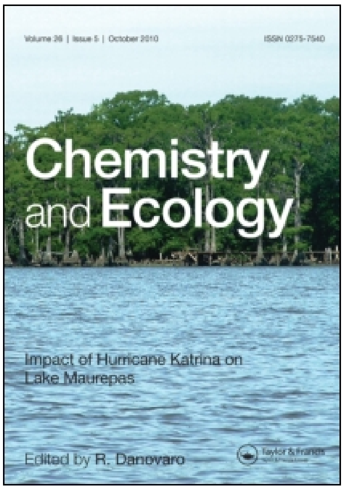

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Vertical Distribution and Inventories of ^{239,240}Pu in Deep Sea Sediments of the Mediterranean Sea (Algerian Basin, Ionian Sea)

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VERTICAL DISTRIBUTION AND INVENTORIES OF ^{239,240}Pu IN DEEP SEA SEDIMENTS OF THE MEDITERRANEAN SEA (ALGERIAN BASIN, IONIAN SEA)

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Deep-sea sediments collected in two areas of the Mediterranean Sea having different sedimentological characteristics have been analyzed to determine present concentrations and inventories of ^{239,240}Pu and to study the main mechanisms controlling them. Plutonium distribution in the deepest part of a submarine canyon (Taranto Valley, Ionian Sea) is compared to that obtained in an abyssal plain (north Algerian Plain). In the latter case, sedimentation is mainly due to the sinking of biogenic particles, while in the former lateral transport of terrigenous material along the slope of the canyon can significantly contribute to sediment accumulation on the bottom.

^{239,240}Pu surface concentration in the canyon ranged from 0.2 to 1 Bq kg^{-1} (dry weight) and this was lower in the abyssal plain. In this area, plutonium was detectable only in the first 4 cm, while in the canyon it was present down to 11–15 cm. ^{239,240}Pu inventories are 3 Bq m^{-2} in the plain and 45–60 Bq m^{-2} in the canyon, indicating considerable input of terrigenous material towards the final part of the Taranto Valley.

KEY WORDS: Radionuclides, plutonium, Mediterranean Sea, sediments.

INTRODUCTION

While a good data set already exists on plutonium levels and inventories in Mediterranean shelf sediments, only few plutonium data are presently available for slope and deep-sea areas. For this reason, selected deep Mediterranean areas having different morphological and sedimentological characteristics were studied, and plutonium vertical profiles and inventories were determined.

In this paper the results obtained for the bottom of the Taranto Valley, a deep submarine canyon in the Ionian Sea, and for an open sea area in the north Algerian Abyssal Plain are reported. The study area and sampling points are shown in Figure 1. The Taranto Valley is a large canyon, reaching a maximum depth of 2200 m. The continental shelf is very narrow and indented by several channels and small canyons, that transport terrigenous materials from coastal to deep areas along the walls of the canyon (Pennetta *et al.*, 1986). Sediment cores have been collected in the central part of the canyon at depths of 1500 m (Station 2) and 2000 m (Station 1A). On the contrary, Station 3 is located in one of the widest depressions of the Western Mediterranean (north Algerian Plain), with an average depth of 3000 m. The whole plain is characterized by the long-range abundant but irregular transport of clastic, turbiditic and emipelagic sediments (Vanney and Jennisseaux, 1985). Recent deposits are mainly due to vertical transport through the water column of biogenic detritus and terrigenous material.

In this paper the influence of morphological and sedimentological factors on plutonium distribution and inventories will be discussed.

MATERIALS AND METHODS

Sediment cores have been collected by a modified Reineck box corer with a wide collecting surface (314 cm^2), to minimize shortening. The cores were sectioned on ship, immediately after collection, in slices 1 cm thick. The central part of each layer was then dried and homogenized.

Aliquots of about 50 g were analyzed for plutonium determination according to the following procedure. After addition of a known amount of ^{242}Pu as yield tracer, samples were ashed in a muffle furnace at 600° C. Sediments were then leached with 8M HNO_3 and plutonium was separated from the matrix by reversed-phase partition chromatography with Microthene – TOPO (Testa *et al.*, 1991). After elution, plutonium was electroplated on stainless steel discs and determined by alpha spectrometry with a surface barrier silicon detector (active area 450 mm^2, 18% counting efficiency).

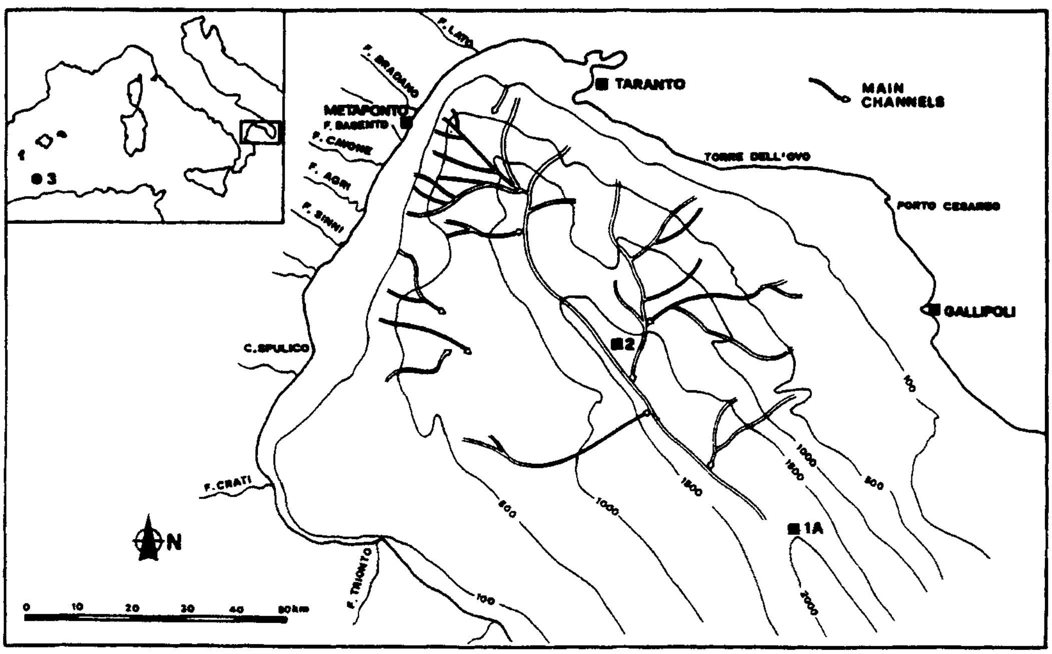

Figure 1 Study areas and sampling points.

In these experimental conditions and with counting times of 120,000–180,000 s, the detection limits for $^{239,240}Pu$ and for ^{238}Pu were 0.012 and 0.021 Bq kg^{-1}, respectively.

The accuracy of the results was checked by analyzing Standard Reference Materials from NIST and IAEA.

RESULTS AND DISCUSSION

$^{239,240}Pu$ vertical distributions in the sediment cores are shown in Figure 2.

The vertical profile at Station 3 (north Algerian Plain) is typical of deep-sea sediments from oligotrophic areas. In fact specific activities of $^{239,240}Pu$ are relatively low (max 0.21 Bq kg^{-1}), close to the lower limits of the values reported for surface sediments of the north Atlantic (0.1–0.7 Bq kg^{-1}) and similar to those found in oligotrophic areas of the northwest Atlantic (Buffoni *et al.*, 1991). The vertical profile shows plutonium activities exponentially decreasing from the surface to depth. In deep sea environments, the sedimentation rate is usually in the order of few centimeters per thousand years. Plutonium, introduced into the environment in the last 50 years, should then be present only in the first few millimeters of sediment. The activity of benthic organisms and the action of bottom currents produce a mixing of surface sediments and the transport of particle associated plutonium to deeper layers. The shape of the profile at Station 3 indicates that this process takes place regularly, but the rate of the mixing is not very intense, as plutonium is only detectable down to 5 cm. This

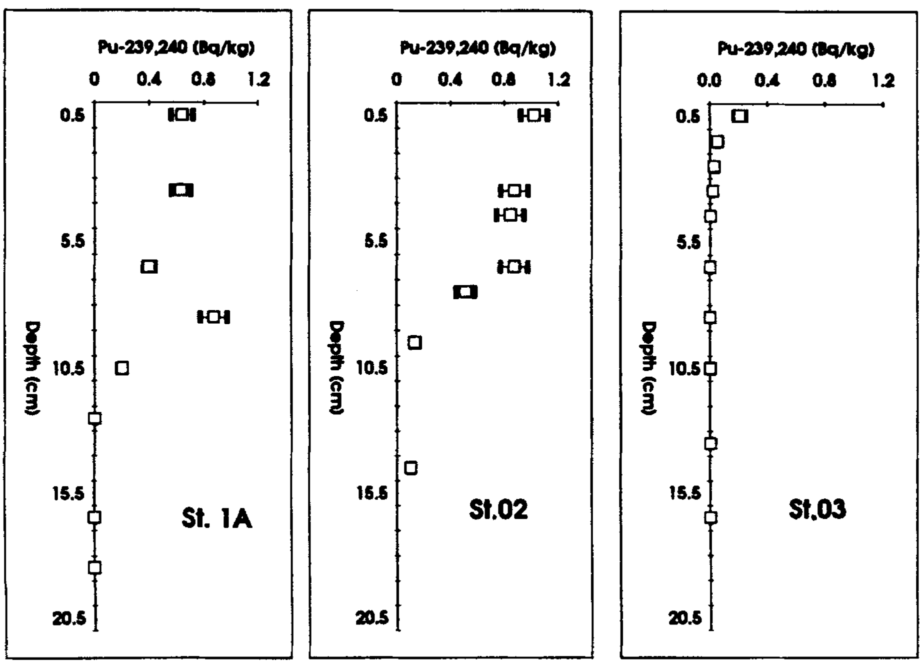

Figure 2 $^{239,240}Pu$ vertical profiles in the Taranto Valley (St. 1A and St. 2) and in the north Algerian Abyssal Plain (St. 3).

situation is typical of oligotrophic areas, where the input of biogenic material is low and the benthic fauna is dominated by mobile detritivor organisms that produce a thin bioturbated layer.

The vertical profiles at Station 1A and 2, located in the Taranto Valley, are significantly different from that found at Station 3. In both cases,

a) plutonium surface concentrations (0.6–1.0 Bq kg^{-1} d.w.) are higher and similar to those typical of shelf and slope areas. In Station 2, ^{238}Pu was also detectable in the first 8 cm. Its concentration is about 40 times lower than that of $^{239,240}Pu$, a ratio similar to that found in fallout from nuclear weapon testing;
b) plutonium activities do not decrease exponentially from the surface to depth, but they are almost constant in the first 7 cm. In the underlying layer, there is a regular decrease at Station 2 and a subsurface maximum at Station 1A;
c) plutonium is detectable down to 15 cm.

The differences between the two environments can be explained having in mind that,

a) the continental shelf of the Taranto Gulf is very narrow and the slope is indented by several small canyons and channels, some of which correspond to river mouths. In these conditions, the particulate matter transported by the rivers and the associated radionuclides can easily be transported to the deep sea, via the channel-canyon system;
b) slumping processes along the walls and hydrodynamic conditions inside the canyon make easier sediment resuspension, thus enhancing the scavenging of particle-associated radionuclides from the water column, resulting in relatively high specific activities of plutonium.

The anomalies in the vertical profiles may be due to slumping along the canyon walls, causing deposition on the bottom of sediment layers characterized by the same content of plutonium. Biological mixing could also be responsible for the observed distributions, but in an area characterized by high environmental energy, physical and sedimentological processes should be prevailing.

The differences between the two environments can probably be better evidenced considering the total quantity of plutonium per unit surface (inventories) in the two areas. The inventories were calculated by summing the total activities of $^{239,240}Pu$ in each horizon divided by the cross-sectional area of the core; plutonium concentrations were interpolated for horizons which were not analyzed. The values obtained are shown in Table I, together with literature data regarding deep areas of the Atlantic Ocean.

Plutonium inventories in the canyon are much higher than those measured in abyssal plains, both Atlantic and Mediterranean. In general, plutonium inventories decrease with increasing water depth. In shelf sediments the inventories are often higher than the cumulative fallout deposition (Buesseler *et al.*, 1985; Delfanti and Papucci, 1988; Gasco *et al.*, 1988). The inventories decrease in deep areas, where the terrigenous input is less relevant. In fact, in the open sea the residence time of plutonium in the water column is much higher than in the coastal zone (Fowler, 1993); in these conditions the fraction of plutonium that reaches the sediment is only a few percent of the cumulative fallout deposition and most of it is still present in the water column. The inventory found at Station 3 is comparable to those obtained in Atlantic areas

Table I Inventories of $^{239,240}Pu$ in sediment cores from the Taranto Valley, the north Algerian Abyssal Plain and some reference areas in the Atlantic Ocean.

Area	*Station*	*Coordinates*	*Depth (m)*	*$^{239,240}Pu$ Inventory ($Bq\ m^{-2}$)*	*Cumulative fallout deposition** (%)*
Ionian Sea	1A	39° 24.09′ N 17° 41.71′ E	1990	58	71
Ionian Sea	2	40° 00.3′ N 17° 15.6′ E	1560	45	55
N. Alger. Plain W-Med.	3	37° 48.7′ N 02° 32.1′ E	2770	3	4
NE-Atlantic		22° 42.8′ N 63° 32.2′ W	5700	1*	3
NE-Atlantic		47° 21.3′ N 19° 42.5′ W	4060	12*	15
NE-Atlantic		31° 24.7′ N 25° 13.4′ W	5265	9*	14

*Buffoni *et al.*, 1992.
**Cumulative fallout deposition at different latitudes after Perkins and Thomas (1980).

characterized, like in the Mediterranean, by low primary production (Southern Nares Abyssal Plain, close to Portorico, Buffoni *et al.*, 1992). The transport of terrigenous material along the walls of the canyon and the enhanced scavenging are responsible for the high inventories in the Taranto Valley.

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