Chernobyl derived radiocesium in marine sediments near the Po River Delta

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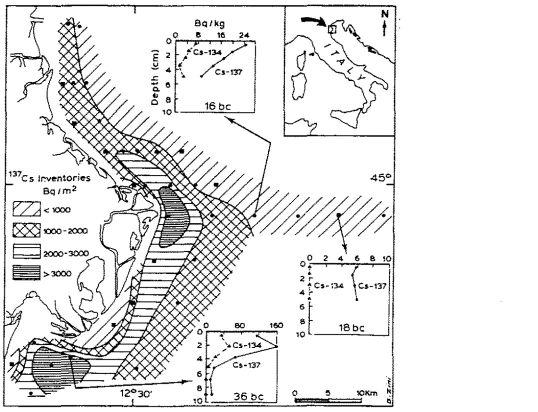
In this paper we discuss sources, concentration and distribution of Chernobyl derived radiocesium in sediments near the Po River delta, in order to establish its usefulness as a tool for studying marine processes, in particular water-sediment interactions, particle transport and distribution. Presently ^{137}Cs is widely used as a stratigraphic marker for determining the extent and rate of sediment accumulation and mixing, especially in conjunction with ^{210}Pb. Nevertheless, many aspects of cesium behavior in the Adriatic coastal environment are still unclear.

Sediment from 35 box cores were collected in July 1987, exactly fifteen months after the accident, at the locations shown in the figure. Sediment was sliced at intervals of 1-3cm, with greater detail in the upper part of the column. Dried material was analysed by gamma spectrometry to obtain ^{137}Cs specific activity. Complete profiles for both ^{137}Cs and ^{210}Pb were measured in thirteen gravity cores (FRIGNANI and LANGONE, 1991; STICCHI, 1990) with the purpose of determining mean accumulation rates for different sites around the delta.

The $^{137}Cs/^{134}Cs$ ratio determined was 2.9-5, compared with respect an original value of 1.9 and a theoretical value of 2.8 after 15 months. Obviously, the highest ratios are typical of samples with a low content of Chernobyl cesium and a significant contribution of the "old" ^{137}Cs. In order to calculate the inventories, a correction was made based on the content of ^{134}Cs and the knowledge of ^{137}Cs activities before Chernobyl, so as to obtain the Chernobyl ^{137}Cs from the measure of the total activity.



Sediment dispersion in the area shows a pattern determined by the cyclonic water circulation system of the Adriatic sea, which causes a prevailing transport southwards. Fine sediments are mostly deposited in 8-30m deep bottoms in the southern part of the study area. In the figure, samples with different lithology are indicated using different symbols (•, mud; ■ muddy sand).

^{137}Cs activities in surficial samples range between 6 and 285 Bq/kg, whereas ^{134}Cs values range from the undetectable to 95 Bq/kg. The figure shows the distribution of inventories, which is very similar to the concentration pattern of the two isotopes. Maximum values are found close to the river mouths of Po delta Pila and Po di Goro, where the materials from these distributors are first deposited. A relatively high concentration is also shown in sediments collected offshore the mouth of the Adige River. Minimums are characteristic of coastal sands and of muddy sands offshore. These results once again confirm that the ^{137}Cs in these coastal sediments was transported by the river from land.

^{137}Cs activity-depth profiles are of three different types (see figure). The ^{137}Cs activities in sample 36bc (type 1) show the typical trend of sediments with relatively high accumulation rates. This is characterized by a sharp peak at 1.5-3cm depth. In all stations with such typical trend a new layer of sediment with a lower cesium concentration was deposited a~er the first contaminating input. In station 36 an apparent accumulation rate in the order of 1.8cm/yr. can be calculated. This value is fairly consistent with a more precise determination previously made on sediments from the same zone (FRIGNANI and LANGONE, 1991). The profile of sample 16bc (type 2) shows a quasi regular decrease from the surface maximum to the pre-Chernobyl value within the first 6 cm. This sample was collected from the distal portion of the Po river prodelta (low sediment accumulation), but the same shape is shown by coarser sediments near the shore. In all these cases the major input of radionuclide is still confined at the sediment-water interface but some downward transport has occurred. This transport can be due either to bioturbation or physical mixing. Penetration of Chernobyl cesium deep into the sediment varies in the area from 0 to about 8cm. The last type is that of box 18bc which as no ^{134}Cs and low and constant values of ^{137}Cs. This means that this sediment did not record the contaminating event, probably because of the very low sedimentation at this site. An erosion event could Ave removed the very low input before sampling. Other intermediate situations with a very low content of Chernobyl cesium were found.

The values of ^{137}Cs inventories are comprised between 338 and more than 16500 Bq/m2. BATTISTON *et al.* (1988) reported a flux from the atmosphere value of about 3500 Bq/m2 for inland stations in Padua for May 1986. We can assume this value as representative for the fallout input over the sea surface, even if we know that rainfall is lower in marine areas. As seen in the map, only four samples show values higher than 3000 Bq/m2. Therefore, since the activity and inventory distributions underline that, in some places, most of the cesium is of riverine origin, transfer from the atmosphere to the sediment is not efficient. This could imply that the interaction between cesium and particles in the marine environment is slow and scarcely efficient.

In a previous paper, FRIGNANI and LANGONE (1991) discussed areal and vertical distribution of radionuclides in NW Adriatic coastal sediments, showing a behavior of ^{137}Cs which seems dominated by river inputs rather than by fallout deposition. The quantification of these phenomena is far from being achieved. It is not even clear, yet, the influence of diffusion and mixing in the formation of the activity depth profile in the sediment. Regarding these problems tentative estimates can be proposed to contrast river input and fallout deposition, and suitable models for the distribution of a pulse input in the sediment column, together with Kd data, are to be used to understand the relative importance of mixing and diffusion on the formation of the activity-depth profile.

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CS-137 and I-131 Distribution in lagoonal and coastal environment of Northern Adriatic

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Radioecological investigations performed in Marano and Grado Lagoons in the years following the Chernobyl accident pointed out the presence of artificial radionuclides in coastal and lagoonal areas of Friuli-Venezia Giulia Region (BELLI *et al.*, 1989). The authors have started a multi-annual program for the monitoring of environmental radioactivity in Northern Adriatic, in order to evaluate the diffusion of artificial radionuclides in areas close to coasts and lagoons between Grado and Punta Tagliamento. This program involves a number of samplings of environmental matrices (superficial sediments, algae, filter feeder, mollusks, macrobenthos, ichtyic fauna) in different seasons. In order to evaluate contamination deriving from Chernobyl accident, Cs-134 and Cs-137 were examined while the evaluation of pollution deriving from medical environment was evaluated through I-131.

40 sampling sites were chosen to determine the main pathways of diffusion of those polluting agents. Some of them were in the final tract of rivers, some in the Lagoons themselves and finally in the marine areas close to lagoonal ores and to Tagliamento and Isonzo mouths. In this preliminary work we report the results obtained from the samples of superficial sediments and algae (Ulva and Gracilaria) collected in the period December 1991-May 1992. Gamma spectrometry was performed on 40 samples of sediments and 41 samples of algae ; radioactivity data were referred to May, 5th 1992.

Figure 1 shows Cs-137 (Bq/kg d.w.) concentrations in samples of sediments. Results allowed to discriminate the following areas :

- river mouths : in these areas the highest concentrations of Cs-137 were detected (Isonzo : 88.1 Bq/kg d.w.; Cormor 74.9 Bq/kg d.w.; Tagliamento 51.8 Bq/kg d.w.), confirming the considerable role played by rivers in the distribution of radiocaesium in the marine environment ;
- Lagoons : higher concentrations were detected in the Marano lagoon, which has more river contributions and lower water exchanges in comparison with Grado lagoon ;
- marine area close to lagoonal ores : this area shows the lowest absolute concentration, ranging from 0.1 Bq/kg d.w. at the lagoonal ore of Primero ;
- external marine area : in this area high values were again detected (up to 69.5 Bq/kg d.w.).

Figue 2 shows I-131 concentration values in Ulva samples. In the western part of the Marano lagoon, in correspondence with mouths of the rivers Stella and Cormor, the highest values of I-131 concentrations were detected. The concentration decreases toward Grado lagoon and lagoonal ores.

Based on the experimental results, the following conclusions can be drawn :

- rivers are the major responsible for transport and distribution of radionuclides in marine environment, as well as for heavy metals, nutrients and micro-organisms. lagoonal environment is quite complex, thus the comprehension of the dynamic of diffusion of pollutants is rather difficult. However, the radionuclide distribution showed in figure 1 practically overlaps with that of some heavy metals analyzed in the same areas (MATTASSI *et al.*, 1991) ; this observation allows the conclusion that radionuclides follow analogous diffusional pathways ;
- Algae are confirmed as biological indicators of radionuclides as well as of conventional pollutants. these matrices allowed to detect the contamination from I-131 at the mouth of the rivers Cormor and Stella, which convey waters coming from Udine and towns nearby.

Monitoring of marine environment thus confirms its validity as an indicator of trace pollutants.

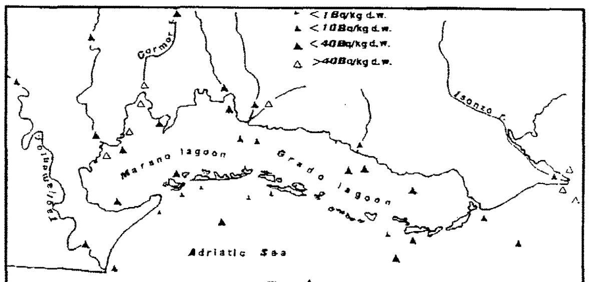

Figure 1

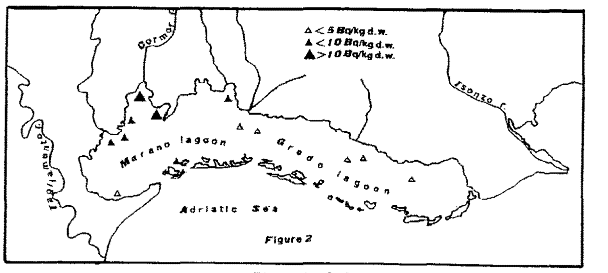

Figure 2

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