FATE OF CHERNOBYL RADIONUCLIDES IN BLACK SEA SEDIMENTS

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Environmental problems in the Black Sea are serious. Following the Chernobyl accident in 1986, the Black Sea riparian countries further identified radioactive pollution as having a high priority. Public concern has been increased by reports of safety deficiencies at some nuclear facilities located in the Black Sea and possible problems related to waste storage (Farby et al., 1993). One of the regions of intensive radioactive fallout during the Chernobyl disaster, when 10^7 Bq of ^{137}Cs was discharged from the reactor (Goldman, 1987), was the Black Sea region to the northwest of Crimea. There are some canyon systems in this region where bottom sediments of the shelf zone are transported to the continental slope region and finally to the abyssal part of the sea. The lack of reliable information on the removal intensity of the shelf sediments, which contain various Chernobyl radionuclides, does not allow changes in the radioactive situation to be predicted reliably enough in the given region. On the other hand, the surface sedimentary layers dated by characteristic Chernobyl fallout make it possible to obtain information on sediment movement rates and directions, as well as other quantitative and qualitative parameters for the mechanisms of canyon processes.

We report here investigations of the energy-and-mass exchange processes that determine propagation of pollution in the bottom boundary layer of the Black Sea. Special emphasis has been placed on possible propagation of Chernobyl radioactive substances via physical mechanisms such as the global circulation, near-bottom gravity and turbidity currents, internal waves, large-scale eddies, and chemical processes in near-bottom layer. One of the key problems has been the modeling of mechanisms of the backward transport of radionuclides during bottom storms from deep water regions toward the beaches and surf zone of the Black Sea. We have investigated the near-bottom density and turbidity current diagnostics and calculation methods for the forecast of these flows on radionuclide transport. Such currents may be catastrophically powerful and may contaminant surrounding waters over tens of meters above the bottom level. The elaboration of current structure diagnostic methods based on the results of spectra analysis of suspended particle size and of current parameter distributions measurements have been performed both in depth and in time. Measurements of the P.P. Shirshov Institute of Oceanology Russian Academy of Sciences expeditions were used for the analysis of the current structures, taking into account the internal waves and eddies on the vertical and longitudinal distributions of the velocity, water density, and sediment concentration with incorporated radionuclides. This experimental base will allow development of diagnostic methods and mathematical models which will then be combined into a general model of the Chernobyl radionuclide fate in the Black Sea sediments.

Present day theory of the bottom boundary layer (BBL) is based on a model with horizontally homogeneous and statistically stationary turbulent currents. However, a real BBL is not stationary. Occasionally there are dramatic velocity increases in the near-bottom current, the so called "bottom or benthic storms" (Weatherly & Kelly, 1985; Kontar & Sokov, 1997). Different eddies above the area studied are supposed to be the cause of the observed events. In the following we suggest that additional mechanisms are needed to explain some observations of bottom storms. The importance of periodic bottom storms springs from the fact that they stir up bottom sediments with incorporated radionuclides, which are then captured and transported over large distances by weaker but stable currents. Some so called "warm" bottom storms are connected with mud flows, forming in the upper horizon of the slopes. This is due to bottom erosion, resulting from creeps of sediment, frequently shaken by local submarine earthquakes (Kontar, 1990). Dimensions of these mud flows were not more than 1.5-2 km.

Some active zones in the Black Sea are the areas of high level exchange between the sea and groundwaters and sediments. They have significant effect on the ecological regime of the Black Sea as a whole and that of in individual regions. Investigation of these active zones is one of the basic aspects of research of the radionuclide distribution in the Black Sea sediments.

The problem is how to find and measure direct groundwater flow into the coastal zone. Prior studies (Burnett et al., 1996) indicate that groundwater seepage is usually patchy, diffuse, and temporally variable. In addition, these studies have shown that radon (^{222}Rn) can be a valuable tracer of direct groundwater discharge. Finding points of discharge is an important first step, especially when contaminated groundwater may be involved. A modeling approach may also be used to estimate quantitatively the volumes of groundwater being discharged.

Although ^{222}Rn in water may be measured reliably by classical methods such as radon emanation techniques, this approach can only provide information about water bodies over limited time periods. Ideally, studies of groundwater discharge would include measurements of dissolved radon concentrations integrated over various periods including time scales of days to weeks. Unfortunately, fine-scale temporal analysis is invariably limited by sampling logistics and time constraints. Therefore, it is desirable to develop a detection system which could be deployed and provide monitoring either in real time, for a rapid site assessment, or moored for a more extended period to provide a continuous record. A few varieties of such an underwater radon detection system, suitable for deployment in the Black Sea coastal zone have been designed at Department of Oceanography of the Florida State University.

The results of measurements of the concentrations of ^{137}Cs and ^{60}Co in the bottom sediments of one of such active zone - the northwestern part of the Black Sea indicate the inhomogenity of their distribution both over the studied area and over the core depth (Domanov et al., 1996). The intermittency of the layers with different concentration of radionuclides in the cores reflects the active horizontal movements and redistribution of sediments on the shelf and continental slope. Using underwater Rn monitoring would help to shed some light on the nature of the predominant patch-like mosaic distribution of radionuclides in the Black Sea sediments.

The results of this study show that the environmental crisis of the Black Sea calls for a concerted international approach and that coordination is critical for the future of various programs addressing these issues. This is the only way to promote sustainable development of efforts towards improved environmental management in the region.

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