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ECOLOGICAL POLICY, ASSESSMENT AND PREDICTION OF THE FATE OF CHERNOBYL RADIONUCLIDES IN SEDIMENTS OF THE BLACK SEA

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The mathematical model has been designed to investigate the fate and distribution of the Chernobyl radionuclides in sediments of the Black Sea. One of the regions of intensive radioactive precipitation during the Chernobyl disaster was the nothwestern Black Sea region. There are some canyon systems in this region, where bottom sediments of the shelf zone are removed 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 different kinds of radioactive precipitation, 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 precipitation made 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. This region was selected for our study. The bottom sediments in this region constitute the permanent repository for material retained by the basin that is derived from the surrounding land mass via the atmosphere, rivers, groundwater discharge and coastal erosion. This includes contaminants, for example heavy metals, organic substances and radionuclides. The results of measurements of the concentrations of ^{137}Cs in the bottom sediments of the northwestern part of the Black Sea indicate the inhomogenity of their distribution both over the studied area and over the core depth. 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. The high degree of variability of the radionuclide activities observed on the shelf is probably due to the very heterogeneous nature of the sediment cover due to erosion and sediment redeposition. Some areas close to the shelf edge appear to be devoid of modern sediment. The bottom boundary layer in this region of the Black Sea has not been studied in detail, although it is known that there are local areas of high rates of sediment transfer due to near-bottom currents, turbidity flows and some other dynamic processes on the boundary between the sea water and the sea floor. Present day theory of the bottom boundary layer is based on a model with horizontally homogeneous and statistically stationary turbulent currents. However, a real bottom boundary layer is not stationary. Occasionally there are dramatic velocity increases in the near-bottom current, the so-called "bottom or benthic storms". Different eddies above the area studied are supposed to be the cause of the observed events. In the following it is suggested that additional mechanisms are needed to explain some observations of bottom storms and mixing processes in the Black Sea. The importance of periodic bottom storms springs from the fact that they stir up bottom sediments with radionuclides incorporated, which are then captured and transported over large distances by weaker but stable currents. Some so-called "warm" bottom storms are connected with lutite 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. There are various approaches for studying the delivery and burial of pollutants in the sea, which were developed in P.P. Shirshov Institute of Oceanology. These approaches were efficiently used for developing the mathematical models. They include determinations of the flux of material from the water column to the sea floor. The materials of the P.P. Shirshov Institute of Oceanology

expedition measurements have been used for the analysis of the current structures, taking into account the internal waves and eddies action on the vertical and longitudinal distribution of the velocity, water density and sediment concentration with incorporated radionuclides. This experimental base allowed approbation of diagnostic methods and above-mentioned mathematical models, which were combined into a general model of the fate of Chernobyl radionuclides in the Black Sea. All the foregoing made it possible to work out a policy and main principles for assessment and prediction of the fate of radionuclides in the Black Sea. The scientificaly-based recommendations for assessing and, mainly, minimizing negative pollution effects on the Black Sea environment have been elaborated, and the approaches to prediction of re-contamination of the coastal zone under different scenarios of climate changes and a growing impact of man-induced factors were worked out. The elaboration baseed on development of the Black Sea-circulation mathematical model tackled by a combined use of radioactive tracers and mathematical modeling of the oceanographic processes. The fluid dynamics mechanisms control the processes of transport and storage of the radionuclides introduced through atmospheric fall-out and river discharge into the Black Sea, including the processes of sedimentation, vertical mixing and geochemical processes in bottom boundary layer (sea water - bottom sediments). We also took into account the processes that could cause a possible backward transport of the pollutants from the deep areas of the Black Sea into the shelf zone. Finally we created a complex mathematical model describing the pollutant behavior from the moment of its input to its output from the ecosystem. This is a step toward the ultimate goal of construction of an ecological model able to give valuable information socio-economic management of the region. Our investigations revealed that the concentration of radionuclides on the Black Sea floor has a patch-like mosaic structure. We used the investigation methods, which include new elements both in the analysis of the natural measurement results and in theoretical interpretations by closure of density currents mathematical models. The density and turbidity current structure theoretical description include four stages: (1) The solution of the hydrodynamic equations for the density current constant in time. This solution gives undisturbed vertical velocity and density distributions. The parameters of these distributions vary in time and along the current very slowly; (2) The solution of the equation system for a model of density or turbidity current. Such a model gives the longitudinal distributions of the velocity and density profiles parameters; (3) The modeling of the vortex-wave distributions field; (4) The description of the current structure as a superposition of the distribution. This superposition includes undisturbed distribution and vortex-wave disturbance profiles in each point and at the corresponding moment of time. The principal possibility and efficiency of such a method has been evaluated during the measurements results analysis. This solution takes into account the simultaneous influence of ambient liquid mobility, turbulent stress profile in stratified medium and the interaction of jet current part with the near-bottom boundary layer. Theoretical distributions describe density and turbidity currents with internal waves in the entire current action field. In the solution of suspended particles diffusion equation, the new turbulent diffusion coefficient distribution - "diffusive triplet" was utilized. On the basis of theoretical solutions and measurements results, the current structure diagnostic method by statistical parameters of suspended particles size spectra was elaborated. As a result of this work scientifically provided recommendations have been elaborated for assessing fate of pollutants in the Black Sea and near-bottom dynamics interaction with the environment in natural and man-induced conditions and also suggestions for monitoring the near-bottom environment, aimed at minimizing negative ecological effects. The results of this work have confirmed once again by research that the Black Sea crisis calls for a concerted international approach and that it is critical for the future of the Black Sea that various programs addressing the Black Sea's environmental problems be coordinated to work together. It promotes sustainable development of efforts towards improved environmental

management in the Black Sea region. The results obtained for the Black Sea can be used in comparable regions of Russia for elaborating a policy, strategy and methodology of predicting the fate of pollution in the sea. Solution of these problems is particularly acute for the new social and economic conditions in Russia.