Using of Caesium-137 for Bottom Sediments’ Accumulation Rates Assessment in the Kuyalnyk Estuary


SUMMARY

Assessment of bottom sediments accumulation rate for two areas of the Kuyalnyk Estuary using radionuclide method. Methodology. Standard methods of sediment core sampling and gamma-spectrometric analysis of radionuclides concentration. Results. Based on the results of the studies of 2016, layer-by-layer concentrations of Caesium-137 and other natural radionuclides were determined. Analysis of vertical profiles of Caesium-137 concentrations enabled us to assess, for the first time, the intensity of sediments accumulation in two areas of the Kuyalnyk Estuary for the periods 1962-1986-2016, which later can be used for indicative dating of anomalies in the profiles of natural radionuclides concentrations. Conclusions. It has been shown that in the lower and middle parts of the Kuyalnyk Estuary average rates of sediments accumulation in 1986 – 2016 made 0.8±0.1 mm/year and 1.8±0.2 mm/year respectively. In 1962-1986 average sediments accumulation rate was practically the same in both parts of the estuary and made 1.9±0. mm/year. Average values for the period 1962-2016 made 1.6±0.1 mm/year and 1.8±0.2 mm/year for the lower and middle parts of the estuary respectively. It has been proposed to perform additional mineralogical studies for more precise dating of the sediment layers accumulated before 1962.
Introduction

Some of the most urgent problems in the current critical state of the Kuyalnyk Estuary are the reduction of water volume and increase mineralization, which lead to negative consequences in the functioning of the biocenosis and the processes of unique medicinal muds formation [Adobovskiy et al., 2012, Loboda and Gopchenko, 2016, Ennan et al., 2014, Medinets et al., 2017]. The main factor contributing to the estuary’s state deterioration, and this opinion is supported by all the scientists, is reduction of water volume in the estuary as the result hydrological regime imbalance because of climate changes and man-made blocking of freshwater inflow from the Velykyi Kuyalnyk River. Another probable cause of shallowing of the estuary, periodically voiced by experts, may be siltation (bottom sediments accumulation in the estuary) as the result of terrigenous runoff. Due to the lack of real experimental data on the intensity of this phenomenon in the Kuyalnyk Estuary, we conducted a special study in the framework of the National research project "To Study the Critical Changes in the Kuyalnyk Estuary Ecosystem and Justify Measures to Stabilize its Environmental Status" (scientific supervisor Prof. Cherkez Ye.A.) The aim of the study was to assess the rate of bottom sediments accumulation in two areas of the Kuyalnyk Estuary with radionuclide method, which was used to establish the individual characteristics of sedimentation and the age of bottom sediments [Gulina and Guinn, 2011, Gulin et al., 2013, 2014].

Methodology

In order to study the speed of sedimentation we took two core samples with undamaged structure on September 15-16, 2016 (Fig. 1): D1, coordinates 46.71311 N, 30.62121 E (from the middle part of the estuary near Kovalivka village) and D2 - 46.57533 N, 30.72405 E (from the lower part of the estuary to the north from sanatorium); position was determined using portable GPS navigator GARMIN GPS-12-XL.

Figure 1 Scheme of cores sampling areas in the Kuyalnyk Estuary: D1 (16.09.2016) and D2 (15.09.2016)

The depth of water layer at the sampling points was 10-15 cm (D1) and - 35-40 cm (D2). The bottom sediments in these areas were represented by black silts covered with a thin crust of gypsum about 5 mm thick. A 1.5 m long plastic pipe with inner diameter of 72 mm was used for sampling.
The pipe was smoothly pressed into the bottom sediments to a depth of at least 60 cm, after which the upper part of the pipe was closed with a sealed plastic cap and the core sample was lifted. After lifting the pipe from the water, the lower part of the pipe was closed with a sealed plastic lid. After the core sample was delivered ashore to a dry area, the first 10 cm of the core were divided into layers every 1 cm, and then from 10 cm to the end of the core every 3 cm using a piston extruder manufactured by the Centre for Environmental Safety LLC. A thin spatula 0.1 mm thick was used as a cutter. Separate samples of the core layers were put into plastic bags and transported to the laboratory of the Centre for Environmental Safety, where, in accordance with the recommendations [IAEA, 2003], they were weighed, dried and placed in special cuvettes for gamma spectrometric determination of Thorium-232, Radium-226, Potassium-40 and Caesium-137 radionuclides concentration. The analyses were performed using gamma spectrometer with spectrometric amplifier BUI-3K, spectrometric processor ATsP-8K-2G, high-voltage power supply BNV-31 and semiconductor detector ORTEC GEM-30185. The gamma-spectrometer was calibrated using volumetric stimulator of the OCH-1 type. Radionuclides Potassium - 40, Caesium - 137, Radium - 226 and Thorium - 232 was determined in accordance with the methodology (MI, 1991) coming out of the energy of gamma quanta with energies: 1460, 662; 186 and 1860 KeV respectively. Processing of gamma spectra and calculations of radionuclides content of in the samples was carried out in accordance with methodology [Danilenko et al, 2017] using the LSRM software. The relative statistical error of gamma spectrometric measurements taking into account the level of the external radioactive background did not exceed 10%.

Results

Analysis of Caesium-137 concentration vertical distribution with depth down the D1 and D2 core samples showed the following. Vertical distribution of Caesium-137 concentrations in the middle part of the estuary (sampling station D1, Fig. 2), was characterized by the presence of maximum values of 47.8-51.4 Bq/kg in the sediment layers at the depths of 3.0-6.0 cm.

Further on in depth the next small maximum of 19.3 Bq/kg was observed in the layer 9-10 cm and then the concentration of Caesium-137 monotonically decreased down to 17 cm depth, after which background values close to detection limit of were observed, which depending on the sample volume the sample ranged from 1.0 to 2.2 Bq/kg.

**Figure 2** Caesium-137 concentration vertical distribution in bottom sediments cores D1 (a) and D2 (b) sampled from the Kuyalnyk Estuary in September, 2016
Keeping in mind the fact that the first maximum of Caesium-127 concentration corresponds to its inflow after the Chernobyl Accident in 1986, it can be stated that the layer of bottom sediments from 3.0 to 6.0 cm, taking into account the diffusion processes in that layer, has formed over the past 30 years and intensity of sediments accumulation over the past 30 years can be estimated in the range from 1.1 to 2.5 mm/year with the average value of 1.8 ± 0.7 mm/year. The next source of Caesium-137 inflow to water bodies in the past is considered to be a series of intense nuclear tests of the 1960s with maximum in 1962, which are used by other researchers [Gulina and Guinn, 2011, Gulin et al, 2013, 2014] in dating of bottom sediments layers. This year corresponds to an increase of Caesium-137 the concentration in the sediment layers from 8 to 20 cm with the maximal depth of 9-10 cm, i.e. the average intensity of bottom sediments accumulation from 1962 to 1986 was 1.9 ± 0.4 mm/year, and for the whole period from 1962 to 2016 - 1.8 ± 0.4 mm/year.

In the lower part of the estuary, (sampling station D2) vertical distribution of Caesium-137 concentrations (Fig. 2) showed a maximum of 17.3 Bq/kg in the sediments layer at depths of 1.0–3.0 cm. It was 3 times lower compared to the D1 core sampled from medium part of the estuary. At the depths from 4.0 to 14.0 cm a small maximum of Caesium-137 concentration was observed (6.03 Bq/kg), which was also 2.7 times less than at the D1 station. Further on the concentration of Caesium-137 was monotonically decreasing to the 14 cm depth, after which background values were observed. Thus, it can be concluded that the layer of bottom sediments from 2 to 4 cm deep in the lower part of the estuary is the layer where Caesium-137 is registered during the last 30 years after the Chernobyl Accident. Hence, taking into account diffusion processes, the intensity of bottom sediments accumulation in the D2 core can be estimated in the range from 0.7 to 1.3 mm/year with average value of 0.8 ± 0.1 mm/year. Estimation of intensity of Caesium-137 deposits originating from nuclear tests in the 1960s showed that the bottom sediments layer containing higher Caesium-137 concentrations in the D2 core was located at the depths from 4 to 10 cm with the maximum at the depth from 8.0 to 9.0 cm, i.e. from 1962 to 1986 (for 24 years) 40-50 mm layer of sediments accumulated, which corresponded to intensity of 1.7-2.1 mm/year with average value of 1.9 ± 0.2 mm/year. Average intensity of sediments accumulation in the lower part of the estuary for the period 1962-2016 is 1.6 ± 0.1 mm/year, which almost coincides with our estimate for the upper part of the estuary.

Thus, it can be stated that the experimentally determined sedimentation levels in the Kuyalnyk Estuary ranged in 1986-2016 from 0.8 to 1.8 mm/year; in 1962-1986 they were almost the same and equallled to 1.9 mm/year, and in 1962-2016 made 1.8 and 1.6 mm/year for cores D1 and D2 respectively. Our estimates agree quite well with the results of other studies for other water bodies and can be further used to establish approximate time for anomalies found in the vertical profiles of concentrations of radionuclides of natural origin along the depth of the cores.

Peculiarity of distribution of Caesium-137 concentrations’ maximum values should also be pointed out. Both 1986 and 1962 concentrations in the middle part of the estuary (D1) were almost 3 times higher than in the lower part (D2), which according to our opinion can be explained by the fact that near Kovalivka village the main contribution of Caesium-137 to bottom sediments happened due to surface runoff and discharge from rivers and beams of the Kuyalnyk Estuary basin, while in the lower part of the estuary the processes biogenic sedimentation could prevail.

High variability of natural radionuclides concentrations’ vertical distribution in bottom sediments and sometimes synchronous changes in their concentrations have led us to examine the correlations between them. Analysis of pairwise correlation coefficients between the series of concentrations of the radionuclides Potassium-40, Radium-226 and Thorium-232 showed that the correlations between them in different parts of the estuary differed significantly.

**Conclusion**

According to analysis of radionuclide concentrations’ distribution with depth in the bottom sediment cores, we had representatively estimated, for the first time in the Kuyalnyk Estuary, the sedimentation
intensities for 1962-1986-2016 in the lower and middle parts of the water body. In 1986-2016 average sedimentation rates were $8 \pm 0.1$ mm/year and $1.8 \pm 0.2$ mm/year in upper and lower parts of the estuary respectively; in 1962-1986 sedimentation intensity of in both parts of the estuary was practically the same and equalled to $1.9 \pm 0.2$ mm/year, while for the entire period from 1962 to 2016 average values for the lower and middle parts of the estuary were $1.6 \pm 0.1$ mm/year and $1.8 \pm 0.2$ mm/year respectively.

In addition, the method of Caesium-137 dating of bottom sediment layers tested by us in the Kuyalnyk Estuary can be recommended to assess the intensity of sediments accumulation in other isolated water bodies in the Black Sea area.

Acknowledgements

The study was carried out in the framework of research activities funded by the Ministry of Education and Science of Ukraine (2015-2016). The authors would like to express their gratitude to the staff of the Regional Centre for Integrated Monitoring and Environmental Studies of Odesa National I.I. Mechnikov University and the Centre for Environmental Safety, LLC for their help in sampling and gamma-spectrometry analyses of bottom sediments.

References


