Short communication

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Modern Sedimentation Pattern in Lake Onego

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ABSTRACT. The spatiotemporal variations of sedimentation processes in Lake Onego were assessed. The quantitative and qualitative characteristics of the suspended matter settling to the bottom and their changes over early diagenesis were determined. The role of bottom sediments in the chemical balance of the lake is discussed.

Keywords: bottom sediments, sediment genesis, Lake Onego

1. Introduction

The aim of this study was to summarize the more than half-a-century long experience of research into the processes of sedimentation in Lake Onego. This challenging task needs to be broken down into units: (1) catchment, (2) water column, and (3) top layer of the bottom sediment. The question for unit 1 is "What comes into the lake?". To answer this, one needs to know the water balance of the lake and the quantitative and qualitative composition of the material coming into the lake from various sources, which are the input parameters for estimating the chemical balance. The question for unit 2 is "What comes into the bottom sediments?". The solution is based on the knowledge of the physical, chemical and biological processes going on in the lake's water column and associated with the transformation of the material coming into the waterbody. The question for unit 3 is "What is buried in the bottom sediments?", since part of the material returns to the water in the process of diagenesis.

2. Material and methods

Lake Onego is the second largest oligotrophic cold-water body in Europe. Its surface area is 9720 km^2, water volume is 295 km^3, average depth is 33 m, catchment area is 53100 km^2, relative residence time is 15.6 years. Suspended matter settling on the bottom was collected by sedimentation traps (staying for 1 year) deployed in 20 sites in the depositional areas of the lake's major regions. Bottom sediments were collected by gravity corers of various designs, permitting the water-sediment boundary to remain intact. The chemical analyses of the water and sediments were carried out at KarRC RAS Northern Water Problems Institute using globally recognized techniques (Hakanson and Jansson, 1983).

3. Results and discussion

The average sedimentation rate was estimated from the lake's chemical balance, taking into account the transformation of chemical elements in the water. The sediment flow into Lake Onego was around 96000 tons. The inputs of the major elements of bottom sediments in dissolved form were 7000 tons of Si, 15000 tons of Fe, 1000 tons of Mn, 4000 tons of Al. For the estimates to include the additional flux to the bottom of the insoluble compounds of these elements, formed through geochemical transformation in the lake water, we introduced the coefficients numerically equal to the lake's retention capacity for these elements as given in papers by N. Kulik (Kulik et al., 2020). The influx of organic matter to the bottom sediments was estimated based on its share in suspended solids at the surface of the bottom sediment and suspended matter in the sedimentation traps. The sediment settling to the bottom of Lake Onego consists of clastic material (imported by river runoff, overland flow, atmospheric transfer), biochemogenic material of inorganic nature (intrabasin processes), autochthonous and allochthonous organic matter. The calculations resulted in the estimate of the total sedimentation load at around 170000 - 190000 tons per year, the bulk of it being silicon (74%), iron (14%), and carbon (8%) compounds. Inorganic material input to Lake Onego bottom sediments is estimated to be 140000 tons per year, of which more than 40000 tons are formed inside the lake. Organic matter inputs to Lake Onego bottom sediments are estimated at 30000 - 45000 tons per year. Thus, over 50% of the material supplied to the bottom sediments is clastic material,

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and some 45% is formed inside the waterbody. The average rate of sedimentation in the lake is 0.2 – 0.4 mm per year.

Lake Onego has a *humus-Fe-Si* type of sedimentation. The lake's recent sediments are oxidized mineral sediments mainly composed of Si, Fe, Al and Mn compounds (Belkina, 2015). Any large body of water with complex basin morphology would feature an uneven distribution of bottom sediments. According to the studies of sediment distribution across the bottom and changes in the chemical composition of the sediments (in the period from 1960 to 2019), Lake Onego falls into 14 large regions: Central Onego, Greater (Bolshoe) Onego, Southern (Yuzhnoe) Onego, Little (Maloe) Onego, Petrozavodsk Bay, Kondopoga Bay, Lizhemskaya Bay, Gorskaya Bay, Unitskaya Bay, Gulf of Povenets, Bolshaya Bay of the Gulf of Povenets, Gulf of Zaonezhye, Kizhi, Velikaya Bay). There are also over 30 smaller bays and bights (Svyatukha, Keften', Chelmuzhskaya, Orov-guba, Perguba, Lumbushskaya, Pinguba, Yalguba, etc.) with specific features of the sedimentation process and, hence, of the material composition of the bottom sediments (Semenovich, 1973; Vasilieva et al., 1999). Proceeding from the analysis of the information about the various sources of matter input to Lake Onego a monitoring network was set up, including the mouths of influent and sources of effluent streams, anthropogenic point sources on the shore and wastewater discharge areas in the lake, depositional areas and bed slopes chosen with regard to the basin morphology, etc. Shore and water areas promising for observations of the bottom sediment formation process were specified for the regions listed above. For the first time, "direct" sedimentation rate observation data were collected simultaneously from different regions of Lake Onego, and the material composition of the suspended matter input to the bottom sediments was studied. The sedimentation rate varied among regions by more than an order of magnitude: 1 mm to 3 cm of freshly settled unconsolidated material or 0.1 mm to 2.8 mm p.a. of compacted sediment (calculated over 20 cm depth). In its chemical composition, the sediment settling to the bottom contained 20-30% more organic matter than the top layer of the bottom sediments. Estimation of the rate of organic matter decomposition in Lake Onego bottom sediments by various methods (based on the concentration gradients of O_2, CO_2 in the water and C_{org} at the water – bed interface, as well as from the C_{org} distribution in the top layer of bottom sediments) showed that depending on the sediment type and storage time this rate ranged from 0.1 mg to 1 g of carbon per square metre, which corresponds to 15000 to 45000 tons of organic matter per year over the period of observations (Belkina, 2011).

4. Conclusions

The process of sediment genesis in Lake Onego at the current developmental stage plays an important role in maintaining the lake ecosystem's resistance to organic and nutrient pollution. The variations in bottom sediment formation among different regions of the lake, which are associated with both natural factors (basin morphology, river runoff, geological and geomorphological characteristics of the catchment, etc.) and uneven distribution of the anthropogenic load, are the background for working out a unique bottom sediment monitoring program for Lake Onego.

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