Short communication

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Paleoecological reconstruction of ecosystem of Lake Imandra (Russia, Murmansk region) based on diatom analysis of sediments

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ABSTRACT. This paper provides information about diatom assemblages in sediments of large arctic reservoir (Lake Imandra). The distribution of the taxonomic composition and structure of diatoms for several centuries has been studied. The periods and causes of changes in the state of the lake ecosystem are determined, and a conclusion about future trends is made. The data obtained can be used for monitoring the ecological state of the environment and water bodies.

Keywords: diatoms, sediments, paleolimnological reconstruction, Arctic, anthropogenic influence

1. Introduction

Lake Imandra is one of the largest Arctic water bodies with major socio-economic importance. The reservoir is used as a source of technical and drinking water supply, as well as for recreation, tourism and fishing. A number of industrial enterprises are located in the catchment area, including Kola nuclear power plant on a direct-flow cooling system, mining, metallurgical and chemical production. It is necessary to understand the long-term trends of ecosystem transformation for the rational management of natural water resources and water quality control, which can help minimize the negative consequences of anthropogenic impact. To solve these problems, diatom assemblages (DA) in sediments are studied, which are a sensitive and reliable indicator of environmental changes. Based on the study of DA, we assessed the changes in the state of the lake ecosystem over the past centuries, both before and after the start of intensive anthropogenic load.

2. Materials and methods

We used two sediment cores from the Bolshaya and Jokostrovskaya Imandra stretches (Bol.I and J.I) as materials for the study, 37 and 57 cm long, were divided into layers of 1 cm each. We prepared samples according to the standard method (Juze et al., 1949; Davydova, 1985), with some modifications developed at Institute of the North Industrial Ecology Problems (Sandimirov et al., 2019). After laboratory processing of samples, taxonomic identification of diatoms to the lowest taxonomic-level was performed using a microscope “Motic BA 300”. Further analysis included our calculation of the relative abundance (by percentage) of taxa in DA, identification of dominant and subdominant species and analysis of the environmental characteristics of the identified diatoms (Barinova et al., 2006). Taxonomic information was checked against the current, regularly updated global algae database (Guiry and Guiry, 2022). Our taxonomic data have been included in the patented database “Algae of the Euro-Arctic region” and in the herbarium of INEP (Borovichyov et al., 2018). Based on the data obtained, the saprobity and Shannon-Weaver species diversity indices, and pH value were determined. To interpret the obtained materials, we used data on sedimentation rates based on the distribution of radionuclides (^{210}Pb, ^{137}Cs) and on the chemical composition of sediments.

3. Results and discussion

DA in sediments were studied in the deepest conditions of two stretches (Bol.I and J.I) experiencing direct anthropogenic influence.

We have identified 275 diatom species belonging to 64 genera in the sediments of Bol.I stretch. Diatoms in the core mostly belong to typically freshwater, planktonic forms that prefer a close to neutral or slightly alkaline habitat. Mass species in almost all analyzed sediment layers are represented by the taxa *Pantocsekiella comensis, Aulacoseira pusilla, P. rossii, Cyclotella bodanica* var. *lemanica, P. schumannii* and *Tabellaria flocculosa*. Radically new subdominants

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A. islandica, Stephanodiscus minutulus and *Cyclostephanos dubius* appear only in the surface layer. Analysis of the distribution of diatoms, indicators of species diversity, pH and saprobity, as well as concentrations of chemical elements in sediments identified the stages of development of the Lake Imandra ecosystem and their periods. The studied sediments was accumulated for *ca.* 200 years. It shows the "pre-industrial" state of the ecosystem in the deepest layers. Changes in the state of the ecosystem was coincided with the beginning of the development of industry in the catchment area of the lake (1910-1935) and with the modern stage, including the last decades. In the first case, there is no radical restructuring of DA, but the species diversity decreases and the number of species increases. In the second case, there is an appearance of new dominant groups, a trend towards an increase in pH and saprobity index, accompanied by an increase in concentrations of toxic and biogenic elements in sediments.

Studying the sediments of the J.I area, we found 262 taxa of diatoms belonging to 68 genera. Diatoms in the core, similar to the previous core, are mostly typically freshwater, planktonic forms living in a neutral or slightly alkaline environment. Mass species in analyzed sediment layers are represented by the taxa *P. comensis, A. pusilla, P. rossii, P. schumannii* and *Lindavia radiosa*, and the number of all these species decreases in the surface layers to compared with deeper ones. In these layers, including the upper 9 cm, new dominants and subdominants *Aulacoseira islandica, S. minutulus, S. Alpinus, A. subarctica, Cyclostephanos dubius* and *T. flocculosa* appeared. The studied sediments was formed for *ca.* 300 years, showing the "pre-industrial" state of the ecosystem in the deepest layers. Abrupt changes in the state of the ecosystem in this area also were coincide with the beginning of the development of industry (1915) and with the current stage, when the maximum increase in production capacity in the lake's catchment area took place in the last 50-60 years. In the first transitional stage, there is also no radical restructuring of diatom complexes, but species diversity decreases, the ratio of dominant species changes, there is an increase in trophic level on the reservoir, expressed in an increase in the saprobity index and concentrations of biogenic elements, as well as concentrations of metals. In the second stage, there is a sharp change in the dominant groups of diatoms and the appearance of new species, an increase in pH and saprobity, and the achievement of maximum concentrations of toxic and biogenic elements in sediments.

4. Conclusions

1. Changes in the composition and structure of diatom complexes of both studied sites occurred during the development of industry, and the most significant transformations have been observed in the last half century.
2. Ecosystem in the central part of the Bolshaya Imandra is less transformed than in the Jokostrovskaya Imandra transit zone, where wastewater from non-ferrous metallurgy and apatite industry enterprises enters. Radical changes in the Bolshaya Imandra have been observed only in recent decades, and new species are just emerging, but have not yet completely replaced the "natural" species.
3. Ecosystem transformations are continuing at the present time, and with the preservation (or increase) of the intake of biogenic and toxic compounds into the reservoir, the situation may approach that observed in previous studies (Vokueva and Denisov, 2020; 2021) in the area of direct impact of the non-ferrous metallurgy and apatite industries (Moncheguba and Belaya Bays).

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Conflict of interest

The authors declare no conflict of interest.

References

Barinova S.S., Medvedeva L.A., Anisimova O.V. 2006. Bioraznoobraziye vodorosley-indikatorov okruzhayushchey sredy [Biodiversity of algae-indicators of the environment]. Tel Aviv: PiliesStudio. (in Russian)

Borovichyov E.A., Denisov D.B., Kornejkova M.V. et al. 2018. Herbarium of INEP KSC RAS. Trudy Kol'skogo Nauchnogo Centra RAN [Proceedings of the Kola Science Center of the RAS] 9(9-6): 179-186. (in Russian)

Davydova N.N. 1985. Diatomovyye vodorosli - indikatory prirodnykh usloviy vodoyemov v golotsene [Diatoms as indicators of Holocene lake environments]. Leningrad: Nauka. (in Russian)

Guiry M.D., Guiry G.M. 2022. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. URL: http://www.algaebase.org

Juze A.P., Proshkina-Lavrenko A.I., Sheshukova V.S. 1949. Diatomovyy analiz. Kniga1 [Diatom analysis. Book 1]. Moscow-Leningrad: Gosudarstvennoe izdatel'stvo geologicheskoj literatury. (in Russian)

Sandimirov S.S., Kudryavceva L.P., Dauvalter V.A. et al. 2019. Metody ekologicheskikh issledovaniy vodoyemov Arktiki [Methods of ecological research of Arctic water bodies]. Murmansk: Publishing house of MSTU. (in Russian)

Vokueva S.I., Denisov D.B. 2020. Using diatom assemblages of surface sediments to assess the current state of large Arctic lakes. Trudy XVII Fersmanovskoj nauchnoj sessii GI KNC RAN [Proceedings of the Fersman Scientific Session of the GI KSC RAS] 17: 84-88. DOI: 10.31241/FNS.2020.17.016 (in Russian)

Vokueva S., Denisov D. 2021. Diatom assemblages in surface sediments of Lake Imandra (Russia, Murmansk region). Polish Polar Research 42(4): 249-268. DOI: 10.24425/ppr.2021.137147