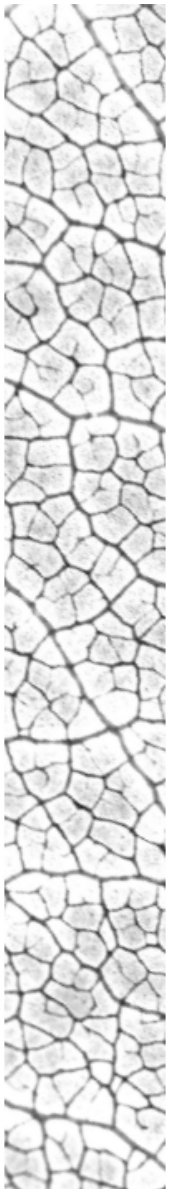

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Macrofauna of hydrobionts in the Gubkinsko-Starooskolsky mining area: the case of the Oskolets River

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Abstract
The areas of iron ore mining and processing are characterized by a high level of anthropogenic load. Among them is the Starooskolsko-Gubkinsky mining area of the Belgorod region. A certain indicator of the influence caused by mining enterprises on the adjacent territories is the state of hydrobiocenoses in surface watercourses located in the zone of their direct influence. The Oskolets River was adopted as a model; its middle reach is located in close proximity to the Lebedinsky mining and processing plant (LMPP), from where the drainage waters of the quarry are discharged. The aim of the work was to differentiate the contribution of this enterprise to the general pollution of the river using bioindication methods. According to Roshydromet (Federal Service for Hydrometeorology and Environmental Monitoring of Russia), analysis of the channel water in the river sections higher than the LMPP and in the Stary Oskol town of shows that among pollutants, MAC is exceeded for sulphates, ammonium, nitrites, copper, petroleum products, phosphates and iron. The more detailed analyzes we have carried out at the sampling works confirm this data in general. At the same time, the LMPP increasing the content of certain pollutants in river water dilutes them with drainage waters. The total water flow somewhat changes the river channel characteristics, locally reduces the accumulation of bottom sediments, the content of suspended and dissolved organics, which is expressly determined by the presence and ratio of indicator species of macrofauna.

Keywords: Lebedinsky mining and processing plant, Oskolets River, macrofauna of hydrobionts, pollution, channel data

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INTRODUCTION

The transformation processes of the river network in the Belgorod region the most intensively occur in the mining areas of the Kursk Magnetic Anomaly (KMA), which makes it important to study the hydroecological situation in these territories.

The catchment area of Oskolets River is located in Starooskolsko-Gubkinsky mining area of the Belgorod region. It is characterized by a high level of anthropogenic load on the part of such enterprises as Joint-Stock Company Lebedinsky Mining and Processing Plant (JSC LMPP), Open Joint-Stock Company Stoilensky mining and processing plant (OJSC SMPP), and the "KMA ore" plant (KMAOP)]. The urban areas of the Gubkin and Stary Oskol towns, and, in part, agricultural production also make their contribution to the anthropogenic pollution. The length of the river is 40 km. The catchment area of Oskolets River makes about 494 km^2. The prevailing width of the river in its greater extent does not exceed 10 m, the depth is 0.4–0.8 m (and more in some places) (Geographical Atlas ... 2018). The floodplain in the survey area is open, meadow, with willow, poplar and maple thickets along the banks in some places; the current changes between calm, moderate and increases to very fast (in places of a narrowed channel). The coasts are mostly flat.

In recent years, with the development of the regional infrastructure and an increase in the production capacity of enterprises, the wastewater volumes drained in the Oskolets River from the Lebedinsky mining and processing plant have increased.

MATERIALS AND METHODS

The methodological framework of hydroecological studies in standing and running continental water habitats were established in the late XIX-early XX centuries (Kolkwitz and Marsson 1908, 1909, Westerlund 1890) and developed in the second half of the 20th century, first in Central Europe, and later in

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Fig. 1. Layout of hydrobiont locations in the Oskolets River in 2012 and 2018
Designations: - inventories in 2007, 2012 and 2018; - inventories in 2012; - hydrochemical analysis in 2007-2018

Eastern Europe, including Russia (Fedorov and Kapkov 2000, Margalef 1964, 1987, Schwoerbel 1970).

The material was collected according to generally accepted methods (Fasulati 1971, Golub et al. 2012).

Identification of the collected material was carried out according to the determinants of the series developed by the Zoological Institute of the Russian Academy of Sciences and other determinants of invertebrates in the European part of the USSR (Mamaev 1972, The determinant of insects ... 1964, 1965, 1987, The determinant of freshwater bionts ... 1977, Determinants of aquatic insects ... 1994–2004).

Ecological characteristics of species are specified in accordance with recognized and regionally adapted guidelines (Chertoprud 1999, 2007, Fyodorov and Kapkov 2000, Margalef 1964, Meyer 1987, Prisny et al. 2018, Shitikov et al. 2003).

Studies were conducted in the spring-summer, summer and summer-autumn periods (7 stations, 11 points) (see **Fig. 1**): 0) the Kandaurovo settlement (4 km west of Gubkin); 1) the Gubkin town, lower than the municipal sewage discharge of Vodokanal Municipal Unitary Enterprise (2 survey points); 2) discharge-2 of drainage water; 3) the mid-point of the mining facility location zone (3 survey points) – higher than the drainage discharge-1; lower than the second discharge; drainage discharge -1; 4) the exit of the river from the mining facility location zone, the Peschanka village, a “beach”; 5) the Peschanka village, lower than the ethanol plant and the feed yeast plant; 6) the western outskirts of the Stary Oskol town (microdistrict Sokovoe); 7) lower reach section in the Stary Oskol town.

The calculation of the saprobity level was made according to the formula: $S = \Sigma n * i / N$, (Prisny et al. 2018).

Plankton sampling was performed using a plankton net by filtering through 100 litres of water. Plankton was fixed with 4% formalin solution.

RESEARCH RESULTS

The published data on the hydrobiont composition in the Oskolets River, including the ichthyofauna, appeared a little more than ten years ago and are associated with studies commissioned by Lebedinsky mining and processing plant LLC (Silina 2008, 2011, Silina and Kostylev 2008, Silina and Prisny 2012). The surveys were carried out with high-quality fishing gear in various parts of the river in the territory of the Gubkinsky and Starooskolsky urban districts, from the Kandaurovo village (higher than the Gubkin town) to the Peschanka village (lower than the Gubkin town) in 2007 and 2018 and to the Stary Oskol town in 2012

Changes in the regional industrial sector affect the dynamics of hydrochemical indicators of river water. Thus, according to the Federal Service for Hydrometeorology and Environmental Monitoring of Russia (Roshydromet), the content of pollutants in the Oskolets River in the period from 2008 to 2018 did not exceed the maximum allowable concentrations for magnesium, chlorides, nitrates, zinc and nickel at observation points (the river section-1 - 0.7 km higher than the Gubkin town, the river section -2 - 9 km lower than the Gubkin town, the river section -3 – city Stary Oskol (points 0, 1, 6 in the figure). At the same time, in different river sections and in different periods, there was an excess of the maximum allowable concentration (MAC) for some pollutants: for sulphates, ammonium, nitrites, copper, petroleum products, phosphates and iron. Our analyses which were more detailed in the sampling points, generally confirm these data. Upon that, LMPP increases the input of certain pollutants to the river water and simultaneously dilutes them with drainage waters.

In the indicated period of studies, the excess of the maximum allowable values of biochemical oxygen consumption [BOC $_5$] at the river sections in 2008–2018 was: 1 - by 3–227%; 2 - by 4–127%; 3 - by 50–102%.

We have also carried out the more detailed hydrochemical analysis in water samples from pints 0, 1, 2, 4, 6 (see **Fig. 1**).

As in previous studies (Kornilov and Kolmykov 2006, Kornilov et al. 2009, 2010, 2013), they confirm the ambiguous nature of the influence of the largest mining enterprise in the Belgorod Region on the hydroecological state of the nearest running water habitat.

In 2007, a total of 117 aquatic invertebrate species were collected and determined. This made it possible to make a preliminary conclusion about the continuing high species and ecological diversity of hydrobiont macrofauna in the Oskolets River and about the significant impact of technogenic and household discharges on the composition, diversity and abundance of invertebrates.

The total number of identified taxa of animals in the samples collected in 2012 was 175, including 60 of not previously reported. Of these, 37 species were characterized by bioindicative properties on the level of saprobity, and 56 on the hydrological regime of water reservoirs. In 2018 the number of such taxa was only 52. In the list of species noted in 2018, there are 11 species that were absent in previous studies.

In 2007 the greatest species diversity of benthos organisms was found in the points located higher than the Gubkin town, before entering of the municipal effluent into the river channel; the minimum diversity was observed below the Lebedin village and gradually increased again to the point in the Peschanka village. From this, we can conclude about the relatively weakly pronounced influence of mining areas on the hydrobiont fauna during this period, which is compensated to the Peschanka point by wastewaters of the ethanol plant and the fodder yeast plant.

In 2012, the situation has changed markedly. Below the Gubkin town and up to the drainage discharge, the species diversity of benthos organisms is much higher than in previous surveys, and immediately downstream the discharge, the diversity falls sharply to its minimum values. A similar fall in this indicator is observed below the next drainage discharge. Below the ethanol plant discharges, it increased as in 2007. The decrease in the benthos species diversity downstream the discharges can be explained by a complex of reasons: a washout of plankton, stagnophiles and parts of rheophiles downstream; a decrease in the content of dissolved and suspended organics in water, the redistribution of bottom sludge accumulations and, possibly, a certain effect of drainage water discharges. In 2018, the trends on changes in the hydrobiont diversity at the recording points that appeared in previous years continued.

Water content and the general level of saprobity in the Oskolets River in 2007 are less than in 2012; therefore the reaction (decrease of this indicator) to the discharge of drainage water is sharper. But in 2007 and in 2012 there was a decrease in saprobity up to the Peschanka village. In 2018, a similar dynamics of the saprobity level, with its overall decrease on average in points 1–5 by 0.13, was also observed. At the same time, the decrease in the index began at the second discharge of drainage waters, and the recovery began downstream the discharges of the Peschansky ethanol plant and the fodder yeast plant containing dissolved and suspended organics.

The conditions in which hydrobionts live reflect their environmental standards. The generalization of such characteristics makes it possible to compile the characteristics of the water reservoir at sampling points, and throughout the watercourse as a whole for rivers. The following are the characteristics for the Oskolets river in the area from the Gubkin town to the Stary Oskol town based on the analysis of 70 species of hydrobionts (see **Table 1**).

For most fish species that live in the Oskolets River, the state of benthos and plankton determine the feeding capacity of the water body. In 2012, compared with 2007, with a general increase in the content of organic substances in water, an increase in the diversity of benthos organisms and epibioses and the density of zooplankton, the food supply of fishes living in the Oskolets River has improved. In 2018, the levels of saprobity decreased, which led to a significant decrease in the diversity, abundance and biomass of plankton and benthos in certain sections of the river and, as a result, to the deterioration of the food supply for fishes there. At the same time, a slight increase in the water content of

Table 1. Characteristics of the Oskolets River watercourse by the occurrence of indicator species (with the specification of the pro rata contribution (%) of hydrobiont species)

Survey points (as text)			Oskolets River from the Gubkin town to the Stary Oskol town
1	2	4	
Clean, standing and sluggish water bodies (5.5%)	Clean perennial standing and sluggish water bodies (20%)	Clean standing, sluggish and running perennial water bodies (26.1%)	Various perennial water bodies: streams, rivers, ponds; clean and polluted (32.4%) Small perennial standing and semi-flowing water bodies, overgrown backwaters (52.9%) Water bodies with unstable level and perennial water bodies (8.8%) Various water bodies with abundant detritus and sludge (5.9%))
Perennial and intermittent standing and running water bodies, incl. with an unstable level (55.6%)	Perennial and intermittent small standing and sluggish water bodies: streams, rivers, ponds, overgrown areas (52.0%)	Perennial and intermittent standing and running shallow water bodies, overgrown areas (39.1%)	
	Standing and sluggish shallow water bodies (20%)	Standing and sluggish shallow water bodies (17.4%)	
Shoals of perennial and intermittent water bodies with abundant detritus and sludge (38.9%)	Shallow reservoirs with abundant detritus and sludge (8.0%)	Shoals of water bodies with abundant detritus and sludge (17.4%)	

the river in the sluggish sections improves the habitat for the fish.

RESUME

The composition and structure of the community of benthos organisms, epibioses and plankton allow us to distinguish 3 river stretches: to the border of the Gubkin town – the Lukyanovka village – the section from the quasi-natural state of the watercourse to the place of influence of sewage and discharges from the Gubkin town; from the point “Discharge 2” to the point “Peschanka, the beach” - the site of the direct influence of the drainage water discharge; from the point “Peschanka, the beach” to the mouth - the integrated influence site of the drains from the Peschansky dry fodder yeast plant, drains and discharges from the Stary Oskol town. The hydroecological and hydrological situation in the Oskolets River is gradually improving throughout the course from the Peschanka village to the boundary of the Stary Oskol town and the influence of the drainage water discharge on it cannot be isolated from the general complex of factors.

CONCLUSIONS

1. The hydrobiont macrofauna very precisely reflects the hydrological and ecological characteristics of the river and can be fully used in similar studies.

2 The composition and abundance of the hydrobiont fauna in the Oskolets River indicate a slight impact of Lebedinsky MPP on it in the hydrochemical aspect, but more significantly in the hydrological and, as a result, in the environmental aspects.

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