Ecological monitoring of water quality in the Bystraya Sosna River

Roman Polyakov[1], *Tatjana* Petrisheva[1*], and *Irina* Usacheva[1]

[1]Bunin Yelets State University, Yelets, Russian Federation

Abstract. Monitoring studies of the ecological state of small rivers occupy a leading position in the system of environmental protection. This paper provides a detailed analysis of the chemical and microbial indicators of the state of the Bystraya Sosna River in the Lipetsk region of the Russian Federation. The connection of environmental indicators for different seasons of the year is carried out. This made it possible to determine the range of potential hazards for the object under study and to predict the most favorable scenario for the development of this ecosystem.

1 Introduction

The ecological state of small rivers is one of the priority areas of our time. A detailed analysis of the ecological state of rivers makes it possible not only to assess the level of their pollution and to take timely measures to restore the ecological balance [1]. Rivers, as active water bodies, are capable of self-purification, and the assessment of this parameter also serves as an indicator of the well-being of these objects [2]. At the same time, it is important to assess the degree of chemical pollution, since it is these substances that have a direct impact on the biota of the ecosystem [3], which often acts as an indicator of the degree of pollution of water bodies [4-5].

The Bystraya Sosna River is one of the small rivers flowing in the territory of the Lipetsk region of the Russian Federation. The length of the river is almost 300 kilometers, and the basin area is just over 17 thousand square kilometers. Residents use the river for swimming and recreation, as well as for fishing. The well-being of nature protection zones and their biodiversity is associated with the functioning of the river [6].

Recreational water use includes the use of water bodies for swimming, sports and recreation of the population. Water quality requirements established for recreational water use apply to all sections of water bodies located within the boundaries of populated areas (clause 5.1.2. SanPiN 2.1.5.980-00).

Following paragraph 2.5 of the Rules for the Protection of Surface Waters - "in the case of the simultaneous use of a water body or its section for various needs of the population and the national economy, the most stringent standards from among those established are imposed on the composition and properties of water." As modern experience shows, such water bodies are subject to the most stringent requirements - fishery MPCs (maximum

* Corresponding author: senc-tatyana@yandex.ru

permissible concentration of a substance in water). The assessment of the effect of chemical pollutants on aquatic biota [7, 8] and the identification of the quality of water treatment [9] are especially relevant. Therefore, in the future, in relation to the Bystraya Sosna River, MPCs will be considered both for recreational waters and for fisheries.

To conduct environmental monitoring of water quality in the Bystraya Sosna River, we evaluated the main regulated parameters: oxygen content, chemical analysis, acidity, microbial analysis. Microbial analysis makes it possible to assess the ecological well-being of a given water system and correlate data on microbial contamination of water with the degree of eutrophication, which has a certain impact on human health [10].

2 Materials and methods

Sanitary and hygienic laboratory studies of the Bystraya Sosna River were carried out in three different places along the river in different seasons: Lebedyansky Bridge, Lavsky Bridge and Karakumovsky Bridge. To evaluate the results, restrictions were applied for two types of MPC: for recreational (MPCw) and fishery waters (MPCf). The number of samples at each sampling point is 50 per season. The studies were carried out during 2022.

Analysis of chemical parameters was carried out by spectrophotometry, titrimetry. The oxygen content was measured by manometric method using OxiTop.

The analysis of the microbial contamination of the object was evaluated by the standard method of microbial inoculation on elective nutrient media (Chapek's medium, Saburo's medium, Endo's medium, meat-peptone agar).

3 Results

The acidity pH of water determines its natural properties and is closely related to other quality indicators. For example, the pH level determines the growth intensity of iron bacteria, affects the efficiency of coagulation and water disinfection processes. The maximum permissible values of water acidity in the test samples should be close to the value of 8.5 units. At all points of sampling, the samples correspond to the norm.

In parallel with the level of acidity, we evaluated the content of dissolved oxygen and BOD5. Estimation of the level of dissolved oxygen in waters makes it possible to estimate their level of pollution with organic matter [9]. The corresponding indicator of water quality, which characterizes the total content of organic substances in water, is called biochemical oxygen demand (BOD). The determination of BOD is based on measuring the concentration of dissolved oxygen in a water sample immediately after sampling, as well as after sample incubation. Samples are incubated without air in an oxygen bottle, in the absence of lighting and at a constant temperature of 20°C. Usually BOD is determined for 5 days of incubation (BOD5), however, the content of some compounds is more informatively characterized by the value of BOD for 10 days or for the period of complete oxidation (BOD10 or BODtotal, respectively).

For the indicator of dissolved oxygen, the following standards are established: for MPCv not less than 4 mg/dm^3, for MPCf not less than 6 mg/dm^3. When analyzing the content of dissolved oxygen by season, at all sampling points, the values were above the limit set by both types of MPC.

When assessing the level of biological oxygen consumption, the data for all sampling points were obtained within the limits of the MPCv with a limit of 4mgo2/l. Deviations were found in the analysis of biological oxygen consumption in the spring at the sampling points: Lebedyansky and Karakumovsky bridges. Exceeding the MPCf in this case is observed in the range of 0.2 and 0.6 mg O_2/l, respectively.

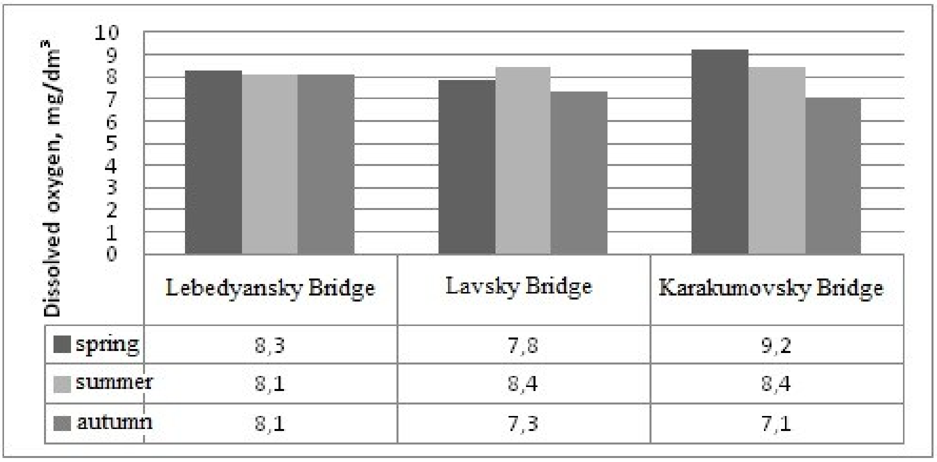


Fig. 1. Seasonal Dynamics of Dissolved Oxygen Content in the Bystraya Sosna River.

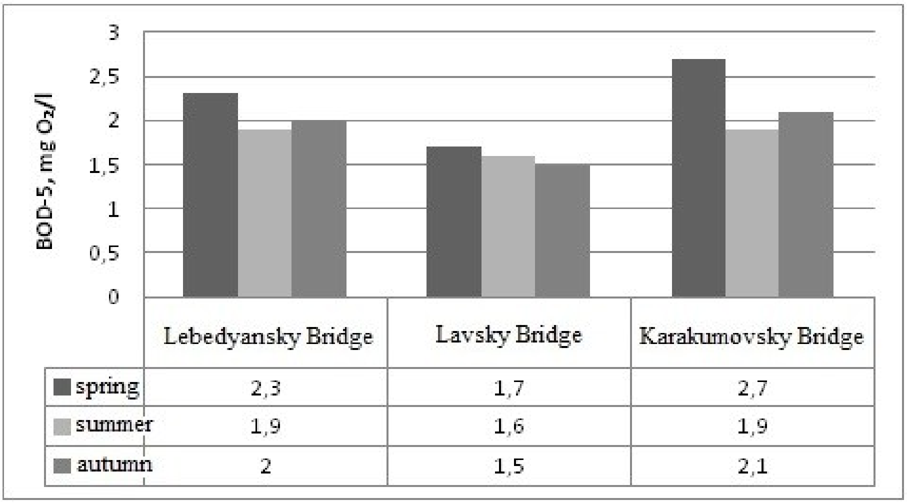
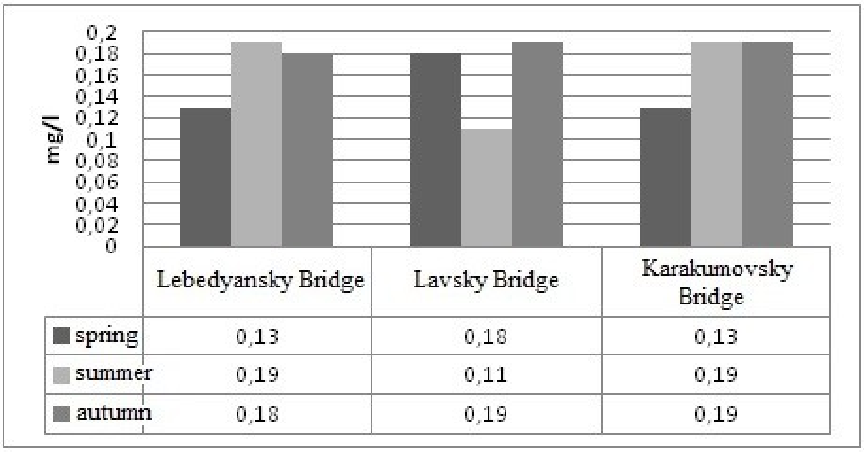


Fig. 2. Seasonal dynamics of biological oxygen demand in the Bystraya Sosna River.

Water pollution with oxidizable organic substances is also assessed by the chemical oxygen demand (COD) indicator. This indicator is especially informative in identifying oil pollution. The samples taken by us at all sampling points met the standards and were significantly lower than the declared maximum allowable concentrations. The level of chemical oxygen demand varied from 3.8 to 7.4 mg/l compared to the norm of 30 mg/l. In the chemical analysis of the presence of oil products in the samples, the results showed a direct relationship, their concentration was much lower than the hole and did not exceed 0.016 mg/l. This fact indicates the absence of oil pollution in the river and a favorable forecast for this indicator.

The Bystraya Sosna River flows near a number of settlements, crosses one of the largest cities in the Lipetsk region, so the necessary indicator is the content of heavy metals, nitrates and nitrites. The content of iron in the waters leads to a significant decrease in their quality characteristics, induces changes in the microflora, increases the layer of silt with a predominance of iron bacteria. The water of the river Bystraya Sosna meets the standards applied to the waters of recreational areas, but significantly exceeds the MPC values for fisheries (0.1 mg/l). Similar data were obtained when detecting manganese content. The high content of iron and manganese in the waters adversely affects the health of humans and animals, so their maximum content should be significantly lower in the waters of fish farms compared to recreational ones.

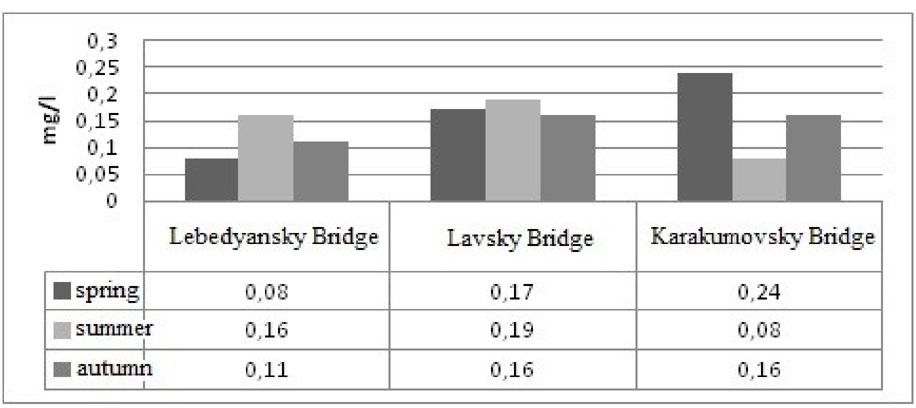


	Lebedyansky Bridge	Lavsky Bridge	Karakumovsky Bridge
spring	0,13	0,18	0,13
summer	0,19	0,11	0,19
autumn	0,18	0,19	0,19

Fig. 3. Total iron content in the Bystraya Pine River by seasons.

One of the indicator indicators of the level of pollution of water bodies is the quantitative analysis of nitrogen compounds. Nitrogen can be present in water in the ammonium, nitrite and nitrate forms, which act as successive stages of the mineralization of nitrogen-containing organics. High ammonia levels may indicate fresh organic contamination.

When analyzing the content of ammonia, it was found that for MPCv and MPCf, the values of 1.5 mg/l and 0.05 mg/l, respectively, were set. It can be seen from the above measurements that all values correspond to MPCv, but completely violate the established MPCf.



	Lebedyansky Bridge	Lavsky Bridge	Karakumovsky Bridge
spring	0,08	0,17	0,24
summer	0,16	0,19	0,08
autumn	0,11	0,16	0,16

Fig. 4. Dynamics of ammonia content in the Bystraya Sosna River.

Nitrite nitrogen is an intermediate in the biological breakdown of ammonia/ammonium. In the presence of oxygen (aerobic conditions), autotrophic bacteria convert ammonia into nitrates.

Nitrate is a more oxidized form of nitrogen. Autotrophic bacteria convert ammonia to nitrite, which then converts to nitrate under aerobic conditions. Bacterial reduction of nitrates under anaerobic conditions can lead to the formation of nitrites.

Nitrites and nitrates, which are part of the nitrogen cycle in the environment, are nutrients and a very important source of nitrogen for plants and complex organisms that consume them. Nitrate ions, made up of oxygen and nitrogen, form naturally in the soil. Since nitrites readily oxidize to nitrates, they are often found in surface waters. Excess concentrations of nitrites and nitrates can adversely affect water treatment processes and pose a health risk. High levels of nitrates in the water may indicate that there is biological waste in the final stages of stabilization, or that fields with a lot of fertilizers have generated runoff water. Treated effluent with a high content of nitrates, discharged into fresh water, can degrade water quality by stimulating excessive growth of algae [10]. Drinking water with excessive amounts of nitrates can cause methemoglobinemia in children (manifested as cyanosis). Nitrates contaminate anaerobic zones, resulting in degradation in biological phosphorus removal systems. Due to the presence of nitrites, the effectiveness of chlorine disinfection systems is reduced. The content of total inorganic nitrogen in treated wastewater contributes to a decrease in the quality of receiving water [9].

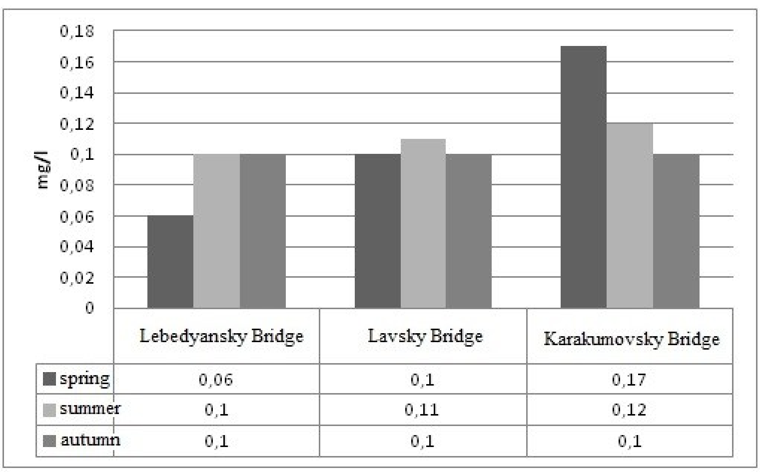


Fig. 5. Measurements of nitrite concentration in the Bystraya Pine River.

Turning to MPCv, it can be seen that the obtained nitrite values do not exceed the limit of 3.3 mg/l. But in relation to MPCf with a limit of 0.08 mg/l, only in one case - spring in the area of the Lebedyansky bridge, the value is satisfactory. At other sampling points, the content of nitrites significantly exceeds the maximum allowable standards. This indicates an active process of mineralization in the waters of the river. Fast Pine. This is evidenced by the indicators of the content of nitrates, which were normal at all sampling points.

In addition to the elements listed above, the concentrations of other substances in the river were measured. Fast Pine. However, either the obtained values of concentrations are orders of magnitude lower than the established MPCs, or they are too small to have any effect on the water body. These elements include

Chromium +3 (concentration less than 0.025 mg/l, MPCv - 0.05 mg/l, MPCf - 0.02 mg/l), Chromium +4 (concentration less than 0.025 mg/l, MPCv - 0.5 mg/l, MPCf - 0.07 mg/l), cyanides (concentration less than 0.01 mg/l, MPCv - 0.07 mg/l, MPCf - 0.05 mg/l), thiocyanides (concentration less than 0.02 mg/l, MPCv - 0.1 mg/l, MPCf - not established.), AS (concentration less than 0.025 mg/l, MPCv - 0.5 mg/l, MPCf - 0.5 mg/l), phenol (concentration less than 0.0005 mg/l, MPCv - 0.001 mg/l, MPCf - 0.001 mg/l).

When assessing water quality, microbial indicators are also taken into account: the total microbial number and the number of enterobacteria. When assessing the total microbial number, the water quality can be assessed as moderately polluted, the titer at all sampling points ranged from $3x10^3$ to $7x10^3$, and the coli-titer corresponded to the value of $1x10^3$. Among the microflora, bacterial prevailed. Microscopic fungi were sown in small quantities, mainly representatives of the genera Aspergillus spp., Penicillium spp.

4 Discussion

The presence of oxygen in the aquatic environment is the most important indicator of ecosystem stability. A decrease in the level of oxygen in the aquatic environment is possible with the growth of carbon-containing biomass for the destruction of which a sufficiently large proportion of this gas is consumed. An increase in the share of organics is facilitated by anthropogenic pollution, including oil products, waste from pulp and paper production, nitrogen-containing organics, etc. At the same time, a decrease in the oxygen level leads to an increase in the proportion of anaerobic organisms due to a decrease in the number of aerobes. And anaerobic microorganisms, often decomposing organic matter or participating in other bioorganic transformations, synthesize toxic metabolites at the same time. So, for example, the substances indole, skatole, cadaverins released during the transformations of the nitrogen cycle under anaerobic conditions negatively affect the biocenosis as a whole. The obtained data on the oxygen content in the aquatic environment indicate the absence of oil pollution of the object under study.

The content of most chemical indicators (the content of orthophosphates, sulfates, heavy metals, cyanides, thiocyanates) did not exceed the maximum allowable standards, which indicates a slight impact of technogenic pollution on this object. This is due to the location of the Bystraya Sosna River far from large industrial plants, as well as the presence of treatment facilities and compliance with environmental standards in the region of the experiment.

The elevated background of ammonium and nitrite compounds causes concern, which indicates the presence of organic pollution. Probably the source of this type of pollutants was the agro-industrial complex, which borders the river basin zone. However, the revealed low level of nitrates indicates the initial stage of self-purification of the reservoir. The revealed level of nitrites suggests that this pollution will be eliminated without additional inclusion of anthropogenic influence.

The seasonal dynamics of the content of the analyzed parameters was practically not revealed. An insignificant correlation was found only for the content of nitrates, which increased by autumn in all variants. This may be due to the seasonal increase in the amount of nitrogen-containing organics and the biomass of nitrifying microorganisms. This is also evidenced by the seasonal increase in the total microbial number from spring to autumn. The coli-titer practically did not change. An increase in the level of the microbial pool and nitrite pollution indicates the need to control pressure from the agro-industrial complex.

5 Conclusion

In the course of the study, it was found that the Bystraya Sosna River can be classified as moderately polluted according to most of the studied water indicators. This water quality corresponds to the norms of recreational waters. However, according to a number of indicators (the content of oxygen, ammonia, nitrite, iron, manganese), this object cannot be classified as a fishery. To improve the water quality of the facility, additional purification and reduction of the agrogenic impact near the located territories, which can be a source of this type of pollution, is necessary. It is also necessary to carry out further monitoring work and expand sampling points for the purpose of detailed control over the preservation of the ecological state of the river, stabilization of parameters that do not meet the standards.

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