Geoecological screening of the state of small and medium-sized river basins to assess the impact of measures for the operation of hydraulic structures

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Abstract. The relevance of the work is due to the annual increase in anthropogenic load on components of geosystems of basins of small and medium rivers. The paper proposes an integrated approach to solving the main problem using a combination of classical and modern methods of analyzing natural systems - the screening method. This paper notes the need for screening control during the implementation of measures for the operation of hydraulic structures to assess the current state of catchment basins of small and medium-sized rivers, which includes the forecast of possible changes in the components of geosystems under the influence of anthropogenic load in order to prevent, minimize or eliminate negative environmental and related socio-economic and other consequences and maintain optimal living conditions for the population. Solving the problem using the screening method will make it possible to better analyze the state of catchment areas, in particular, the basins of small and medium rivers with a high anthropogenic load, which will make it possible to promptly identify environmental risks that have a negative impact on the components of geosystems and take more effective measures to eliminate them. The development of a methodology for screening control will make it possible to comprehensively assess the impact of anthropogenic factors on the geoecological state of the catchment area of the Osetr river, to study the current ecological state of the study area, identify the main factors of impact, as well as assess the degree of pollution, zone the study area according to the degree of anthropogenic load, and develop a geoecological passport for the catchment area of the Osetr river.

1. Introduction

A catchment basin is a system of landscape formations that differ in structure and function and are combined with a landscape aquatic ecosystem. There is a close relationship between the geographic structure of the catchment area and the functioning of the hydrographic network.

Small and medium-sized rivers reflect the ecological state of the environment and determine the hydrological and hydrochemical characteristics of large rivers, which makes them vulnerable to overexploitation of both water resources and drainage basins.

When developing a methodology for assessing the geoecological situation of small river basins, which significantly react to any anthropogenic impacts within the catchment area, N. P. Karpenko noted that the catchment areas of medium-sized and small rivers had become the subject of special attention due to the high degree of their transformation as a result of anthropogenic activity [1].
In their works on the geocological analysis of the catchment area of a small river as exemplified by the Ugra basin (Levin, 2007); geocological assessment of the state of small watercourses in the Kaliningrad region (Nagornova, 2012); assessment of the impact of the development of the catchment area of the Verkhnyaya Sukhona River (Vologda region) on the chemical composition of the waters of its tributaries (Ivicheva, Filonenko, 2017); the influence of diffuse pollution on water bodies (Ratkovich, Markin et al., 2016), the authors indicate that medium-sized and small rivers have a lower capacity for self-purification and are more prone to pollution, as a result of which their ecological state deteriorates. At present, the anthropogenic impact on river basins, catchment areas and directly on water bodies is growing very rapidly, which is associated with the high growth rates of cities and the developing industry, agriculture, an increase in transport networks and transport itself, which leads to a change in the quality and functioning of aquatic ecosystems.

Long-term operation of surface and underwater structures of hydraulic structures on small and medium rivers has a significant impact on the catchment basin and the natural environment as a whole, with subsequent positive or negative effects.

I. S. Moiseev, V. V. Malakhianov, Yu. P. Lyapichev note in their works on studying the experience of designing and building earth dams, classifying the states and criteria of the operational reliability of hydraulic structures and hydrological and technical safety of hydraulic structures, that the safety of hydrosystems, especially small ones, decreases due to unreliable initial data for assessing the environmental situation at the site of work. One of the significant results of the influence of hydraulic structures on the catchment basin is a change in the hydrological regime of rivers and formation of conditions for the qualitative composition of water [2–4].

In this regard, it becomes necessary to carry out activities for integrated environmental monitoring and geocological assessment, which will make it possible to trace changes in water quality in the basins of small and medium-sized rivers and determine their impact on larger water bodies and draw up a picture of anthropogenic impact in general. For geocological assessment of the catchment areas of small and medium-sized river basins, an integrated approach to solving the main problem using a combination of classic and modern methods of analyzing natural systems is proposed.

River catchment area screening is a comprehensive method for assessing the components of geosystems. The application of the "screening" method will allow one to obtain an objective assessment of the geocological situation in the studied catchment area, as it will provide an opportunity to better analyze the state of the catchment areas, in particular the basins of small and medium rivers with a high anthropogenic load, which will make it possible to quickly identify environmental risks that have a negative impact on the components of geosystems, and take more effective measures to eliminate them [5, 6].

Adam, Begun, Dmitriev et al. (2016); Dmitriev, Kupressov, Ledovskaya, Romanenko (2018) note in their works on substantiating the methodology of screening control of hydrosphere objects to detect accidental oil spills and the use of screening methods for environmental monitoring of hydrosphere objects, that this approach will reveal the excess of a given normative (or background) determined parameter of a water body, information about which is possible to obtain remotely in real time, as well as through additional research of selected samples in the laboratory, to analyze data on the state of water bodies for a certain period; identify the causes of pollution and factors affecting its distribution, and predict the state of water bodies in different phases of the water regime, before and after various emergencies.

The main goals of geocological screening are: to classify (zone) the sites according to the degree of anthropogenic load on the environment of the water catchment, taking into account the indicators of the state of the environment in the territory of the method implementation; to determine the contribution of anthropogenic sources of pollution; to find out how pollutants enter the water body; to describe environmental problems, at solving of which the project is aimed; to determine characteristics of possible changes in the state of the components of geosystems, etc. [5, 6].
2. Materials and methods
The development of a screening method for obtaining an objective assessment of the geoecological situation in the studied catchment area of the Osetr river basin is based on long-term monitoring data for the period 2015-2020, scientific concepts, regulatory documents, statistical and cartographic materials of the Federal Service for Hydrometeorology and Environmental Monitoring, the Ministry of Ecology and Nature Management of the Moscow region, the Administration of the Zaraysky district, Ryazanproekt LLC, RusHydro, the company "Shooting from the air", "MOSEKOMONITORING", analytical laboratories "Meshchersky Scientific and Technical Center" and "EcoCenter", Federal Agency for Water Resources, Federal Forestry Agency, etc.

The work is based on methods for calculating complex indicators (water pollution index, specific combinatorial index of water pollution); analysis of the environmental risk of anthropogenic impact; assessing the anthropogenic load on river ecosystems, taking into account their regional characteristics (point-rating method); methodological recommendations for the development of unified integrated survey programs for catchment areas, waterworks and drinking water MR 01-19 / 52-17 and Earth remote sensing data [7-13].

Geoecological studies will be carried out on the basis of analysis of samples of water, soil, bottom sediments and bacterioplankton taken from different parts of the Osetr River catchment area.

The territory of the catchment basin of the Osetr river within the Moscow region from Serebryanye Prudy settlement to Akatevo settlement was taken as the studied area. The middle and lower section of the Osetr river from Zaraysk settlement to the mouth zone of the river (the area where it flows into the Oka River – Akatevo settlement) was taken as a screening site.

3. Results and discussion
Osetr is a river in the European part of Russia, in the Moscow, Ryazan and Tula regions, that is classified as an average river in length and catchment area and is one of the largest southern tributaries of the Oka river.

Studies of the current state of the territory of the catchment area of the Osetr river are of great importance, both in theoretical and practical aspects, and are becoming more relevant due to the growth of anthropogenic load. Due to the fact that in the study area in the middle and lower river course of Osetr (from Zaraysk settlement - Vlasyevo settlement - Akatevo settlement) there are no gauging stations or there is the least number of gauging stations operating year-round, a significant problem arises for monitoring surface waters. Early studies led to the conclusion that, like many other small and medium-sized rivers in the region, the Osetr river is highly sensitive to anthropogenic impact, which is due to a number of reasons associated with hydrological and natural-climatic characteristics, namely: relatively small volumes of runoff, low self-cleaning ability, dependence of the water regime on climatic and weather conditions, etc. [7,10-13].

The main sources of pollution in the river basin are industrial enterprises, utilities, agricultural land, transport, whose effluents are insufficiently treated and contain a large amount of pollutants. In addition, industrial enterprises dump garbage and household waste in water protection zones, ravines and gullies.

Despite the lack of study of the river Osetr basin, some issues require complex generalization and further solutions. The most problematic for Osetr is the content of organic pollution (according to BOD₃), biogenic elements (nitrite ion), suspended solids and some metals. A significant concentration of chemical pollutants falls on the lateral inlet. The degree of water pollution of the Osetr river is characterized as high, which is due to the violation of the existing standards for 5 ingredients. Long-term operation of the surface and underwater components of the structure of the Zaraisk dam has no less significant impact on the natural environment [2-4, 7, 12, 13]. Due to the absence or gross violations of the rules for the operation of the dam, the low efficiency of measures to ensure public safety, an incompetent assessment of the expected flooding zones, poor engineering training during the construction of the dam, etc., the long-term operation of the structure led to the wear of the dam structures by more than 70% [7, 8]. An equally important aspect is the lack of design documentation
for the majority of owners, which determines an increased interest in the problem and makes it difficult for specialists to assess the safety of hydraulic structures according to the established class of structures. Measures for the reconstruction and operation of hydraulic structures have a significant impact on the components of geosystems with subsequent positive or negative consequences [2-4,7, 8].

According to the Administration of the Zaraysk District and Ryazanproekt LLC, during the reconnaissance survey, it can be noted that no critical violations in terms of environmental indicators, including assessment of radiation, chemical, sanitary-epidemiological and physical risk factors, were found. Monitoring of interaction of the hydraulic structures with the environment is of great importance for taking urgent measures, if necessary, to prevent undesirable effects or to mitigate them. The composition of monitoring studies is determined on the basis of an analysis of specific aspects of the impact of hydraulic structures on the environment [7, 8].

The study is aimed at a comprehensive geocological study and assessment of anthropogenic impact on the catchment area of the Osetr river. The development of a methodology for screening control will make it possible to comprehensively assess the impact of anthropogenic factors on the geocological state of the catchment area of the Osetr river, study the current ecological state of the study area, identify the main factors of impact, as well as assess the degree of pollution, zone the study area according to the degree of anthropogenic load and develop a geocological passport for the catchment area of the Osetr river [5, 6].

Complex geocological monitoring, analysis and assessment of the catchment area, changes in the hydrographic network and water content of the Osetr river will be conducted using Earth remote sensing data, modeling data and ground measurements.

To assess the quality of water in the screening and study areas, the following parameters will be determined: water temperature, pH value, electrical conductivity, turbidity and color, dissolved oxygen content, ionic composition, mineral and general forms of nitrogen and phosphorus, concentrations of heavy metals, oil products and organic substances. The measurements will be carried out by the following laboratory-field methods: high performance liquid chromatography (HPLC), atomic absorption spectrometry, potentiometry, fluorimetry, spectrometry, gas chromatography with mass spectrometric and flame ionization detection [9].

To assess the level of eutrophication of a water body, to determine the ability to self-purification and, as a consequence, to calculate the proportion of anthropogenic load, in accordance with the methods used in hydrobiological studies, a laboratory study of the main significant representatives of the phytoplankton community (Bacillariophyceae, Cyanobacteria) will be carried out. It is planned to determine the concentration of heavy metals and oil products in the bottom sediments [14].

Sampling and assessment of the qualitative state of soils are planned to be carried out at the screening site at the boundaries of the zones of sanitary protection zones, taking into account local topographic conditions and wind rose for non-specific, specific and microbiological indicators in accordance with MR 01-19 / 52-17.

The resulting geocological models (schematic maps) of changes in the natural environment are supposed to be implemented in the form of GIS-oriented maps.

Based on the proposed methods and approaches for processing and analyzing the data obtained, a geocological passport of the catchment area of the Osetr river basin will be created. A geocological passport of a water body is a document reflecting the ecological state of a water body in accordance with generally recognized water protection standards and requirements for recreation areas to ensure the functioning of ecological well-being, forecasting eco-crisis situations and early warning of environmental hazards when assessing the state of a water body [15, 16]. A geocological passport of the catchment areas of small and medium-sized rivers contains comprehensive information on the current state of nature and anthropogenic impact and can be used to assess and compare the characteristics of different basins. Studies on the creation of a geocological passport include complex hydrological-hydrochemical, hydrobiological, ecgeochemical, radiation, landscape-ecological and sanitary-bacteriological surveys, as well as data from long-term field measurements using GIS.
technologies and mathematical modeling [15, 16].

4. Conclusion

Studies of the current state of the catchment areas of small and medium-sized rivers are of great importance, both in theoretical and practical aspects, and are becoming more relevant due to the increase in anthropogenic load.

Small and medium-sized rivers, as close as possible to consumers, reflect the ecological state of the environment, determine the hydrological and hydrochemical characteristics of large rivers, which makes them vulnerable to excessive use of both water resources and catchment basins.

This research is aimed at a comprehensive geocological study and assessment of anthropogenic impact on the catchment area of the Osetr river.

Early studies led to the conclusion that, like many other small and medium-sized rivers in the region, the Osetr River is highly sensitive to anthropogenic impact, which is due to a number of reasons associated with hydrological and natural-climatic characteristics, namely: relatively small volumes of runoff, low self-cleaning ability, dependence of the water regime on climatic and weather conditions, etc. For example, the long-term operation of the surface and underwater components of the Zaraisk dam structure led to the wear of the structure by more than 70%, which significantly affected the natural environment [2-4,7,8].

In this regard, the development and application of the screening method will make it possible to obtain an objective assessment of the geocological situation in the studied area of the catchment area of the Osetr river basin, since it will provide an opportunity to better analyze the state of the catchment areas, in particular, the basins of small and medium rivers with a high anthropogenic load, which will make it possible to promptly identify the occurrence of environmental risks that have a negative impact on the components of geosystems, and take more effective measures to eliminate them.

With an annual increase in anthropogenic load on the components of the geosystems of small and medium-sized rivers basins, the creation of a geocological passport for a catchment basin using a screening approach that takes into account a comprehensive geocological assessment of anthropogenic impact on the catchment area of the Osetr river basin is an urgent land management and water management task in solving issues of sustainable development of the territory.

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