Geoecological assessment of the state of water bodies in the Irtysh river basin within the Omsk region

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Abstract. The ecologically successful development of the watershed is determined by the ability to resist external pressures exerted by natural and anthropogenic factors. The state of the drainage basin and its resistance to external influences is determined by the natural resource potential, the value of heat and moisture supply and the quality of water in water bodies. An urgent problem of our time is the deterioration of the quality of land surface waters as a result of anthropogenic impact, which in turn has a negative impact on the ecological state of the basin. The article assesses the ecological state of the catchment basin of the Irtysh River within the territory of the Omsk region. For river basins, the main environmental parameters of nature management are determined, calculated taking into account the modern technogenic load. Conclusions and corresponding recommendations are formed to improve and preserve the environmental sustainability of natural systems of existing river basins.

1 Introduction

The first Basin of the transboundary Irtysh River, starting from the eastern part of the Altai Mountains [1], extends within China, Kazakhstan, and Russia. Flowing through the territory of large industrial cities of the republics, on the one hand, the river solves the important task of providing water to the sectors of the national economy, on the other hand, it is subjected to a colossal anthropogenic load. In this regard, it is obvious that a careful attitude to the resources of the Irtysh and its catchment area is a guarantee of uninterrupted water supply to all water consumers of the three states that meet their water needs from the riverbed.

The Irtysh river enters the territory of the Russian Federation at about 53.5 degrees' north latitude and does not have a single tributary for about 200 km before the confluence of the Om river. Located in the southwestern part of the West Siberian Lowland, the catchment area has a characteristic flat relief and appropriate climatic conditions. Within the region, the natural conditions of the catchment area vary from steppes in the south, forest-steppe in the middle part to the forest zone in the north of the territory.

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In hydrological terms, the flow of the rivers of the Irtysh river basin within the Omsk region is mainly formed in the spring due to the precipitation of the cold period [2]. Depending on the water content of the year, this indicator averages from 60 ... 90% of the annual value. Thus, according to the nature of the water regime, the rivers of the territory are classified as rivers with spring-summer floods and floods in the warm period of the year. Also, the rivers of the territory are characterized by significant runoff variability both within the year and over a long period (figure 1).

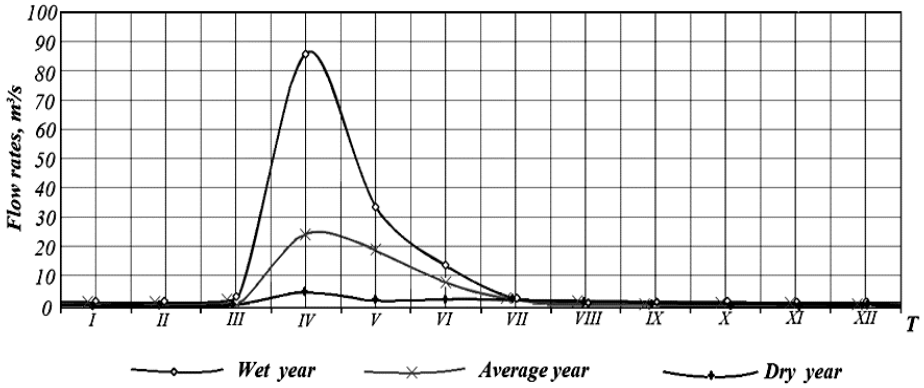

Fig. 1. Hydrographs of runoff in years of different water content of the river. Bolshoi Aev near Bolshie Uki alignment.

2 Materials and methods

Despite the sufficient volume of runoff in the whole region, at the present time there are often problems associated with a lack of water. This is primarily due to the natural variability of natural processes involved in the formation of surface runoff. Water resources, as is known, are a derivative of the interaction of heat and moisture resources, which in turn are components of the heat and power and water balances [3].

A wide variety of natural and climatic conditions of the Irtysh river basin determines the different levels of formation of runoff resources. Figure 2 shows diagrams of the distribution of water balance characteristics for two river basins in the study area.

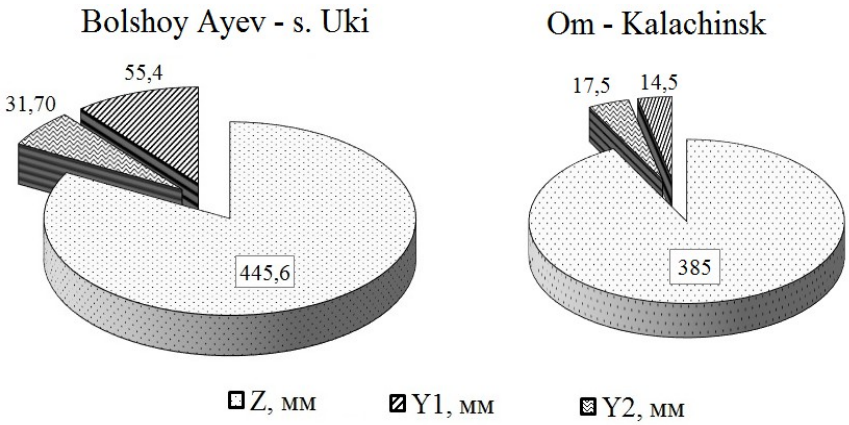

Fig. 2. Water balance elements: Z – evaporation, mm; Y1 and Y2 - surface and underground runoff, mm.

In addition to natural factors, the runoff variability is significantly affected by the production and economic activities of water consumers and water users. Such activities include water abstraction from water bodies, irretrievable water consumption, wastewater discharge, as well as various types of flow regulation and agro-forest reclamation measures within the catchment area of river basins.

For various reasons, the volume of runoff use in the basin varies from year to year [4]. For example, fresh water withdrawals from all sources in 2021 decreased by an average of 23% compared to the previous year. The volume of consumption of the largest water consumer, household water supply, in 2021 decreased by 35.4%, and the volume of water disposal, respectively, by 26.1% compared to 2020.

An important indicator of the ecological well-being of water bodies is the quality of water, therefore, the actual problem of our time is the deterioration in the quality of land surface waters. Among the main pollutants of water bodies in the study area are enterprises of the chemical industry and housing and communal services, which have a negative impact not only on water quality, but also worsen the general ecological condition of the basin. An objective representation of the ecological state of water bodies makes it possible to make the right decisions on their effective use in a timely manner [5].

3 Results

To assess the ecological state of water bodies within the Irtysh River basin, studies were carried out on the main environmental characteristics of nature management, such as the natural resource potential of river basins, the numerical values of the ecological technological intensity of the territory, the maximum permissible technogenic load, as well as parameters characterizing the general ecological state of the natural system according to signs of its sustainability.

The natural resource potential of the territory [6] implies the amount of natural resources that can be used in the production and economic activities of individual territories. It is the natural resource potential that is the fundamental factor in the economic development of the region, which determines the volume of the production activity of society [7], and the technogenic load on the ecological system and its components. Therefore, the paper considers the resources of river runoff and determines the parameters of resistance to technogenic load in several river basins of the Omsk region. Table 1 presents the values of the main environmental characteristics of nature management in the study area.

Based on the analysis of the ecological capacity of the territory presented in the form of a diagram in figure 3, it can be seen that the river basins with the most optimal conditions for moistening the territory, that is, those with good water resources, have the highest values of technological intensity.

The values of the maximum permissible technogenic load of river basins [8] are synchronous with the values of ecological technological intensity. In general, it can be noted that the territorial variability of environmental technological intensity, in turn, depends on the climatic parameters of moisture and heat supply. As for the temporal variability, there is a direct relationship with the corresponding variability of runoff characteristics. The values of the environmental sustainability of the natural systems of the Irtysh River basin are determined on the basis of the sustainability coefficient recommended in the works of N.B. Popova (2001) [9].

Undoubtedly, the criteria for assessing the ecological state of water bodies should be quality standards, represented by the maximum permissible concentration of pollutants (table 2). In view of this, the assessment of water quality and the ecological state was

carried out according to the average long-term indicators of water quality in the studied river basins.

Table 1. Environmental parameters for assessing the impact of economic activities on river basins.

Pool number	River - target	Catchment area, km^2	Specific ecological potential (t/km^2*year)	Specific maximum permissible technogenic load (toe/km^2*year)	Specific environmental technical capacity of the territory, (std.t/km^2*year)
1	Om - the city of Kalachinsk	47800	293.12	86980	1.1
2	Osh - the village of Treshchetkino	11300	153.82	45644	0.58
3	Osh - Kutyrly village	9380	218.00	64687	0.82
4	Bol. Aev - Chebakly village	4580	300.52	89176	1.12
5	Bol. Aev - the village of Uki	4070	311.15	92331	1.16
6	Tui - the village of Ermilovka	6500	321.67	95450	1.20
7	Tui - r.p. Tui	3050	321.67	95450	1.20
8	Tara - the village of Muromtsevo	16400	275.83	81849	1.03

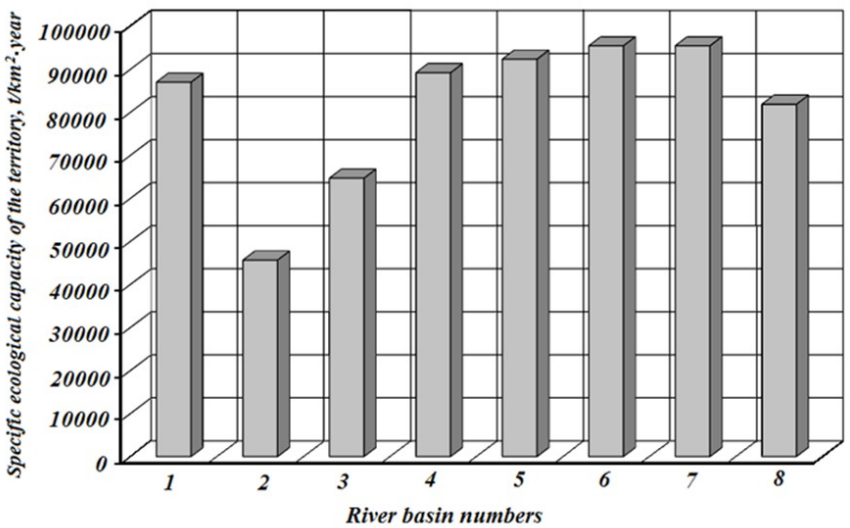

Fig. 3. Quantitative values of the specific ecological capacity of the territory of river basins.

Table 2. Comparative data on the concentrations of pollutants and the maximum permissible concentration for fishery and water management reservoirs, mg/l.

Pollutant	Pollutant concentration, mg/l	MPC for fish, mg/l	MPCwater, mg/l
BOD5	2.61	3.0	2.0
Fe	0.43	0.3	0.1
Cu	0.008	0.001	1.0
Mn	0.043	0.01	0.1
Zn	0.024	0.01	1.0
Phenols	0.005	0.001	0.001
Oil products	0.08	0.05	0.3

Based on the analysis of the concentrations of pollutants in wastewater discharged into the river network and the quality of water in the control sections of the rivers of the Omsk region, the following conclusions can be drawn:

- The content of organic substances (according to BOD5) in discharged wastewater is 2-5 times higher than the content of organic substances in water bodies.
- The content of limiting substances (compounds of iron, copper, zinc, oil products) in wastewater only slightly exceeds the content of similar substances in water bodies.
- Wastewater discharges from housing and communal services and industrial enterprises, for the most part, have a negative impact on water bodies by increasing the content of organic and biogenic compounds.

Thus, the predominant pollutants [10] in most cases are organic substances according to BOD5, compounds of iron, copper, manganese, phenols, and petroleum products (figure 4). The analysis data show that the surface waters of the water sources of the study area are generally assessed as "polluted" and "dirty".

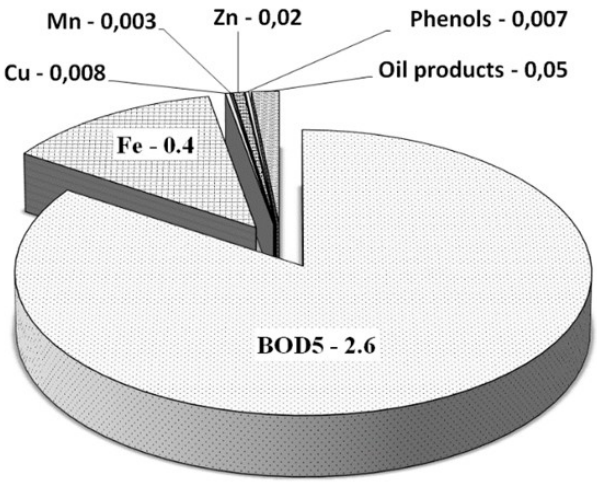

Fig. 4. Diagram of pollutants discharged into the Osh River.

Under the stability of natural systems, it is common to understand the state of the system in which the system maintains stability in its development, with the invariance of the conditions of influence of the external environment, represented by natural and man-made factors. This takes into account the ability of the ecosystem to withstand the technogenic load and self-healing. In general, the essence of the general mechanism of sustainability lies in the fact that natural systems are able to adapt to changing environmental conditions dictated by anthropogenic loads [11]. At the same time, stability

is characterized by the range between the minimum and critical values of the parameter, within which the natural system is able to maintain structural and functional features that are optimal for its development. In our work, the coefficient of environmental sustainability acts as such a parameter.

Taking into account the adopted provisions, the environmental sustainability of the natural system [12] or, in the specific case of the river basins of the territory under consideration, can be determined by comparing the values of the actual technogenic load and the total environmental technological intensity of natural systems. It becomes clear that the equality of the listed values characterizes the territory being in a state of limit (critical) and, as a result, an unstable state of equilibrium of the natural system.

4 Discussion

The results of the studies performed indicate that the territory of the river basins of the Omsk region can be divided into two main zones according to the values of the stability coefficients. The territory of the first zone is characterized by conditions of marginal ecological balance. The second one is characterized by the conditions of critical ecological balance.

Assessing the current ecological situation by the value of the coefficient of stability of the natural system, we can conclude that most of the considered river basins belong to the zone of the limiting ecological balance of the territory (I zone). The coefficient of ecological sustainability of these river basins takes values in the range from 0.5 to 0.7, which indicates that the load on natural systems ranges from 50% to 70% of the total ecological capacity of the study area. Whereas the second zone has almost exhausted its reserve of resistance to external loads and is in critical condition. These territories are mostly concentrated in the more developed southern part of the region with a shortage of water resources.

5 Conclusion

As a result of the data obtained, it can be concluded that the identified state of the waters of river catchments, characterized as the limiting state of equilibrium of the territory, is primarily associated with a significant impact of economic activity within the study areas. The considered river basins have a number of different features that form the total water content of the territory and, accordingly, different quantitative values of ecological technological intensity. It is this fact that predetermines the distribution of technogenic load in river basins.

Thus, the calculations performed in the work can serve as a basis for establishing criteria for assessing the total technogenic load on river basins. And also be used for a general environmental assessment of the state of surface waters.

The obtained calculations allow timely development and proposal of measures for the rational (targeted) use, restoration and protection of water resources, prevention and elimination of pollution of water bodies, as well as determining effective methods for the overall protection and improvement of the state of aquatic ecosystems. In conclusion, the results of the study are described.

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