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Analysis, Evaluation and Measures to Reduce Environmental Risk within Watershed Areas of the Eastern Zauralye District Lakes

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Abstract. The authors have performed an analysis for the use of watershed areas of the lakes of the Eastern Zauralye district (the territory to the east of Ural) for national economic purposes. The analysis gave a possibility to assess the impact of watersheds depending on the applied technologies on the dump of various runoff into the reservoir waters. The watershed areas of all lakes have been found to be actively used as pastures, farmland and recreational resources. Some of the main sources of solid and liquid industrial waste are cattle farms and agricultural land using outdated equipment and technologies.
The study of 26 km of the watershed line areas showed that pollutants (household garbage, fuels and lubricants) and organic substances (phosphorus and nitrogen) got into the waters of the reservoirs. The maximum runoff of solid and liquid waste into the waters of the lakes happens in summer which leads to increased concentrations of organic substances, an increase in productivity of alga and higher aquatic flora determining the degree of eutrophication and trophy in the reservoirs. The average annual trophic status of TSI lakes of the Eastern Zauralye district is 56 which corresponds to the typical phase of eutrophy. The reduced transparency of lakes is also the evidence of an increase in biological productivity of reservoirs, their eutrophication and, as a result, the water quality deterioration. The intensive eutrophication of reservoirs, in its turn, most significantly affects the concentration of the ammonium form of nitrogen, total phosphorus and total nitrogen, increase in pH and deterioration of oxygen condition.
The authors have developed various activities to reduce a technogenic risk in the watershed areas of the lakes in the Eastern Zauralye district which can be applied to other areas using the analogy method.

1. Introduction

The present territory of Chelyabinsk region is very insufficiently provided with clean drinking water. Some territories of Eastern Zauralye, such as Etkulsky and Oktyabrsky districts are water-scarce. Due to the fact that the groundwater resources in this area are low, lakes are the only sources of water supply especially in winter (Lebyazhe, Mediak, Butash etc.).

The peculiarity of the territory is lack of humidification (HA 0.4) compared to the rest of the region (HA 0.6-0.8) that contributes to drought in the area. Dry weather leads to shallowing and drying of lakes. In addition, due to the absence of large river systems in this territory, lakes assume all economic and recreation load increasing the likelihood of both natural and technogenic risks. As there is no centralized water supply system in many households, water consumption for economic purposes is increasing annually.

1.1. The relevance of the research
The relevance of studying the impact of anthropogenic (technogenic) factors on polluting the above lake systems is determined by the importance of water bodies for household use, especially as sources of drinking water. Human economic activity has affected both watershed basins and water bodies (recreation, fish farming, construction and reconstruction of various hydraulic facilities etc.).

Human impact destroys the natural balance of biotic and abiotic elements of the ecosystem. This leads to siltation, shallowing and eutrophication of lakes, and as a consequence their transformation into bogs.

Research of the influence of anthropogenic and natural factors on polluting water systems and their watershed areas was carried out by scientists from different countries. Works of the Russian researchers [1-9] and foreign scientists [10-12] studying lakes are particularly noteworthy. Since 2001 we have been conducting research on the territory of Eastern Zauralye to study the impact made by natural and especially anthropogenic factors on polluting water bodies and their ecosystem changes, including the impact from increasing untreated industrial and agricultural waste from farms and fields. The authors' previous studies of are reflected in the following works [13-19].

1.2. The main objectives of the study
A significant source of anthropogenic pollution of lakes is cattle farms of the villages located in close proximity to water bodies (50-150 m from the shoreline), which contradicts the requirements of the Water Code and Sanitary Regulations and Norms of Chelyabinsk region. To determine the impact of cattle farms and agricultural fields on the removal of organic (nitrogen and phosphorus) runoff into the waters of the studied reservoirs, we performed an analysis of anthropogenic impact on the watershed area of three lakes Lebyazhe, Mediak and Butash.

2. Methods
To achieve the objective, we used a variety of field and scientific methods. In particular, landscape-geochemical studies in the watershed areas of the studied water reservoirs were con-ducted using the method of selected points representing the ranks of geochemical facies replacing each other from the watershed tops to the lake. In total over 26 km of watershed line areas were investigated.

The conditions for formation of surface runoff on the Eastern Zauralye territory were studied by means of artificial sprinkling on runoff sites (2x2 m) (12 sites).

Studies of the chemical composition of the lake waters were carried out mainly within the open water period (June-August). Sampling was carried out by means of Molchanov's bathometer. Chemical analyses of the water samples were performed in the laboratories of Chelyabinsk Hydrometeorology Centre; determination of ions $HCO3^{-}$, $SO4^{-}$, NH4+, $NO2^{-}$, $NO3^{-}$, permanganate value and O2 and CO2 was per-formed by the following methods: GD (guidance document) 52.24.486-95; GD 52.24.381-95; GD 52.24.380-95; GD 52.24.387-95; GD 52.24.403-95; Nature Protection Regulatory Document 14.1:2:149-99 (05-01-MVI). The samples were prepared according to the integrated chemical analysis techniques.

Field studies carried out in watershed areas of the studied reservoirs led the following conclusions. In watershed areas of all reservoirs there are cattle farms with varying degrees of technical equipment for collection and disposal of industrial wastes. Most farms have no specialized equipment for disposal or recycling of wastewater. Therefore, liquid industrial wastes get directly into the waters of the reservoirs, except for solid wastes that are disposed of on ground, mostly with violation of generally accepted technologies. Namely, solid wastes (particularly manure) are taken to agricultural fields, located in the watershed areas of the studied reservoirs, as fertilizer without complying with standards and technical regulations.

In summer, pasturing and watering of cattle happen within the sanitary protection zones of these reservoirs. Accordingly, the amount of organic substances (phosphorus and nitrogen) in the water of these reservoirs increases significantly. Taking into account standard indicators of removal of organic sub-stances, which are a nutrient for aquatic ecosystems, in wastes from one animal (table 1) [20], we calculated its delivery to the lakes during the summer period (table 2).

Table 1. The average removal of organic wastes from one animal (kg/day).

Cattle	Solid wastes	Nitrogen	Phosphorus
Beef and dairy cattle	4.53	0.15	0.05
Pigs	0.4	0.03	0.01

Table 2. The average removal of organic wastes from cattle and pig farms (kg/day) into the lakes within the summer period.

Lake	Livestock number	Solid wastes	Nitrogen	Phosphorus
Lebyazhe	cattle – 89	403.7	13.35	4.45
	pigs - 0	-	-	-
Mediak	cattle – 120	543.6	10.2	3.4
	pigs - 40	27.2	1.2	0.4
Butash	cattle – 105	475.6	11.25	3.75
	pigs - 0	-	-	-

From table 2 it is evident that intensive pollution of reservoirs and their watersheds by organic wastes riches its maximum in summer and is caused by cattle farms located in the sanitary area, pasturing and watering of cattle, which ultimately leads to increased concentrations of organic substances.

On the whole, it should be noted that the anthropogenic pollution of the studied lakes deteriorates the overall state of the ecosystem in the reservoirs and at certain stages of this process it poses a risk to humans' and animals' health. The watershed area and its landscape structure play a significant role in the formation of removal of biogenic elements. It is known that removal of biogenic elements increases with the increase of surface runoff, at the same time this increase is noticeably less in watersheds with an area of less than 2 km^2 than in smaller ones with an area of less her 1 km^2.

3. Results

The research conducted by the authors has identified the dependence of removal of phosphorus and nitrogen from the watershed area. So, there is a noticeable decrease in removal of biogenic elements if the watershed area is from 3.94 to 141.0 km^2, plowing of this area is 40-60% and the layer of annual runoff is 30 mm. This is because large watersheds have different pattern structure (forest, meadows, plowing land etc.) that affects the reduction in removal of biogenic elements into the waters of the lakes.

In the summers of 2014-2016 the authors carried out integrated studies of the landscape structure of lake Butash watershed area (the largest of the studied reservoirs) and estimated its influence on the dynamics of removal of biogenic substances. In the process of this research the following results have been obtained.

Based on the modern schemes of land use of the nearby village Pisklovo and clarifications made during the fieldwork (2014-2016), plowing land, pastures, cattle-breeding and pig-breeding farms, residential and commercial buildings, etc. were recorded and contoured. Natural-anthropogenic structure of lake Butash watershed was studied on the example of a local stream "Korablevsky", which is a tributary of the lake and the watersheds of which are farmland.

The comparison of the results of the studied stream watersheds allowed us to allocate the structure types of the local watersheds. Two main groups were singled out on the basis of the complexity of the watersheds: monostructural and polystructural. The differences in removal of phosphorus depending on the watershed's structure were discovered when comparing the allocated types of structures in the stream watersheds with the data on the contents of total phosphorus in the water of Korablevsky's stream. The comparison was conducted according to the average content of total phosphorus over the observation period (table 3).

Table 3. Typification of lake Butash watersheds ин their landscape structure on average over the observation period.

Watershed Structure type	Landscape	The content of total phosphorus in the of Korablevsky's stream, mg/l
Entirely anthropogenic complex	Plowing land, a swamp is peripherally	0.075
The combination of natural and anthropogenic complexes	Plowing land is the core, there is a boggy meadow and pasture peripherally	0.046
	A boggy meadow is the core, there is an extended bog, broad boggy lowland and forest peripherally	0.051

Comparison of the results shows that in the case where the watershed is entire prowing land surrounded by a boggy area, we observe the greatest (0.075 mg/l) removal of total phosphorus into the stream due to the high water permeability of the soils. If the watershed is polystructural with an extended bog or boggy meadow, removal of total phosphorus becomes less (0.051 mg/l) due to a complex watershed's pattern structure.

The authors have found that, in general, watersheds of the studied lakes are characterized by the predominance of anthropogenic landscapes transformed using engineering and technology.

Proof of their influence on the increase in the content of organic and biogenic substances in the reservoirs and dependence of the eutrophication area of lakes on the ratio of the landscapes in the watersheds are given in table 4.

Table 4. The ratio of natural and anthropogenic landscapes in the watersheds of the lakes (%).

Lake	Watershed – natural landscape	Watershed – anthropogenic landscape	Average biogenic elements		S Eutrophication (%)
			P_{total}	NH_4^+	
Lebyazhe	18	89	0.280	0.27	40.2
Mediak	36	64	0.546	0.35	22.4
Butash	32	68	0.249	0.02	31.4

The obtained results confirm the known facts about the greatest removal of phosphorus from cultivated areas and the need to take into account agricultural land. A significant change in conditions of surface runoff generation that occurs due to plowing of Eastern Zauralye steppe lands led eventually to the change of silt generation. Because of cultivation of the soil, its erosion resistance has significantly decreased; thus, removal of phosphorus with solid runoff has become dominant.

On the basis of data on the dependence of removal of phosphorus with solid runoff on the gradient and length of a slope, (table 5), the authors have determined the average value of removal of phosphorus into the waters of the largest reservoir, lake Butash, from the nearby watershed areas.

Table 5. Dependence of removal of phosphorus with solid runoff on the gradient and length of a slope.

Slope length, m	Gradient	Removal of total phosphorus, kg/ha
100	2	0.71
200	2	1.59
400	3.5	2.92

Since the watershed areas of lake Butash are mainly armlands, with the average slope of all watershed areas from 2 to 3.5 º and the average slope length of 300-400 m, the rate of removal of phosphorus was of 2.76 kg/ha. In natural conditions this indicator does not exceed 1.52 kg/ha. Therefore, in generation of removal of phosphorous and other silt, though insignificantly, but the role of gradient and length of slopes of watershed areas of lakes increases.

Thus, the role of this factor is clearly demonstrated in the watershed areas of the studied small lakes of Eastern Zauralye. It has been found that the greater the watershed area of a particular lake, the less noticeable influence it has on the reservoir. Length and slope of watersheds is diverse on watersheds of large area. An increase in soil loss on slopes of one exposure is compensated by a reduction on another.

4. Findings

Thus, studies carried out on Zauralye lakes allowed us to identify the uniqueness of their ecosystems, to assess the conditions of generation of surface runoff affecting the current state and to identify particular ways of restoring their ecosystems. Water shortage and the quality of water of the studied areas are important tasks that need to be addressed through restoration of lake ecosystems. The analysis and assessment of anthropogenic pollution of watershed areas of Zauralye lakes allowed the authors to develop measures for reducing technogenic risk.

We have proposed a project to restore the ecosystems of the studied Zauralye lakes, which was developed on the basis of Limnology-Ecological Centre of South Ural State Humanitarian Pedagogical University (SUSHPU). When developing the measures to improve the ecological conditions of Zauralye lakes the following priority guidelines to restore the lake eco-systems have been identified:

- reduction in the volume of biogenic and other pollutants getting into the reservoirs and streams of the lakes;
- introduction in the watershed areas of lakes of gentle technogenic actions that do not result in a drastic change in the ecosystems of forest, meadow and other areas.

Based on these guidelines, the authors have designed the technologies to reduce risks in the usage of the reservoirs. All the technologies were divided into water protection measures and measures in the watershed areas, the essence of which is as follows:

1) water protection measures the main purpose of which is the reduction or complete elimination of discharges of polluted wastewater especially from livestock and pig farms, for example - to conduct water protection zoning by Ecology and Rational Nature Management Committee of Oktyabrsky district of Chelyabinsk region with a mandatory allocation of protected and native zones and the subsequent development of coastal margins within the water protection zones.

2) the measures in the watershed areas, for example - to build sewage disposal facilities on the banks of all studied lakes using modern technologies for purification of wastewaters of livestock farms; to build manure yards at every farm with a maximum capacity of semi-annual or annual storage of manure. In addition, a very promising method to implement is full recycling of wastewater through cultivation of green fodder using the hydroponic method [3]; to carry out additional banking-up of farms obligatory equipping them with storm water tanks.

5. Conclusion

On the whole, the rehabilitation measures, proposed by the authors, will help greatly improve the ecological state of the studied Zauralye reservoirs. This will subsequently make it possible to use their water resources for the purposes of economic and drinking water supply in the area, which is important due to its water shortage. Measures to reduce technogenic risks in the watershed areas of the Eastern Zauralye lakes, developed by the authors, can be applied to other areas using the analogy method.

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