Assessment of the ecological state of surface waters (using the Baksan River as an example)

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Abstract. The paper presents the pollution assessment results of the Baksan River. Baksan is a river in the North Caucasus in Kabardino-Balkaria, a right tributary of the Malka river. In the upper reaches it is called Azau. The purpose of this work is to study the ecological state of the river and identify the main pollutants. The paper provides an integral assessment of the ecological state of the river based on hydrobiological and hydrochemical indicators. This article uses the method of field research and observations, comparative geographical and descriptive methods. The high concentration of heavy metal compounds in the Baksan River water, exceeding the level of concern, is due to the proximity of mineral ores in the water-collecting areas. The physical properties and organoleptic indicators of the water throughout the watercourse (color, smell, transparency, and temperature) are satisfactory and vary depending on the season and weather conditions.

1. Introduction

On the territory of Russia, almost all water bodies are subject to anthropogenic influence. The water quality in most of them does not meet the regulatory requirements. Water bodies pollution poses a threat to the population health, the normal implementation of economic and other activities, the state of the natural environment, as well as biological diversity [1].

Water is a key factor in major global environmental problems. The deterioration of anthropogenically transformed natural ecosystems and agricultural systems is either a consequence of a changed water regime or, conversely, anthropogenic transformations in systems lead to changes in such important hydrological characteristics as the water retention capacity of soils, rainfall interception by vegetation, infiltration capacity, etc., with corresponding changes in the hydrological regime.

There are two main categories of water pollution sources: point and diffuse sources. The first category includes, for example, industrial effluents and discharges from municipal wastewater
The second category includes agricultural-related pollution, such as water pollution by fertilizers and pesticides [2–5].

The purpose of this work: to assess the ecological state of the Baksan River, to provide an integral assessment of the ecological state of the river in terms of hydrobiological and hydrochemical indicators.

![Figure 1. A schematic map of the Kabardino-Balkar Republic](image1.png)

The water resources of the Kabardino-Balkar Republic are rivers, lakes, ponds, glaciers and underground waters. The total length of the river network is 5,470 km and consists of 2,172 rivers and streams, of which 11 main rivers are actively used. A schematic map of the Kabardino-Balkar Republic (KBR) rivers is shown in Figure 1.

![Figure 2. A satellite image of the Baksan River section](image2.png)
The river network of Kabardino-Balkaria is closely connected with the peculiarities of the climate and terrain. Part of the republic is characterized by snow-glacial rivers. In their regime, the summer maximum of discharges (July) is clearly traced, associated with the increased snow-melt of Kabardino-Balkaria – the Malka, Baksan, Cherek, Chegem and Urukh – originate from glaciers and all of them are ultimately left tributaries of the Terek River [6–8].

The nature of riverbed processes depends on the zone. In the mountainous part, the rivers flow in narrow canyons and the erosion of the riverbed is barely noticeable. Rivers are characterized by high water velocity, which leads to numerous large sediments entering the rivers from the descent of glaciers, snow avalanches and mud-flows. Larger sediments are deposited in the foothill part, and smaller ones are deposited in the flat part of the riverbed [9].

The Baksan is a river in the North Caucasus in Kabardino-Balkaria, a right tributary of the Malka river. In the upper reaches it is called Azau. The length of the river is 169 km, its catchment area is 6800 km. A satellite image of the Baksan River section is shown in Figure 2.

**Methods and materials**

Pollution sources are objects dumping the discharge or other intake of harmful substances that degrade the quality of surface waters, limit their use, and also negatively affect the state of the bottom and banks of water bodies [2]. Water quality according to hydrochemical and hydrobiological indicators is monitored in four sections:

1. above Terskol Village;
2. below the tailing dump, Bylym village;
3. water intake of the Baksan-Malka channel;
4. city of Prokhladny – river mouth.

The oxygen regime throughout the entire watercourse is satisfactory (8.6–13.5 mg/dm³). The hydrogen index ranges from 7.0 to 7.7 pH units. There is a decrease in the concentration of metals in the river throughout the watercourse.

The high concentration of heavy metal compounds in the Baksan River water, exceeding the LOC, is due to the proximity of mineral ores in the catchment areas, which is confirmed by long-term observations (molybdenum – 3.4–16 LOC, iron up to 2.3 LOC, aluminium 11.8–16.5 LOC, copper 1.2–1.5 LOC).

The water quality above the town of Tyrnyauz is satisfactory for all the indicators [10–13]. The next sections of observation along the river are the sections above and below the Baksan hydroelectric power station. The water quality in these sections is satisfactory for all the observed components.

The water quality of the Baksan River in the section above the city of Baksan corresponds to the LOC standards for the water of fishery water bodies in most indicators. The water quality according to the water pollution index in this section corresponds to class III ”moderately polluted” (Table 1).

**Table 1. Classification of water bodies by water pollution index in places of wastewater discharge in 2018–2019**

| Observation station | The value of the water pollution index | Water quality class | Class Description |
|---------------------|----------------------------------------|---------------------|------------------|
| Above the dump of the sewage disposal plant Municipal unitary enterprise "Baksangorvodokanal", city of Baksan | 0.787, 0.656 | II, II | clean, Clean |
| Below the dump of the sewage disposal plant Municipal unitary enterprise "Baksangorvodokanal", city of Baksan | 6.058, 2.55 | V, IV | Heavily polluted, polluted |
In the upper reaches of the Baksan River, the biocoenoses are poor in vital resources. Their state can be described as background. Downstream of the river, as the water mass is enriched with biogenic elements, the productivity and species diversity of biocoenoses increases — a state of anthropogenic ecological stress (or "ecological progress") is observed.

Such state of the Baksan River biocoenoses is observed from the high-mountain village of Elbrus to the Mukulan gulch (town of Tyrnyauz). At high levels of anthropogenic stress, the situation is replaced by a state of ecological regression, which is characterized by an increase in the quantitative development of the biocoenoses with a simplification of the structure. This state is observed on the Baksan River below the town of Tyrnyauz in the zone of the mining plant impact. Here, water pollution is noted even visually and organoleptically.

3. Results

The water quality of the Baksan River in the section below the city of Baksan varies by easily oxidable components: BOD5 (biological oxygen demand) on average is 6.7 mg/dm³ (3.3 LOC), the permanganate oxidability is 1.6 LOC; the ammonium ion is 1.9 LOC, and the nitrite ion is 1.1 LOC. For the rest of the determined components (nitrates, sulfates, chlorides, phosphates, petroleum products, anionic surface-active agents), the water quality corresponds to the LOC standards for fishery water bodies [5].

Water quality in mouth section (city of Prokhladny) in terms of physical and chemical composition is improved by diluting with the water of the Chegem and Cherek rivers. The excess of easily oxidable pollutants in comparison with the previous section is small (BOD 5 (biochemical oxygen demand five-day test) – 1.5 LOC, permanganate oxidability – 1.1 LOC). There are also excesses in the ammonium ion (1.2 LOC), the nitrite ion – 1.5 LOC, and the sulfate ion – 1.2 LOC. Such components as petroleum products, anionic surface-active agents, phosphates, chlorides, nitrates are present within limits that do not exceed the LOC for fishery water bodies. The water quality in the mouth section corresponds to class III "moderately polluted" [2].

The total volume of insufficiently treated wastewater and polluted without treatment, in the reporting year – 35501.3 thousand m³.

In the Kabardino-Balkar Republic, there are 18 wastewater treatment plants with a total design capacity of 238.8 thousand m³/day.

The technical condition of many wastewater treatment plants remains unsatisfactory. The existing treatment schemes are outdated, and there are no additional wastewater treatment units and modern wastewater disinfection units in all wastewater treatment plants. The volume of polluted wastewater (without treatment) discharged into rivers in 2018 – 636.44 thousand meters.

Due to the lack of sewerage networks in localities, the wastewater treatment plants are loaded from 10 to 50 %.

Wastewater accumulates in cesspools, filtration fields, primitive sedimentation tanks, and so on, which worsens the environmental situation.

The reduction of the technological service had a negative impact on the operation of the wastewater treatment plants, as a result, the wastewater treatment of many plants began to deteriorate every year. In the reporting year, due to the lack of funding, the previously undertaken construction of treatment facilities was not carried out.

At the design capacity of the wastewater treatment plant of 11.0 thousand m³/day, the wastewater flows 3.5 thousand m³/day (32 % of the design capacity utilization).

During the reporting period, at the wastewater treatment plant, current repairs of the inlet and outlet tracks of individual settling tanks were carried out, the valves on the bypass lines of the 2nd air filter were replaced.

The technical condition of the treatment facilities is satisfactory, but due to the lack of a post-treatment unit, the quality of wastewater does not meet the standards. BOD is full – 11.37–161.0 mg/dm³ at LAP equals to 5.55 mg/dm³. The excess values were recorded for the nitrogen content of ammonium salts from 7.99–8.3 mg/dm³. At a LAP (Limited Admissible Pollutions) of 1.05 mg/dm³.
[5]. The nitrogen content of nitrates in 2018–2018 is 0.44 mg/dm³. If the LAP is not lower than 3.3 mg/dm³, which is a negative indicator of the wastewater treatment plant operation, the excess is also noted for other indicators.

The water quality of the Baksan River slightly deteriorates, but the concentrations remain within the limits of the LOC for fishery water bodies (a small runoff volume, and sufficient dilution of them with river water).

The following measures are necessary for improving the quality of wastewater:

- Capital maintenance of wastewater treatment plant, industrial building (roof repairs);
- Construction of a post-treatment unit and a wastewater disinfection unit.

At the design capacity of the wastewater treatment plant of 4.2 thousand m³/day, wastewater flows 0.825 thousand m³/day (19.6% of the load of the design capacity). In 2017, at the wastewater treatment plant significant repair, reconstruction, and construction of an additional line adjacent to the treatment facilities of the old complex were carried out. The old technological equipment was replaced with a new one, and the production building was renovated.

The quality of wastewater after the treatment does not meet the LAP standards for the content of BOD full 12.0–16.0 mg/m³ at LAP of 9.37 mg/dm³; nitrogen of ammonium salts 5.7–7.8 mg/dm³. At a LAP of 2.7 mg/dm³.

The technology of wastewater treatment has not been restored yet (low average daily temperatures, low volume of wastewater, and etc.).

Due to the small volume of wastewater and the significant flow rate of the Baksan River, the effect on water quality has not been established.

To improve the environmental situation in the field of water disposal, it is necessary to:

- Complete the construction of a sewage and sediment decontamination plant, for that reason to build dehelmintizators.
- Install a flow metering of runoff volume;
- Expand the sewerage system.

Thus, the physical properties and organoleptic indicators of the water throughout the watercourse (colour, smell, transparency, and temperature) are satisfactory and vary depending on the season and weather conditions. According to the salt composition, the water at the mouth of the Baksan corresponds to the average mineralization, according to the degree of hardness, it refers to the water of medium hardness.

The high concentration of heavy metal compounds in the Baksan River water, exceeding the LOC, is due to the proximity of mineral ores in the catchment areas, which is confirmed by long-term observations (molybdenum – 3.4–16 LOC, iron up to 2.3 LOC, aluminium 11.8–16.5 LOC, copper 1.2–1.5 LOC).

4. Conclusion
Since 2001, the activities of the Tyrynauz Mining and Processing Plant (MPP) – the main pollution source of the Baksan River – have been suspended. As a result, the wastewater volume has significantly decreased. However, the MPP tailing dump, which occupies a significant area in the Baksan Valley and is not subject to solid reclamation, remains a major source of river pollution. The water quality in the Baksan River has significantly improved compared to the period of the MPP activity. In the background section, a significant content of Al, Fe, Mn, and Cu was observed due to the presence of polymineral ores throughout the catchment area. Therefore, the water pollution index most often characterizes the background sections as "moderately polluted". In the altitude aspect, changes of the ecological state in different sections of the Baksan River were noted. A significant impact on the Baksan River ecosystem is caused by wastewater from the Baksan treatment facilities, which significantly worsen the ecological state of the river. Below the city of Baksan, in the area of the Kishpek village, a sharp deterioration in the quality of surface water is observed, caused by the direct discharge of the city sewage and domestic wastewater directly into the river. This negative impact is mitigated only after the Cherek River flows into the Baksan River.
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