Current hydroecological state of the Ural River in the lower reaches

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Abstract. Climate and hydrological changes in the Ural River basin, together with water management activities determine the current hydroecological state of the river in its lower course. In comparison with the conventional natural background, the salinity of water in high water period increased by 2.5 times, in low water period - by 5 - 8 %. Contamination of the lower course of the river is caused by the inflow of pollutants from the upstream sections and the confluence of the polluted tributaries. In the area with no tributaries, the water is characterized as "standard-clean". The saprobity indices, which characterize the content of organic substances in water, are located within the boundaries of the b-mesosaprobic zone, which characterize low level of water contamination. The content of dissolved oxygen indicates insufficient aeration of the river water during most of the year. The lowest oxygen content is observed during winter period.

1. Introduction
The Ural River (on the territory of the Republic of Kazakhstan – the Zhayik River) is an intra-zonal river, the landscape and climatic conditions of the basin of which are characterized by great diversity. It is reflected in the chemical composition along the entire length of the river [1–4]. Modern climatic changes lead to a decrease in water runoff, to a change in the ratio of supply sources, the chemical composition, and mineralization of water. The contrast between mineralization and mineral composition intensifies with an increase in the aridity of the territory. The runoff regulation by reservoirs, on the contrary, leads to the levelling of the intra-annual variation of water mineralization, its increase during the flood period.

The middle part of the Ural River basin is characterized by the maximum technogenic load on water bodies [5]. The Irkilinskii Reservoir (the largest reservoir in the Ural River basin) is a “regional hydrochemical barrier” [6] that improve water quality in terms of a number of indicators. However, the positive impact of the reservoir is offset by the water pollution of the Ural River and its tributaries in the territory of the Orenburg region. The deterioration in water quality is caused by enterprises classified as “ecological hotspots” [5]. The high level of the Ural River water pollution within the Russian part of the basin has remained over the past 15 years and affects the water quality in the downstream of this transboundary river.

2. Materials and methods
Information on the chemical composition and hydrochemical regime was obtained from federal and regional information bulletins and reports "On the state of the environment" [7], from the "Scheme for
the Integrated Use and Protection of Water Resources of the Ural River” of Kazakhstan [8], from literary sources and Internet resources. Obtained in 2019 during two expeditions the author’s own data was used to characterize the current hydroecological state in the downstream of the river. They were supplemented with the data from KAZHYDROMET, which organized detailed unscheduled surveys in 2019 at 13 gauges above and below the city of Atyrau.

We used a number of biotic indices to determine water quality at each sample location. These included: Ephemeroptera-Plecoptera-Trichoptera density index (EPT); Trent Biological Index (TBI) and Average Score per Taxon (ASPT). The EPT index is a standard method using aquatic macroinvertebrates for monitoring and assessing river ecology, and has been previously used for biomonitoring studies of transboundary river basins throughout Eurasia [9-11].

3. Results and discussion

The current hydroecological state in the downstream of the Ural River is influenced by natural and anthropogenic factors. The Caspian Lowland belongs to the area of chloride salinization; therefore, the soils in the catchment area contain highly soluble chlorides. This leads to increased mineralization and to an increased chloride composition of not only groundwater but also surface water. Groundwater plays a major role in recharging the river during the low-water period when water inflow from the catchment surface decreases or stops completely.

Mineralization and mineral composition. In the period of natural conditions, the waters in the lower reaches of the Ural River in terms of chemical composition belonged to the hydrocarbonate-chloride (chloride-hydrocarbonate) type. The cationic composition of the water had mixed type - sodium-calcium or calcium-sodium-magnesium. During the low-water period, the mineralization increased, and the water had a chloride-sodium composition. Recent changes in value and regime water runoff had led to an increase in water mineralization, both during the flood and low-water seasons. Compared to the natural background (until the end of the 70s of the twentieth century), the water mineralization during the spring flood season had increased by 2.5 times, in the low-water season - in 5-8%. In 2019 the water mineralization had reached the highest value by the end of the winter low-water season (760-850 mg/dm³). During the summer low-water season, it was 600-650 mg/dm³, and the water was characterized by a chloride-sodium composition. Chlorides and sodium ions dominated in the mineral composition throughout the year; below the city of Atyrau the absolute and relative content of these ions in water increased [10].

During the low-water period when the river is recharged by groundwater, the excess of EMPC (Estimated maximum possible concentration) was noted for sulphates and magnesium ions. For the catchment area of the Ural River, in addition to chloride salinization the sulphate salinization takes place [5]. The increase in the content of sulphates in the river waters is most likely associated with the influence of the natural mineral content of the Ilek and the Shagan river’s water, as well as with the inflow of sulphates of anthropogenic origin from the Ilek River.

Heavy metals. In the water of the Ural River during the low-water period (March and July 2019), concentrations of heavy metals (HM) exceeding the fishery standards were observed. The highest number of almost all HMs was noted near the Inderbor settlement. Downstream, the concentrations of manganese, chromium, lead, and copper decrease. Excess of EMPCfishery by zinc (15.3-22.7 μg/dm³) and copper (2.23 μg/dm³) is associated with a technogenic source (transboundary transfer from the territory of the Russian Federation and with the flow of polluted tributaries). Along the river, the concentration of soluble iron changes little. Despite the exceeding of EMPC, its concentration (140-190 μg/dm³) corresponds to the natural geochemical conditions. Iron is found in the catchment soils and groundwater. In addition, there are not any industrial sources of iron pollution in the lower reaches of the Ural River. Besides the oxidation-reduction conditions, the increased concentration of the fine suspended particles (mainly clayey) in the lower Ural River affects the intensity of iron migration. The surface of clay particles absorbs well not only iron but also other metals. According to KAZHYDROMET, in 2019 near the Atyrau city the concentration of soluble iron did not exceed EMPCfishery.
The most important indicator of the water quality of the Ural River is the content of boron. Content of boron and hexavalent chromium in river waters can be traced in the territory of Kazakhstan and the Russian Federation. Boron EMPC (in ionic form) for potable and household water is 0.5 mg/dm$^3$, the same quantity is the limit for fishery purposes. According to the research [12], in 2016 the boron content in downstream of the Ural River varied within wide limits (0.06–1.56 mg/dm$^3$). The minimum concentrations along the entire length of the river were recorded in October, the maximum - in May during the flood period. According to the data of 2019, the excess of EMPC of boron was not noted.

Organic and biogenic substances. The total content of organic substances (by COD - chemical oxygen demand) in the landscape conditions of the catchment area of the lower Ural River is low (10.1 - 12.9 mgO/dm$^3$). The predominant form of mineral nitrogen is nitrate nitrogen, the content of which ranges from 4.6 to 5.3 mgN/dm$^3$ (more than 97% of the mineral nitrogen content). Phosphorus compounds are consumed by aquatic organisms; therefore its proportion makes up no more than 30% of the overall. During the winter low-water period, it increases to 60-70% as a result of mineralization processes. In 2019 the overall phosphorus content in the low-water period did not exceed 60 μg/dm$^3$. There is a favourable ratio of biogenic elements in the water of the river, which are the mineral basis of bio productivity both in the river waters and in the water of the northeast of the Caspian Sea.

Oil products the downstream of the Ural River is completely technogenic origin. The content of oil products varies in a wide range: from 0.023 to 0.085 mg/dm$^3$, in 2019 averaging 0.04 mg/dm$^3$. Oil products enter the river with diffuse runoff, rain, and drainage runoff.

Dissolved oxygen. The content of dissolved oxygen indicates insufficient aeration of the river water during most times of the year. The absolute values of maximum permissible concentrations for fishery water bodies (MPCs) were not exceeded; however, the aeration of water averaged only about 60%. The worst situation is typical for the freeze-up period (the minimum was 35% of aeration). The oxygen content was also relatively low in spring. The tendency to an increase in the absolute and relative oxygen concentration values appeared in July-August due to the growth of photosynthesis.

The usage of only physical and chemical methods for controlling the negative anthropogenic impact on the aquatic environment is insufficient due to the large variety of such impacts. The research of phytoplankton in downstream of the Ural River did not reveal significant deviations in its development. It is characterized by high species diversity (Shannon index 2.6-4.9).

Saprobity indices characterize the content of organic substances in the water which are at different stages of decomposition. They are small and vary from 1.6 to 2.1, that fall within the boundaries of the β-mesosaprobic zone, which is characteristic of low (moderately) polluted water. The water of the Ural River below the city of Atyrau did not show an increase in saprobity.

At the same time a low species diversity, a low Woodywiss index, and a low representation of oxyphilic insect larvae indicate a problem. However, this issue needs additional research.

4. Conclusion

The current hydro-ecological state of water in the lower reaches of the Ural River is influenced by local natural and anthropogenic factors, as well as by global climate change.

A decrease in runoff in flood season had led to an increase in water mineralization by 2.5 times compared to the mineralization in natural period (until 1980) and had changed the water class to sodium chloride. During the low-water period, the water mineralization had increased by 5 - 8%. In spring, the river channel is not washed and is silted up, the amount of dissolved oxygen decreases. A decrease in the area of floodplain spawning grounds in spring leads to damages to the fish fauna.

Pollution of downstream of the Ural River is mainly caused by the inflow of pollutants from the upper sections of the river (from the Irikinskiy Reservoir to the city of Uralsk) and as a result of the inflow of the tributary Ilek polluted waters. The Ural River water is characterized as “moderately polluted”. Down the river the pollution level decreases. In the non-tributary area within the Atyrau region, the water is characterized as “normatively clean”. This is helped by the absence of wastewater
discharges directly into the river. Existing sources of water pollution are diffuse surface runoff from industrial sectors, settlements, livestock farms, water used by city filtration plants. The aeration of the river waters is low during most of the year. In winter that is caused by the freeze-up period. In summer the water eutrophication is observed, which leads to a deterioration of the oxygen regime. The water “blooms”, and oxyphilic invertebrates are almost absent at the bottom of the river.

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