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ASSESSMENT OF MODERN ECO-HYDROLOGICAL CONDITION OF THE KURA RIVER BASIN

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Статья посвящена оценке современного эко-гидрологического состояния бассейна реки Куры. Выполнено исследование состава и количества загрязняющих веществ в речном стоке. Ведение многообразной хозяйственной деятельности в бассейне Куры, в частности, строительство промышленных и бытовых объектов, создало ряд экологических проблем в регионе. Среднегодовая концентрация растворенного кислорода в период 2014 – 2020 гг. в бассейне реки Кура удовлетворительна. В целом, концентрации $БПК_5$ и NH_4^+ указывают на незначительное влияние деятельности человека на качество воды в бассейне реки Кура, поскольку большинство измеренных концентраций не превышали установленных предельно допустимых концентраций (ПДК). Горнодобывающая деятельность, металлургическая, химическая и кожевенная промышленность, а также естественные геохимические и гидрохимические процессы представляют угрозу загрязнению поверхностных вод тяжелыми металлами.

Ключевые слова. точечные источники; диффузные источники; источники загрязнения.

The Kura River Basin spans over 188 000 km^2 across the territory of five countries: Turkey, Armenia, Georgia, Azerbaijan, and Iran. The basin contains the larger Kura and hundreds of smaller tributaries that flow into these main rivers. The Kura River runs a total length of 1515 km from its source in the Turkish mountains through eastern Turkey, central Georgia and Azerbaijan where it empties into the Caspian Sea.

The Kura river basin includes the whole of Armenia, 69 % of Azerbaijan and 50 % of Georgia. The population distribution differs slightly from the surface area division, due to the specific location of major municipal centers. As such, the basin includes the whole population of Armenia, 57 % of the population of Azerbaijan, with Baku located outside the basin, and 61% of the population of Georgia, with Tbilisi located inside the basin. The largest portion of the basin population lives in Azerbaijan (47 %) and the smallest in Georgia (24 %), with Armenia's population accordingly accounting for 29 %. The urban population of Armenia and Georgia is high, as many smaller cities and towns are classified as urban [3, p. 8].

The total water resources of the Kura basin are 25.9 km^3. 16.8 km^3 water resources is formed in the Kura basin and the remaining 9.1 km^3 is formed in the Aras basin. Water resources which formed in the Kura basin (without Aras basin), 9.39 km^3 belongs to Georgia, 4.6 km^3 of Azerbaijan and 1.54 km^3 to Armenia. 3.5

km^3 flow is generated in the Turkish part of Kura basin. 0.9 km^3 of this belongs to Kura and 2.6 km^3 belongs to Aras basin [1, p. 89].

In the case of surface waters, the WFD requires the identification of significant pressures from:

- point sources of pollution;
- diffuse sources of pollution;
- modifications of flow regimes through abstractions or regulation;
- morphological alterations;
- as well as any other pressures such as the estimation of land use patterns, including
- identification of the main urban, industrial and agricultural areas and, where relevant,
- fisheries and forests.

Indicator organisms are known for biodiversity in the basin. They determine the degree of contamination of water with organic substances. Mostly 4 groups (olisaprob, β-mezosaprob, α-mezosaprob, polisaprob) are considered. 87.3 % of the organisms found are salicocapribs in the Kura River. Not all species are bioindicating organisms. The stated organisms are bioindicators. Materials from all the river systems of Azerbaijan (hydrology, microbiological, hydrobiological, hydrochloric) are collected. Collected materials refer to water ecology. Works are systematic and must fully meet the EU WFD requirements. Currently, biomonitoring measures that are in line with the EU Water Framework Directives (EU WFD) are not being implemented in a complex manner [3, p. 115].

Experts estimate that more than 7,500 plant species, 10,000 invertebrate species, 152 mammals, 70 kinds of reptiles, and about 17 amphibious species are found in Georgia, Armenia, and Azerbaijan.

Since the beginning of the 20th century, major human developments, including economic and population growth, have occurred in the South Caucasus. These activities, such as increased water use for domestic, municipal and industrial needs, agricultural irrigation, energy and reservoir purposes throughout the basin, have changed the river's ecology over time. As a result, the ability of the water to support natural ecosystems in the Kura River Basin is now in jeopardy.

Almost more then 60 species of fish inhabit the Kura River and its tributaries in Azerbaijan. Some common families include cyprinidae (sazan, bream, roach(vobla), et. and many of these fish are endemic to the region. Among rivers of the Caucasus, the Kura has the largest number of endemic species. The upper section of the river supports much higher biodiversity than the lower half, which is typically more turbid and polluted. This pattern is also apparent in most of its tributaries, especially the larger ones that span more climate zones, such as the Aras and Alazani.

There are 196 species and semi-infusions registered in the Kura River. Among the mentioned infusion fauna there are some species, breeds and seasons that are new to science and fauna of the country.

As a result of hydrobiological studies conducted in different years, 86 species of zooplankton have been recorded in the Kur River. As a result of hydrobiological studies conducted in water reservoirs, the highest variation of zooplankton was observed in Varvara (58 species) and Shamkir (57 species) reservoirs and the weakest biodiversity in Mingachevir reservoir (35 species).

As a result of the hydrobiological investigations, various types of macrozoobenthos have been found in the Kura River. During hydrological studies conducted in water reservoirs 82 species of macrozoobenthos in Mingachevir reservoir, 118 species of Varvara water reservoir, 89 species of Shamkir reservoir, 108 species of Yenikend water reservoir were registered. Main the generalized species composition of macrozoobenthos in the Kura river is as follows:

It is formed by the Caspian fish that flows through the river and moves along the river to breed river fishes in the Kur River. As a result of recent studies the ictiofauna of the Kura river consists of 40 species. At present, The Kur River differs according to the intensity of occurrence, the most bulk, bum, ghost, weight, naha and adult fishes. These fishes have a specific weight in fishing.

Conducting various economic activities in the Kura River basin, in particular, the construction of industrial and household facilities has created a number of environmental problems in the region.

Pollution in the Kura river includes organic pollution from untreated sewage, heavy metals from mining, hydrocarbons from industry, nutrients and organo-chlorine pesticides from agriculture, and high sediment loads from deforestation and flood irrigation practices. Cities and industrial centers are the main sources of pollution, with low capacity of waste water treatment plants or their absence in general.

Effectively, the treatment capacity of the working waste water treatment plants does not exceed 20 % of the water volume in need of treatment. Accordingly, large quantities of waste waters are discharged into the Kura river untreated. With a population of 11 million this leaves a discharge load of 8.5 million inhabitant equivalent of organic pollution, of which more than 35 % is concentrated around Yerevan and Tbilisi. For example, sewerage collecting systems exist in about 40 towns in Georgia, but only 70 % of the urban population is connected.

In rural areas, the connection rate is much lower. Currently, only one waste water treatment plant of Tbilisi/Rustavi, managed by a private company - is in operation, but applying mechanical treatment only.

Human activity affects the state of riverine ecosystems through direct impacts on river biocoenoses (e.g. introduction of alien and invasive species), changes in water quality or physical state of habitats. The water quality of rivers is understood to mean the physical, chemical and biological characteristics. The Kura River quality is identified by a number of features [2, p. 102]:

• river water is in contact with well-wetted basin located above the erosion base;

• the effect of soil due to changes in the level of water in the rivers and low evaporation in river basins;

• the relationship between water quality indicators and quantitative indicators in rivers.

The observed pH values are normal and typical for mountainous rivers, especially in the upper reaches of the basin in both Georgia and Armenia. Although the river become quite low towards its delta in Azerbaijan, the average annual concentration of pH still in good conditions and varies from 8.0 to 8.2 in all the stations in Azerbaijan.

Dissolved Oxygen (DO) refers to the amount of oxygen dissolved in river water, and hence available to sustain aquatic life. DO is the most important indicator of the health of a water body and its capacity to support a balanced aquatic ecosystem of plants and animals. Wastewater containing organic – oxygen consuming - pollutants depletes the DO and may cause death of aquatic organisms. The average annual concentration of DO in the Kura river basin is satisfactory or higher, largely exceeding 7 mg/l, sustained by the rather natural hydro-morphological conditions and hydrological regime of the river. The higher the flow rate, the higher the DO concentration. The lowest concentration of DO was measured at Borjomi in Georgia and N.E. Banka in Azerbaijan. The DO increased in downstream direction in Georgia, reaching a maximum concentration at Rustavi, just before the outfall of the Tbilisi waste water treatment plants. The impact due to poorly treated waste waters from the waste water treatment plants is clearly shown in the DO reduction from almost 8 mg/l in Rustavi, to 7.2 mg/l in Shikhli, across the border in Azerbaijan.

The average annual concentration of DO during the period 2014-2020 in the Kura river basin is satisfactory or higher, largely exceeding 7,6 mg/l Kura Zardab point, 7,9 mg/l Aras Novruzlu, 7,5 mg/l Kura Surra (Figure 1), conditioned by the rather natural hydro-morphological conditions and hydrological regime of the river.

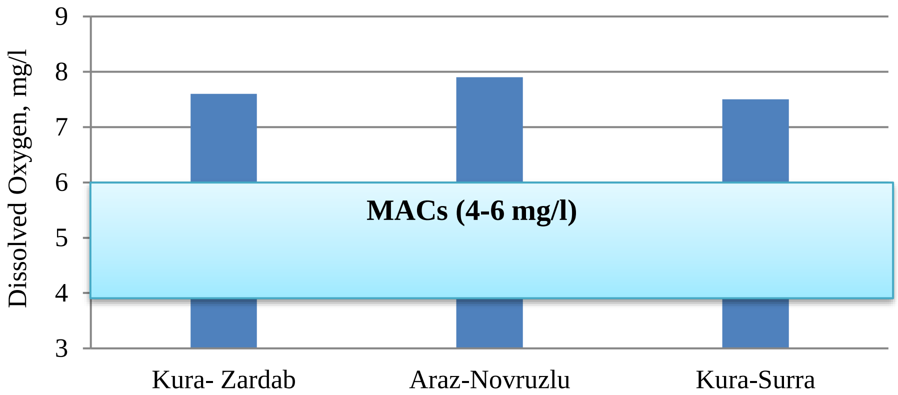

Figure 1 – The average annual concentration of Dissolved Oxygen (DO) in the Kura Zardab, Aras Novruzlu and Kura Surra monitoring stations (the period 2014 - 2020).

Biological Oxygen Demand (BOD_5) indicates the amount of oxygen needed for the biological degradation of organic substances in water in mg O_2/l.

At Shikhli, downstream of the Georgia-Azerbaijan border, the BOD_5 value has almost doubled, indicating pollution with organic substances. However, the value of BOD_5 exceeds the norm of 3 mg/l only in 10 – 20 % of all water samples analyzed, suggesting that the combination of specific hydrological regime, the natural features of the river basin, especially its mountainous character in the upper and middle reaches, causes a rather fast oxidation of organic substances.

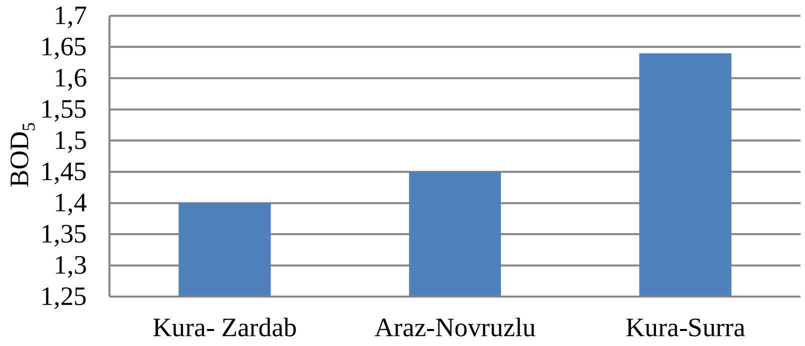

Figure 2 – The average annual concentration of Biological Oxygen Demand (BOD_5) in the Kura Zardab, Aras Novruzlu and Kura Surra monitoring stations (the period 2014-2020)

The higher the BOD_5 value, the higher the amount of organic matter from pollution in the sample. The Figure 2 show the average annual concentration of Biological Oxygen Demand (BOD_5) in the Kura Zardab, Aras Novruzlu and Kura Surra monitoring stations during the period 2014-2020. The MACs of BOD_5 for rivers are 3 mg/l.

Ammonium (NH_4^+) is the ionized form of ammonia (NH_3), which occurs when the water is acidic. The degree to which NH_3 forms NH_4^+ depends on the pH of the river water. If the pH is low, more NH_3 molecules are converted into NH_4^+ ions, while when the pH is high the hydroxide ion abstracts a proton from the NH_4^+ ion, generating NH_3. When NH_4^+-nitrogen levels in surface waters are too high, they can be toxic to some aquatic organisms. On the other hand, if the levels are only moderately high, plant and algal growth will usually increase, due to the abundance of nitrogen available as a nutrient. Accordingly, this will impact on other water quality attributes, such as increasing the BOD_5 and lowering DO levels. DO levels can also be lowered when NH_4^+ nitrogen is high due to the increased occurrence of nitrification.

Average annual concentration of NH_4^+ for the monitoring stations Debed-Ayrum in Armenia, Kura-Rustavi in Georgia and 5 monitoring stations along the Kura river in Azerbaijan. Trend is transboundary, with the NH_4^+concentrations increasing between Rustavi and Shikhli (Azerbaijan), related to the discharge of untreated waste water from the Gardabani waste water treatment plants, which operates with a low efficiency and provides only mechanical treatment.

After the Mingechevir reservoir the NH_4^+ concentrations decrease, due to the trapping of most sediments and nutrients carried by river water in the reservoir. Trend of increasing NH4+ is observed between Yevlakh and N.E. Banka, a result of the local impacts of untreated waste water released from villages and farmlands in the vicinity of the river, in addition to the outflow of agriculture drainage water with high nutrients load.

Overall, the concentrations of BOD_5 and NH_4+ indicate a limited impact of human activities on water quality in the Kura river basin, as most measured concentrations did not exceed the established Maximum Allowable Concentration (MAC) limits (these from Soviet times which are not very much to the point nowadays). Exemptions were observed for certain months during the low flow seasons. The above analysis also shows the occurrence of certain transboundary issues in water quality, caused by the releases of organic pollutants into the river from municipal and agricultural sources. Although the impact on chemical river water quality appears to be still limited, there is an urgent need for the riparian countries to develop a long-term integrated regional environmental compliance action plan aiming at reducing the pollution loads from different sources, with special focus on municipal waste water from main cities and villages located in the river basin. Meanwhile there is a lack of information on the impact of pollution loads on the biological river water quality.

In the countries of the Kura river basin increased attention is paid to the problem of heavy metal pollution of the aquatic environment. Mining activities, metallurgical, chemical and leather industries, as well as natural geochemical and hydro-chemical processes all pose a threat to surface water contamination with heavy metals.

Heavy Metals are metals with a high relative atomic mass, including arsenic, copper, cadmium, chromium, lead, manganese, mercury, nickel, and selenium, persisting in nature and potentially causing damage or death in animals, humans, and plants, even at concentrations as low as 1 – 2 micrograms. Used in industrial processes, heavy metals are carried by air and water when discharged in the environment. Since heavy metals have a propensity to accumulate in selective body organs (such as brain and liver) their prescribed average safety levels in food or water are often misleadingly high.

In the countries of the Kura - Aras river basin increased attention is paid to the problem of heavy metal pollution of the aquatic environment. Mining activities, metallurgical, chemical and leather industries, as well as natural geochemical and hydro-chemical processes all pose a threat to surface water contamination with heavy metals.

During the period 2014 – 2020 average annual concentration of copper (Cu) for the monitoring stations was observed in Aras Novruzlu 2.12 mkg/l, Kura Surra 9,79 mkg/l. The MACs of Cu for rivers are 10 mkg/l. For this period average annual concentration of zinc (Zn) was observed in Kura Zardab 3,89 mkg/l, Aras Novruzlu 7,92 mkg/l, Kura Surra 17,5 mkg/l. The MACs of Zn for rivers are 10 mkg/l.

The average annual concentrations of Zn as observed at monitoring stations in Azerbaijan. A transboundary impact is clearly visible for Shikhli, downstream of the border with Georgia. Also the Mingechevir reservoir's impact on trapping the Zn load can be observed, as concentrations downstream the reservoir are much lower than those in the upstream area. However, due to the local sources and the contribution of the Aras river, Zn concentrations increase again in Shirvan, to reach a maximum of 16,6 mkg/l. Further downstream the Zn concentrations decrease sharply in North East Banka, to 2,35 mkg/l (UNDP/GEF project, 2013).

High concentrations in Shikhli are due to transboundary loads from anthropogenic activities in Georgia, including releases from the Khrami river, while the high concentrations in Shirvan station are due to local sources upstream of the station as well as the contribution from the Aras river.

The concentration of phenol in the Kura river at Shikhli, downstream of the border between Georgia and Azerbaijan, exceeds the Azerbaijan and Georgia MAC limits (0.001 mg/l) at least 2-fold, hinting at the high level of pollution coming from Georgia, and possibly attributed to industrial discharges from the Rustavi industrial area, located about 20 km upstream of Georgia's border with Azerbaijan. The concentration of phenol reduces after the Mingechevir reservoir, possibly due to less anthropogenic activities in this river stretch. Further downstream the phenol concentrations slightly increase at Shirvan, indicating the impacts from high population numbers and the lack of sanitation services in the cities of Shirvan, Salyan and others. Additionally, also the Araz river can have contributed to the increase in phenol concentrations. The analysis of the available data from water quality monitoring stations in the Kura – Aras river basin shows limited evidence of transboundary pollution on an annual basis, due to the hydro-morphological characteristics of the rivers in the upstream. These largely mountainous rivers are characterized by higher velocities of water flow, contributing to improved aeration processes and the decrease in organic matter.

Some countries in the basin experienced a significant economic decline during the last decades, the stress on water quality in some parts of the river has decreased, at least temporarily. For the future, as the economies in the region are envisioned to grow, with some industrial activities already being restored, and with an envisioned decrease of the annual flood volume resulting from climate change, it is expected that threats to river water quality will again increase.

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