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THE MAIN FACTORS AFFECTING THE FORMATION OF MACROZOOBENTHOS IN THE RIVERS OF AZERBAIJAN-A REVIEW

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Abstract. The article provides information on the main factors affecting the formation of macrozoobenthos. The focus here is on the structure of macrozoobenthos, indicators of the saprobity index of macrobenthos in river ecosystems, factors of influence of macrobenthos in rivers of urbanized areas and features of the influence of heavy metals on macrozoobenthos. At the same time, cluster analysis was carried out. Through cluster analysis, species composition and quantity development of dominant species were determined. Cluster analysis was performed using the UPGMA method, Euclidean genetic distance index and Bray-Curtis's analysis in 2 directions. The main emphasis was placed on the distribution of macrobenthic organisms by region. The analysis was carried out in 9 regions, it was found that the maximum development was in the 9th cluster (49.73%).

Keywords: *macrobenthos, biomass, region, fauna, saprobity, species.*

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1. Introduction

Important factors affecting the formation of hydrobionts in rivers are the flow rate, the nature of the soil, aquatic plants, biotopes, water transparency, pH, and the content of solutes (Protasov *et al*., 2011). Studies have shown that the flow plays a leading role in the formation of water ecosystems. River flow forms the course of rivers, determining the stability and mobility of bottom sediments, the transport of course materials in the form of suspended and conducted sediments (Fedorovskiy, 2017). At the same time, the presence of a special bottom fauna for various soils is fundamental (Chertoprud, 2011).

At the same time, the factors of formation of the structure of macrozoobenthos are closely related among themselves and are determined by the living conditions of bottom invertebrates, a complex of physical, chemical, and biotic parameters (Aliyev *et al*., 2021a). An intuitively clear and visual method of complex description of the main factors of macrozoobenthos formation is the separation of river bottoms into biotopes. So, Jadin (1940) singled out five main river biocenoses for areas with significant flow-lithoreophilus, psammoreophilus, argyloreophilus, pelloreophilus, phytoreophilus. Lithoreophilic and argillophilic biocenosis predominate in the rivers of Azerbaijan mainly in terms of area. For example, Shubina noted that there are three bottom

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biotopes characteristic of the Ural rivers: Pebble, sandstone, and gravel indicate the biocenosis of higher aquatic plants. Of the biocenoses, crushed stone is more widespread, it has the highest indicator, based on the number and biomass. There are 9 biotopes of water basins. From these biotopes in the rivers of Azerbaijan, “petrified soil in a fast stream”, “stones thrown with moss or algae” and “stone-sandstone soil” are found.

Several factors have a destructive effect on the fauna of invertebrates living in macrobenthos. For example, high speed, large volume flooding, drought, glaciation, etc. These factors lead to catastrophic consequences that cause serious damage to the bottom fauna (Aliyev *et al*., 2022). For example, a strong flood in the Kura River in 2010 led to a change in the biocenosis of the river. At the same time, the bottom of the lakes around the Kura River has been washed away, the ecological situation of the lakes with a bad hydro chemical regime has changed for the better for years. Completely flooded areas around the Kura. The Shin River of the Greater Caucasus periodically has strong floods and mudflows. As a result, water floods large areas, the formation of fauna is impossible on this river.

Illies (1961) was the first to pay attention to the pattern of differentiation of macrozoobenthos of the upper, middle, and lower reaches of rivers. The main water flow zones have been created: crenal-cold-water wells covered with crowns of trees, the amount of the initial crop is small, but the role of leaf fall is high, detritus pickers and crushers prevail in macrozoobenthos: ritral-oxygen-rich water, fast flow and stony soil, important role of producers in the energy balance (algae and macrophytes, a large number of phytophages and; potamal-laminar flow, sandstone and silty soil, relatively high temperature and oxygen deficit, poor development of producers, the dominance of detritophages and filtrators in macrozoobenthos is a river part located below the ritral. Further development of these ideas led to the separation of ephy, meta and gipo subzone in each zone (Petrojitskaya *et al.,* 2010; Chertoprud, 2011; Bogatov & Fedorovskiy, 2017; Khamenkova *et al*., 2017).

The study of complex formation processes of macrozoobenthos in rivers requires the introduction of methods that allow considering the simultaneous influence of interaction factors (Aliyev *et al*., 2021b). One of the modern methods of generalizing multiple factors into a small number of “indices” is the use of the method of multidimensional statistics (Shitikov *et al.,* 2013; Li *et al.,* 2012). They allow, on the one hand, to present a quantitative description of biological objects and the environment, and on the other hand, a general representation of a large array of data.

The analysis allows us to reveal the significant factors of the formation of the structure of macrozoobenthos for each group of watercourses. So, for the rivers of the Lesser Caucasus, the location in the Northeast and low temperatures, a small number of flowing lakes and a small anthropogenic impact on the territory are typical (Aliyev, 2022). A small number of macrozoobenthos and a small number of species included in it are most likely associated with an unsustainable and relatively cold growing season, as well as with a limited intake of organic matter (leaf fall) into tea.

In the lower reaches of the lake river system, located in the small southern part, the structure of macrozoobentos is greatly influenced by flowing lakes and large open spaces. The biomass of macrozoobentos also has a high species richness, the share of filtrates (up to 95% of biomass). The ingress of organic matter from flowing lakes, the influx of biogenic substances from farm territories and a relatively long biological summer contribute to the high trophiness of these watercourses and a rich new feed base for bottom invertebrates. In addition, the collection of organic matter from the source to the mouth is monitored.

Rapid population growth and active economic activity of man in the 21st century led to significant changes in the flow of matter and energy in terrestrial and aquatic ecosystems (Winberg, 1975; Semernoy, 2010). Water bodies and streams are subject to the intensive influence of numerous factors arising in connection with human activities. Anthropogenic transformations of freshwater ecosystems are found practically everywhere. It is known that the process of thermophication in Hydropower plants has a negative effect on macrofauna. Among the numerous methods of assessing the degree of pollution of water bodies and watercourses and the quality of water, a special place is occupied by the assessment of the state of ecosystems based on biological indicators. (Razlutskiy *et.al*., 2010). This circumstance is also relevant for rivers, where river ecosystems are ultimately affected by urbanization of water piles, rural and fishing waste, pollution of the territory with heavy metals, disruption of courses because of construction and forest clippings (Yakovlev, 2005; Kashulin *et al*., 2012; Sterligova *et al*., 2018).

2. Factors affecting the formation of the structure of macrozoobenthos

Urbanization of reservoirs significantly damages river ecosystems, as waste of a production and economic nature enters the flow of surface waters: biogenic elements, organic matter, mineral suspended particles, heavy metals, petroleum products, etc. (Tikhonova, 2011) water quality is negatively affected by surface runoff from construction and industrial areas (Pitsil, 2013) changes in the structure of macrozoobenthos occur for Rivers of different regions. Changes in the structure of the bottom fauna are manifested in a decrease in quantitative indicators, a decrease in species composition, structural degradation, and a decrease in the number of dominant species (Konnova, 2011; Lock *et al*., 2011).

The problem of eutrophication of rivers because of agricultural development also deserves special attention (Gao *et al.*, 2014; Nhiwatiwa *et al.*, 2017) in recent decades, larger amounts of organic and biogenic substances enter large and small rivers by fish farms (Sterligova *et al*., 2018). However, it is known that harsh natural climatic conditions can inhibit the development of eutrophication processes observed in mesotrophic and eutrophic water bodies in temperate latitudes (Yakovlev, 2005).

In the 21st century, the periodic dumping of toxic waste into rivers by industry, especially mining and metal-processing enterprises, creates global problems. In recent years, because of the exploitation of mineral deposits in the areas near the source of Balakan and Filizchay, located in the Balakan region of the Greater Caucasus, wastewater pollutes the rivers of the region. At the same time, industrial work of this type is carried out in the Rye field of Dashkasan region. These wastes contain Ni, Cu, Co, Zn, Cd, Hg, and toxic organic compounds (phenol, dithiophosphate, etc.) in the surface layers of river bottom sediments forms its high concentration. (Ozgeldinova *et al.*, 2018) the ecosystem of surface waters is also negatively affected by the oxidation process because of the fall of acid-forming substances from the atmosphere (their introduction into connection).

As can be seen from the pictures, 9 cluster analysis is called Euclidean genetic distance by the UPGMA method. Based on the analysis, the dominance of the quantitative development of macrobenthic organisms was determined. Of the 431 known species of macrobenthic organisms, 90 species have been dominant. It was established that the 1st cluster had 21 types, 2nd cluster had 5 types, 3rd cluster had 6 types, 4th cluster had 16 types, 5th cluster had 2 types, 6th cluster had 13, 7th cluster had 3 types, 8th cluster had 9 types, 9th cluster had 24 types.

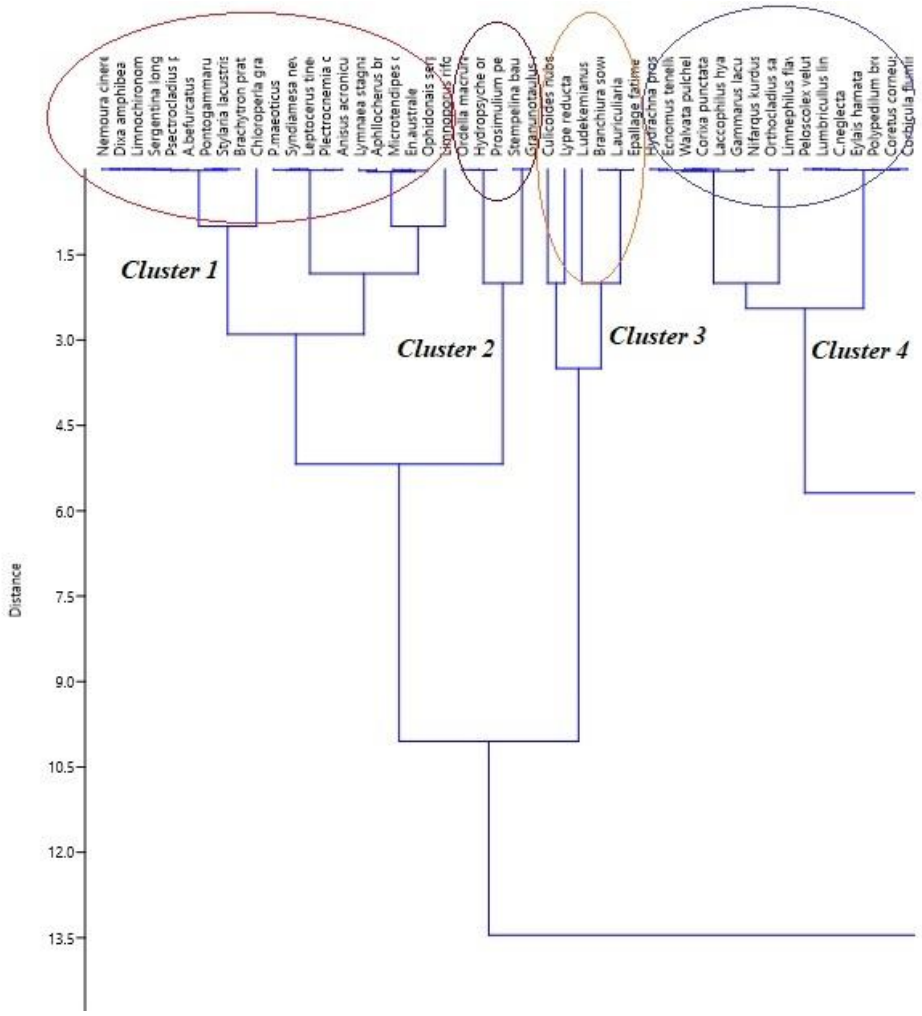

Figure 1. Cluster analysis. Dominance of macrozoobenthos based on the UPGMA method and the Euclidean genetic distance index

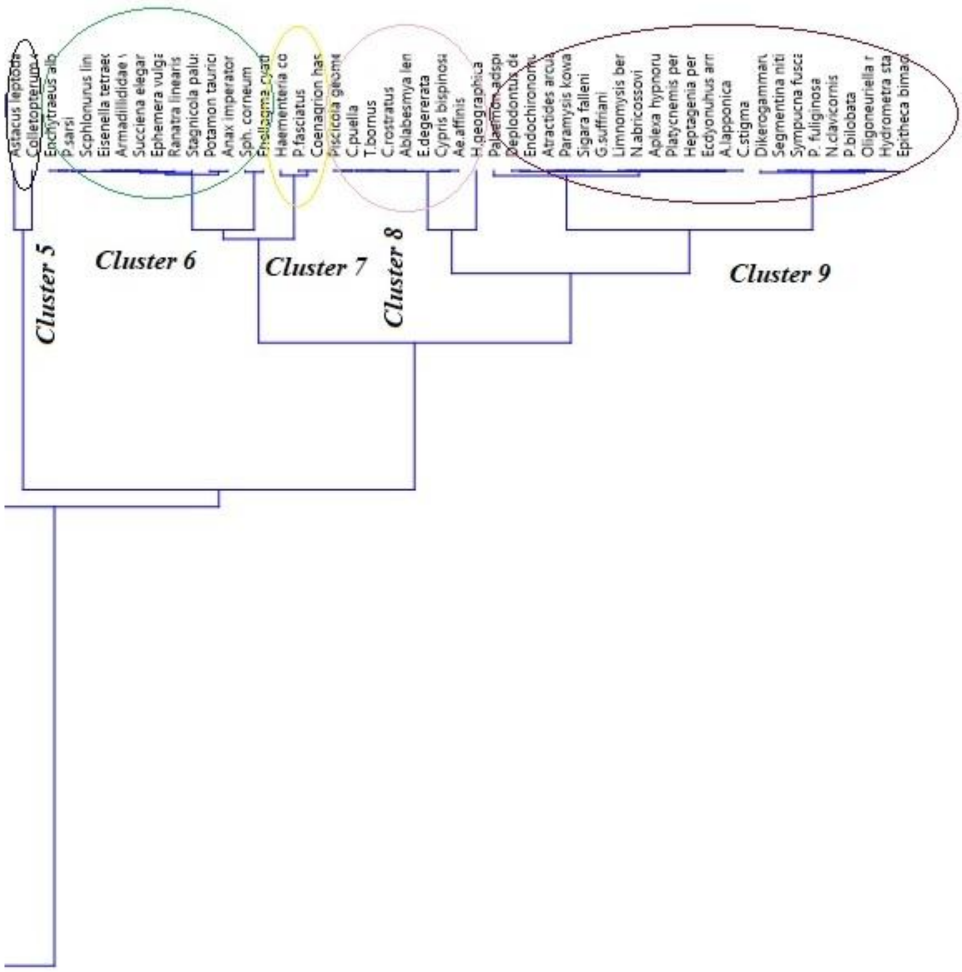

Figure 2. Cluster analysis. Dominance of macrozoobenthos based on the UPGMA method and the Euclidean genetic distance index

3. Indicators of saprobic index of macrozoobenthos in river ecosystems

In rivers, the mass of water moves from the source, which is higher than the sea level, to the outlet under the influence of its own gravity. Due to favorable oxygen and temperature regime created in rivers, self-cleaning processes take place. The degree of organic pollution in rivers decreases significantly due to biological self-regulation as the distance from the source of pollution increases. However, the intensive flow of organic matter beyond the bioactivity of biocenoses leads to the deterioration of the ecological situation in any rivers (Aliyev *et al.,* 2023). As a result, hydro fauna is destroyed, water becomes a source of infection. Flood events prevent biological self-cleaning in rivers, they simply displace polluting organic matter further upstream. The main sources of organic pollution in rivers are biogenic elements and heavy metals entering the basin.

The ability of different types of living organisms to survive well in different degrees of organic pollution is used to assess water quality and the degree of anthropogenic pressure on water bodies. Pollution assessment based on the Pantle-Buck method and its modifications is a widely used and more developed system of freshwater quality measurement. Saprobity indices of the macrozoobenthos of Azerbaijani rivers have been determined. The saprobity system was first proposed by the German researcher Kolkwitz-Marsson in 1908-1909. Later, these studies were continued by Nikitin and Stroganov. In recent years, Czechoslovak hydrobiologist V. Sladechek has developed a biological scheme of water bodies. According to Sladechek, saprobity is the biological condition of water bodies determined by the concentration of organic matter and the intensity of its decomposition process. In the saprobic system, several saprobic zones (xenosaprobic -x, oligosaprobic, α-β- mesosaprobic and polysaprobic) have been identified, which differ according to the degree of its contamination.

According to the scheme of biological quality of water drawn up by V. Sladechek in 1973, saprobic indicators are assigned zones (x – xenosaprobic, O – oligosaprobic, B – mesasaprobic, A – mesasaprobic and polysaprobic) (Semernoy, 2005; Shitikov et al., 2013). In addition, the volume of the pollution index depends on several natural factors - the size of the water flow, geographical latitude, etc. depends significantly on the parameters. For this reason, it is impossible to estimate the degree of anthropogenic organic pollution by indicator species without considering the data of pollution index indicators specific for the region and a few local factors.

As a result of human activities, many various pollutants enter water bodies. Pollutants are divided into several groups: 1. Household waste, 2. Industrial pollutants, 3. Toxic chemical active substances, 4. Surfactant substances, 5. Radioactive substances, 6. Thermal pollutants. As a result of this, unnatural conditions are created in rivers, which in turn leads to the destruction of fauna. Hydrobionts accumulate heavy metals in their organs and tissues through sorption, especially radioactive substances that are more accumulated in primitive aquatic organisms. These organisms form the basis of food for fish and their babies and play the role of a transmitter of radioactive substances.

It should be noted that macrobenthic organisms identified in Azerbaijani rivers play a key role in determining the biological quality scheme of water. 299 of the 431 detected species are indicator organisms: Hydrozoa - 2, Oligochaeta - 17, Hirudinea - 9, Mollusca - 21, Decapoda - 8, Amphipoda - 8, Mysidisea - 2, Isopoda - 1, Branchiura - 2, Branchiopoda - 1, Ostracoda - 7, Cerapatogonidae - 2 , Plecoptera - 11, Odonata larvae - 24, Ephemeroptera - 23, Hemiptera – 20, Coleoptera - 31, Trichoptera - 46, Diptera - 7, Chironomidae - 29, Heleidae - 11, Culicidae - 7, Simulidae - 3.

In the rivers of Azerbaijan, the value of the pollution index, which is not related to the "background" or anthropogenic pressure, based on the macrozoobenthos, was compared for the regions located at different latitudes and belonging to different water basins. The influence of local factors was also evaluated. There were no significant differences from the norm in the distribution of pollution index indicators. The non-observability of the difference allows us to use the parametric statistics method.

Factors are in descending order of influence: water flow size, proximity to settlements, latitudinal zonation, distance from the lake. Thus, the size of the water flow has a significant effect on the volume of the pollution index adjusted by the distance from the residential areas.

In general, relatively low pollution index indicators located in the β-mesosaprobe zone are typical for the rivers of Azerbaijan, mainly macrozoobenthos.

4. Effects of urbanized areas on the macrozoobenthos of rivers

Azerbaijan has a rich river network. Together, they form the Kura-Aras basin. Up to 13 million people live in the Kura-Aras basin. People use river water for many purposes. Thus, they are widely used in hydropower production, irrigation, recreation, navigation, tourism, drinking water supply of the population, irrigation works in agriculture and other purposes. At the same time, rivers are used for the development of poultry farming and fishing. The river is considered a natural breeding ground for transient and semi-transitory fish. In a word, rivers are of great importance in preserving the gene pool. 15% of Azerbaijan's electricity, and 28% of Georgia's, is accounted for by hydropower. More than 80% of agricultural products in Azerbaijan and Georgia are obtained from irrigated lands, where the role of Kura and Aras waters is decisive. Kura and Aras rivers and their main tributaries are formed from transboundary waters and cross the borders of neighboring countries (Iran, Turkey, Georgia, and Armenia) and flow into the Caspian in the territory of Azerbaijan. With this, all the ecological problems of the South Caucasus are transported to the territory of Azerbaijan and from there to the Caspian Sea.

Pollution is more in the part of the Kura River that passes through the territory of Georgia. Here, industrial waste and sewage are discharged directly into the river. At the same time, wastewater from a large industrial complex (Nitrogen plant) located in Rustavi is discharged into the Kura River without treatment. For many years, the wastewater of plants located in Sumgait city was discharged into Sumgait River. The river has become a dead river. According to the conducted studies, living things were almost non-existent in the mouth of the river. Various farms and small agricultural enterprises are in the coastal zones of other rivers. Their wastewater is also discharged into nearby rivers. As a result, the formation of the fauna deteriorates, blooms occur in some rivers. As pollution in rivers increases, it leads to mass destruction of larvae and springtails, the main characteristic group of rivers.

14 systematic groups of aquatic invertebrates were recorded in the macrozoobenthos of the Aras River. A defined group of benthic invertebrates is typical for European rivers. Their amount is relatively less than those mentioned for the entire Aras River. The number and biomass of Aras River macrozoobenthos varied widely both within a station and across sites.

Greater density and biomass of macrozoobenthos are observed in pollution in the central part of the city. An increase in numbers at the initial stage of eutrophication is typical for oligotrophic river systems. The "stimulation effect" decreases (turns off) in the relevant zone, and here the quantitative indicators are minimal. The composition of benthic communities is subject to change depending on the rate of river flow through the city.

The determined main trend is the decrease in the share of rheophilic larvae of amphibian insects belonging to the orders of Ephemeroptera, Plecoptera and Trichoptera in the tributary zone. The number of Plecopterans in the estuary areas decreases by about 4 times in the parts located higher than the industrial areas, Trichoptera larvae and pupae are found everywhere except the area-river estuary, where more pollution is observed. In the areas affected by the streams, the share of Plecoptera is more in the area near the source part of the stream.

The impact of urbanization seems to be the main reason for the small number of taxonomic groups of benthic invertebrates recorded in the river compared to other rivers of the Kura basin.

Water quality assessment of the Kura River according to the Woodiviss system has determined the deterioration of the water quality in the urban area.

Pollution occurs in some rivers downstream. Here, the quality of water decreases, a difference is observed in the scoring system (13-16). In the parts of the rivers close to the city, river water is polluted. Pollution assessment based on the pollution system is also an indicator of water quality. Thus, under the influence of urban flows, the composition of the macrozoobenthos of the river undergoes significant changes: the amount of rheophilic insects decreases until they completely disappear - the development of representatives of Simulidae, Plecoptera, Ephemeroptera, Trichoptera Oligochaeta and Chironomidae begins.

5. Effects of heavy metals on macrozoobenthos

It should be noted that in the part of the Kura River passing through the territory of Georgia and the Aras River by Armenia, the wastewater formed because of heavy pollution of Gajaran, Gafan copper-molybdenum and ore combines, Metsamor Nuclear Power Plant is discharged directly into the Aras River. The composition of this wastewater also consists of heavy metals and their compounds. As a result, heavy metals exceed the permissible concentration limit and have a negative effect on the formation and development of macrozoobenthos. It is known that the Aras basin is strongly influenced by mining, processing, chemical and energy enterprises. As a result of waste from those enterprises, it is the source of high concentration of Ni, Cu, Pb, Mn, Cr, Fe, Al, Zn and Cd in the surface layers of bottom sediments. The concentration of heavy metals exceeding the background indicator by 10-380 times is noted within a radius of 10 km from the pollution source.

It is known that the amount of heavy metal in river water undergoes drastic changes depending on the dynamics of the flow (Yakovlev, 2002). Greater concentration is noted in the winter-spring period and reaches its maximum during the abundant period. Due to the high durability of river systems, accumulation of heavy metals in sediments is relatively low. Thus, the structure of the macrozoobenthos is affected by previous critical stages, increased concentration of heavy metals and oxidation. It is difficult to fix them in one-size-fits-all sizes.

It is known that pollution of the water environment with heavy metals has serious consequences for macrozoobenthos: 1. Increase of bad biomass; 2. Degradation of invertebrates in terms of quantity and quality; decrease of sensitive species.

The assessment of the effect of man-made pollution because of oxidation of the water of rivers and coastal zones was carried out in accordance with the scale of biological distribution of organism and taxon species extracted by us for the Kura and Aras rivers. The benthic fauna of the studied areas includes species showing a low degree of water oxidation (*Baetis vernus, B. tricolor, Acentrella lapponica, Arctopsyche ladogensis*, *Potamantus ruteus*, *Metretopus borealis*).

The chemical parameters of the studied rivers are listed in Table 1. As can be seen from the table, water pH, oxygen regime, choral content, nitrate, nitrite, sulfate, phosphate, turbidity, turbidity, electrical conductivity of water was determined according to chemical indicators. Analyzes were conducted based on ГСТ 2874 standards, AI 9383 norms of European Union Directives. In rivers, pH (7.2-8.7), oxygen (8.2-10.1), chlorine (80.4-84.3), nitrate (0.01-0.04), nitrite (3.8-4.2), phosphate (115-142), turbidity (375-120), turbidity (415-914), electrical conductivity (1000-1180) changed.

Table 1. Chemical indicators of the water of the studied rivers in 2019-2020

Rivers	Indicators								
	pH	O_2	Cl	NO_2	NO_3	SO_4	Hardness, mg/eqv	Turbidity, NIU	Electrical conductivity
Akstafachay	8,1	94	84,3	0,03	3,8	126	310	826	1180
Zayamchay	7,2	9,6	80,4	0,01	4,1	130	434	780	1010
Tovuzchay	8,8	9.00	92,1	0,02	4,00	137	436	804	1040
Hasansuchay	8,6	8,4	80,4	0,02	3,7	132	420	840	1180
Khramchay	7,4	8,0	88,2	0,01	3,4	124	396	800	1020
Shamkirchay	8,8	10,1	94,2	0,03	4,2	140	340	600	1010
Soyugbulagchay	8,8	9,2	70,2	0,02	4,0	136	390	680	1015
Khachinchay	7,6	8,2	85,4	0,01	4,4	136	420	502	1030
Gar-Garchay	6,8	8,8	80,2	0,01	4,00	131	450	596	1070
Tartarchay	7,2	8,0	81,1	0,02	4,00	129	440	546	1080
Injachay	7,3	8,6	80,2	0,03	4,01	115	520	415	1050
Alazani	7,8	0,2	94,1	0,01	3,9	136	350	650	1060
Ayrichay	7,6	0,1	90,2	0,02	4,1	144	360	420	1080
Balakenchay	7,4	0,6	86,00	0,03	4,2	114	370	440	1100
Kumrukchay	7,6	10,2	82,6	0,01	4,6	160	330	380	1102
Lankaranchay	7,5	9,4	80,6	0,03	3,4	150	410	520	1130
Gudyalchay	7,9	9.1	92.2	0.01	7.0	136	370	800	1000
Gusarchay	7,8	9.2	90,4	0,02	4,1	140	410	814	1010
Aras River	8,2	10,4	75,2	0,02	3,26	118	310	720	1080

Table 2. Results of analyzes of water samples of rivers studied in 2019-2020

Rivers	Pb	Cu	Ni	Zn	Mn	Cr	Cd	Fe	Al
Kura River	4,73	1,78	5,58	0,36	4,08	0,03	1,87	49,96	193,8
Tovuzchay	12,37	0	1,68	0,40	2,64	0,07	4,10	58,46	63,30
Gudyalchay	5,21	0,19	1,27	0,21	1,24	0	6,72	64,02	58,94
Akhstafachay	2,47	0	1,43	0,05	1,24	0	2,10	9,51	38,91
Lankaranchay	2,02	0	2,04	0,16	22,16	0,01	0,87	1,55	0,88

6. Conclusion

It has been determined that the distribution of macrobenthos in rivers is highly dependent on environmental factors and the hydro chemical composition of water. The main parameters are the role of biotopes and biocenoses in the spread of organisms. Each biocenosis has its own character types. On the other hand, the distribution of organisms depends more on the river's flow rate and physical parameters. As a result of pollution factors, river water pollution causes the destruction of organisms when the number of heavy metals exceeds the permissible concentration.

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