Research in: Agricultural & Veterinary Sciences
Vol.9, No.2, 2025, pp.69-81
https://doi.org/10.62476/ravs.9269

ECOLOGICAL STATUS OF AZERBAIJAN'S RIVERS

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Abstract. Restoring and improving the natural beauty of the Karabakh and Eastern Zangezur region, which suffered from over three decades of occupation and severe ecological harm, is a pressing concern today. Recommended initiatives include implementing environmental monitoring of local rivers, constructing small water reservoirs and establishing small-scale hydroelectric power plants. Since 2021, a variety of studies have been undertaken, along with regular analyses of river water quality. Acts of sabotage have significantly harmed the region's agriculture, environment and irrigation systems. Therefore, it is vital to implement effective purification methods and prevent such violations. Although most river parameters are within acceptable limits, the presence of elevated nickel and copper levels is concerning. While many metals remain below the WHO's safety thresholds, the variability in concentrations - particularly for manganese, aluminum and iron - emphasizes the importance of regular monitoring to ensure water quality and identify potential sources of pollution. To guarantee the long-term safety and quality of the water supply, continuous monitoring and potential mitigation strategies are necessary. Thorough treatment is required to remove heavy metals before the water can be considered safe for consumption. Furthermore, additional studies should be conducted to evaluate the impact of this water on specific crops and blending it with cleaner water sources should be explored whenever feasible.

Keywords: *Analysis of heavy metals, water quality monitoring, pollution levels of rivers, the quality indicators, radioactivity analysis, microbiological structure.*

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Received: *28 April 2025;* ***Accepted:*** *23 June 2025;* ***Published:*** *7 August 2025.*

1. Introduction

The southeastern part of the Lesser Caucasus between the Tartarchay Araz River and the rivers of the volcanic plateau make up the rivers of the Karabakh region. Among these rivers, Tartarchay, Gargarchay, Khachinchay, Karacachay are the right tributaries of the Kur and Kondelanchay, Bazarchay, Hekarichay, Okchuchay and Basitchay are the left tributaries of the Araz. Tartarchay and Hekarichay (Bazarchayla) are the big rivers of the region and the rest are medium and small rivers (Imanov *et al*., 2021). In addition to them, there are dozens of medium and small rivers that dry up in the region (Cakhmagchay).

Tartarchay and Hekarichay, Bargushad River, Basitchay and Okchuchay rivers of the Karabakh region are important in terms of irrigation and energy resources. Rivers can be important for the biodiversity (fish) that live there, as well as for drinking water (Imanov & Alakbarov, 1957).

Revitalizing and enhancing the beauty of the Karabakh and Eastern Zangezur region, which endured over 30 years of occupation and significant ecological damage, is a key issue today (Imanov & Alakbarov, 1957). Proposals such as conducting environmental monitoring of local rivers, creating small-scale water reservoirs and setting up small hydroelectric power stations are highly recommended. However, the priority is to first assess the region’s current condition through detailed monitoring. Since 2021, numerous studies have been conducted in this area and regular analyses of river waters have been carried out.

Table 1. Sample water quality indicators

River	**pH**	**Conductivity µS/cm**	**(TDS) mg/L**	**Salinity %**	**DO mg/L**	**DO %**	**T°C**	**Resistance µs/h**
Oxchu River	7.87	508	254	0.03	8.89	96.2	19.2	0.047
Zangilan, 3rd Aghali	8.04	320	160.7	0.02	9.59	103.6	19.1	0.043
Hekari River	7.93	506	253	0.03	8.44	91.3	17.2	0.047
Zangilan, entrance bridge, Oxchu River	7.96	228	114.1	0.01	9.46	101.9	18.9	0.043

Source: Imanov et al. (2021)

Table 2. Analysis results of water samples taken from the Okchuchay River on June 2, 2022

Indicato r	**Unit of Measure**	**Burunlu upstream**	**Taghli middle stream**	**Jahangirbeyli downstream**
Fe	µq/l	362,7	752	125
Mn	µq/l	82,4	99,9	18,8

Source: Mao et al. (2018)

2. Materials and Methods

In recent years, water samples have been periodically taken from the Tartar River (up until August 2020). These samples underwent on-site rapid analyses and radiometric measurements, as well as organoleptic, physicochemical and microbiological analyses conducted in the laboratory of the Azerbaijan National Academy of Sciences (ANAS). The results of the comprehensive analyses revealed that the quality indicators of the Tartar River water do not meet the relevant regulatory requirements (Imanov & Alakbarov, 1957).

In 2023, the “Ministry of Ecology and Natural Resources” Caspian Complex Environmental Monitoring Department conducted regular monitoring of water bodies in the liberated Eastern Zangezur and Karabakh economic regions, specifically targeting the Okchuchay river in Zangilan district to assess and control pollution levels (Mammadov, 2002). These monitoring efforts were carried out every ten days throughout the year, with periodic reports prepared based on the analysis results and submitted to relevant authorities. During the 2023 monitoring, 108 water samples were collected from various points along the upper, middle and lower reaches of the Okchuchay. In total, 1,728 physical-chemical analyses were performed on these samples. To assess pollution levels, 39 sediment samples were taken over the course of the year and 398 physical-chemical and 3 ecotoxicological tests were conducted to determine the presence of heavy metals. The results revealed that zinc, iron, manganese and copper concentrations were higher compared to other metals.

In the first eight months of 2024 (January-August), six water samples were collected: three from the Kalbajar district and three from the Vang village. A total of 101 corresponding physicochemical analyses were conducted by “AzeLab” LLC.

Additionally, four monitoring sessions were conducted in the Balasoltanli area of the Hekari River in the Gubadli region, resulting in the collection of four water samples. “Azelab” LLC performed 70 relevant physicochemical analyses on these samples.

During the first 8 months of the year (January to August), regular monitoring of the Bargushad River was conducted every ten days. In total, 72 water samples were collected and 1,170 physical-chemical analyses were performed. To determine and monitor pollution levels in the river, 24 sediment samples were taken over this period and 240 physical-chemical analyses for heavy metals were carried out by “Azelab” LLC. The results indicated that concentrations of zinc, iron, manganese and copper were higher compared to other metals (Mammadov, 2002).

At the same time on April 13, 2024, a sample was taken from the area known as Lachın Boulevard and submitted for analysis at Azecolab's laboratory (number 21032-01) on April 15, 2024. Several techniques were used for analysis, including IC, ICP-MS, spectrophotometric methods and respirometric methods.

Table 3. Methods of analysis

PP Code	Test Parameter	Test Unit	Ref Method	Technique	LOD	MU, %
1380A04	Nitrate (NO3)	mg/L	ASTM_D4327	IC	0.016	9
1380A05	Sulphate (SO4)	mg/L	ASTM_D4327	IC	0.02	8
2005A18	Nickel (Ni)	µg/L	EPA_6020B	ICP-MS	0.02	2
2005A19	Copper (Cu)	µg/L	EPA_6020B	ICP-MS	0.11	2
2005A30	Lead (Pb)	µg/L	EPA_6020B	ICP-MS	0.01	2
3022A01	COD	mg/L	ASTM_D1252B	Spectrophotometric	4	11
3030A01	BOD5	mg/L	SM_5210D	Respirometric	1	14

The Limit of Detection (LOD) standards, along with the Measurement Uncertainty (MU), were determined.

3. Current situation of rivers Flowing in the Kharabakh and Eastern Zangezur Regions

The water resources in the Karabakh region, calculated using the CWBM method, were estimated to be 2.127 km^3 in 1998 and 1.804 km^3 in 2021. Over this time, there was a 15.2% reduction in total water resources with the Complex Water Balance Method indicating a decrease of 9.87%). By 2021, the long-term flow coefficient of Karabakh rivers was 0.2431, signifying that 75.7% of precipitation did not contribute to the total river flow and was utilized by other sources. During this period, surface runoff’s share in river replenishment fell to 47.9%, while underground runoff rose to 52.1%.

The rise in underground runoff is attributed to an increase in soil moisture levels, both maximum and actual, while the drop in surface runoff is linked to a higher rate of evaporation. It was found that 4.9% of the decrease in water resources from 1998 to 2021 was caused by climate-related factors, while the remaining 10.3% was due to other influences (Eminov *et al*., 2023).

Analysis of Water Quality Monitoring Results (2021-2024)

During the monitoring of Zabukhchay, Khachinchay and Kondalanchay throughout the year, water samples were analyzed and the quality indicators were found to be within permissible limits. Notable findings include that, the concentration of iron (Fe) was 1.2 times higher in the Tartar River. In the section of the Hekari River passing through the Zangilan region, the cadmium (Cd) levels were 1.3 times higher, in Tutgunchay rate for cadmium (Cd) reached 2.9 times higher than permissible limits and the levels of iron (Fe) were 1.5 times higher in the section of Guruchay passing through Fuzuli, while in the section near Shukurbeyli village, cadmium (Cd) levels were 4.0 times higher than allowable limits.

Throughout 2022, monitoring of Hekari, Zabukhchay, Tartar, Tutgunchay, Guruchay and Kondalanchay resulted in water sample analyses that indicated quality indicators remained within permissible limits.

In 2023, monitoring was conducted quarterly on Zabukh, Guruchay, Khachinchay, Tartar, Hekari and Kondalanchay. Analysis of samples from Zabukhchay and Guruchay confirmed that the quality indicators were within allowable limits.

Irrigation and energy purposes have led to the construction of the Sarsang and Sugovushan reservoirs on the Tartar River. Currently, several small hydroelectric power stations (SHPS) have been built and commissioned along different sections of the river.

During the first eight months of this year (January-August), a total of 6 water samples were collected from two locations on the Tartar River - 3 samples from the Kalbajar district site and 3 from the Vang village site. These samples were subjected to 101 relevant physical-chemical analyses by “AzeLab” LLC.

Based on the analysis results, it was found that only the concentration of iron (Fe), among the heavy metals, exceeded the permissible concentration limit by 1.1 times during the second quarter of this year and only at the Kalbajar district site (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan).

Hakari

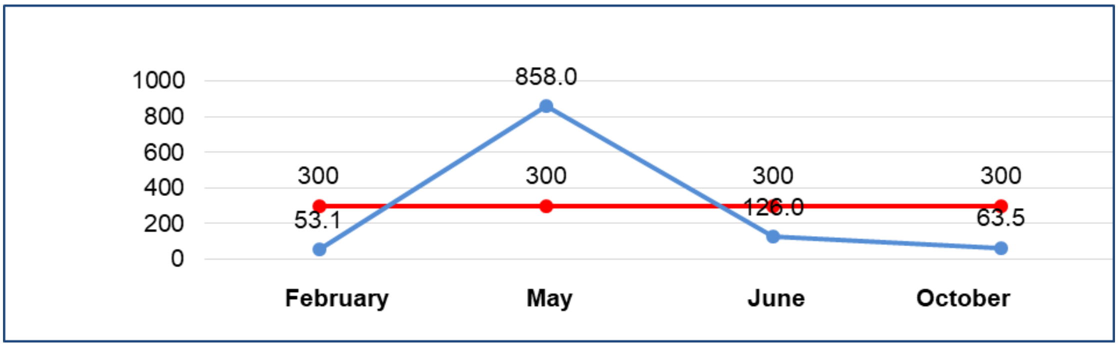

Figure 1. Change dynamics of iron (Fe) in Hekarichay's water environment for 2023, consentration limit is 300 mg/l

During the first eight months of 2024 (January-August), monitoring of the Hakari River was conducted once per quarter. A total of 3 water samples were collected and subjected to 49 relevant physical-chemical analyses.

Nickel (Ni): The nickel concentration of 3.8 µg/L exceeds the WHO guideline of ≤ 0.07 mg/L and is close to the EPA standard of ≤ 0.1 mg/L. It is crucial to address this level, as prolonged exposure could pose health risks.

Copper (Cu): The measured level of 3.32 µg/L also surpasses both the WHO guideline (≤ 2.0 mg/L) and EPA standard (≤ 1.3 mg/L). High copper levels may lead to gastrointestinal problems and affect water quality, necessitating further investigation and potential remediation.

Lead (Pb): The lead concentration is <0.01 µg/L, which meets the stringent guidelines set by both WHO and EPA. This is a positive result, as lead is highly toxic, especially for children.

While most parameters are within safe limits, attention should be directed towards the elevated levels of nickel and copper. Continuous monitoring and potential mitigation strategies are recommended to ensure the long-term safety and quality of the water supply. Based on the analysis of the water samples taken from the Hakari River, the quality indicators in all samples were found to be within the permissible concentration limits.

Table 4. Parametrs of some analysis taken from Lachin boulevard region on April 13, 2024

Test Parameter	Unit	Result	WHO Guideline	EPA Standard	Notes
Nitrate (NO_3)	mg/L	1.7	≤ 50 mg/L	≤ 10 mg/L	High levels can cause methemoglobinemia (blue baby syndrome) and other health issues.
Sulphate (SO_4)	mg/L	14.3	≤ 250 mg/L	≤ 250 mg/L	Excessive sulphate can cause gastrointestinal issues and affect water taste.
Nickel (Ni)	µg/L	3.8	≤ 0.07 mg/L	≤ 0.1 mg/L	Nickel in drinking water should be kept low to avoid health risks.
Copper (Cu)	µg/L	3.32	≤ 2.0 mg/L	≤ 1.3 mg/L	High copper levels can cause gastrointestinal problems and discoloration of water.
Lead (Pb)	µg/L	<0.01	≤ 0.01 mg/L	≤ 0.015 mg/L	Lead is highly toxic and even low levels can be harmful, especially to children.
COD	mg/L	6.01	≤ 25-50 mg/L	Not directly regulated	COD is generally more relevant for surface water; low levels are preferred for water quality.
BOD5	mg/L	4,00	≤ 5-10 mg/L	Not directly regulated	BOD5 is more relevant for surface water; low levels are preferable for drinking water quality.

Okchu River

Based on the analysis results of water samples taken from the Okchu River in 2023, the dynamics of pollutant variations by ten-day periods in the water environment are as follows (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan):

Table 5. Summary of water quality parameters (Shayifli Region)

	Hardness			NH_4			Mn			Mo			Fe			SO_4		
	PCL = 7			PCL = 0.5			PCL = 100			PCL = 250			PCL = 300			PCL = 500		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
January		16.4	16.5		0.0	1.3		144	574		164	308		392	908		372	586
February	17.1	14.0	10.0	1.3	1.2	2.4	438	642	674	233	247	674	638	808	811	498	476	277
March	10.6	10.8	9.9	1.5	1.6	1.6	427	386	625	234	170	233	875	104	183	372	381	247
April	11.8	8.4	7.6	0.0	0.0	0.0	163	175	153	95.4	202	219	223	886	664	205	104	200
May	8.8	8.4	6.0	0.0	0.0	0.0	414	319	158	234	204	122	203	111	946	212	294	171
June	3.1	3.89	4.2	0.0	0.0	0.0	212	170	143	38.5	44.4	65	154	705	444	93	133	141
July	4.86	6.0	6.9	0.0	0.0	0.0	325	102	238	135	143	245	181	511	101	129	205	217
August	7.3	7.76	8.3	0.0	0.2	0.0	125	19.8	34.8	221	248	237	564	34.1	58.9	213	225	253
September	8.2	8.1	8.0	0.1	0.0	0.0	11.2	10.8	7.5	263	141	94.9	40.5	77.1	44.5	251	257	372
October	9.69	8.33	10.1	0.0	0.0	0.0	35.8	142.7	20.5	153	126	170	53.1	51	37.7	359	390	403
November	10.45	12.5	12.4	0.0	0.0	1.1	8.1	276	140	73.5	273	114	8.1	162	76.6	348	476	498
December	11.4	9.23	11	0.0	0.4	0.0	200	35	45.8	295	237	277	161	87.7	75.1	400	272	365

Observations:

- **Hardness** levels vary, with the highest in February.
- **NH_4** levels are consistently low, mostly at 0.0, except for February and March.
- **Mn** shows significant variation, peaking in March.
- **Mo** remains mostly low, with peaks in March and May.
- **Fe** levels fluctuate significantly, especially high in March and August.
- **SO_4** levels also vary, with notable peaks in March and October.

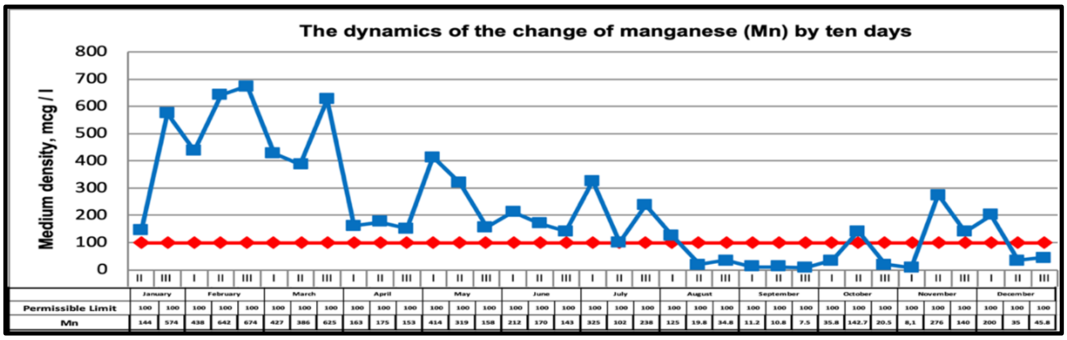

Figure 2. The dynamics of the change of Mn in Okchu river Shayifli region by ten days of 2023 year

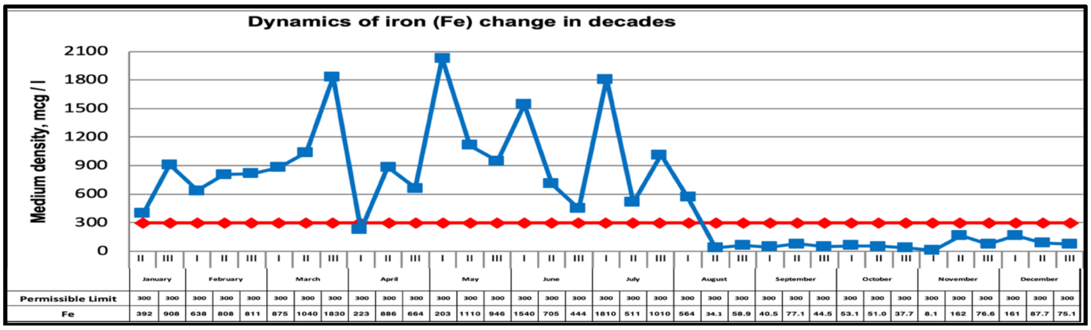

Figure 3. Dynamics of Fe change of Okchu River Sayifli region by ten days of 2023 year

During the monitoring conducted over the first eight months of 2024 (January-August), a total of 91 water samples were collected from observation points covering the upper, middle and lower reaches of the Okchuchay River, with 1,474 corresponding physicochemical analyses performed. To determine the level of pollution, sediment samples were collected during the current year and 240 relevant physicochemical analyses for heavy metals were conducted. Based on the results, it was determined that the amounts of zinc, iron, manganese and copper were higher compared to other metals.

In 2024, a total of 24 water samples were collected from the Shayifli point of the Okchu River, with 390 corresponding physicochemical analyses conducted. Based on the analysis of the water sample results, the pollution levels in the area were found to exceed the allowable concentration limits by 1.4 to 2.0 times, with the highest pollution recorded in the second ten-day period of March.

The concentration of ammonium ions (NH4) varied from 1.8 to 4.4 times above the permissible limits, with the highest levels occurring in the second ten-day period of January and the first ten-day period of February. Among heavy metals, the concentration of manganese (Mn) was found to be 1.1 to 4.0 times higher, peaking in January, while molybdenum (Mo) levels in January were 1.1 to 1.2 times above the limit. Iron (Fe) levels were above the permissible limits by 1.2 times in the third ten-day period of March.

It is worth noting that in February of the current year, due to observed changes in the water environment of the Okchu River (such as the foul odor spreading from the river to surrounding areas and the presence of large and small household and industrial waste flowing from upstream), intensive monitoring has begun to assess the pollution levels in the water environment.

Based on the analysis results of water samples taken from the Khachinchay in the second quarter, the concentration of iron (Fe), an indicator of heavy metals, was 1.2 times higher.

At the same time, monitoring results from the section of the Tartar River passing through the Kalbajar region indicated that the amount of iron (Fe) was 2.5 times higher in the second quarter. Monitoring in the first quarter revealed that ammonium ion (NH_4) levels were 9.4 times higher in the section of the Tartar River that runs through Vang village in Kalbajar, while in the second quarter, iron (Fe) levels were 2.4 times higher and in the third quarter, iron (Fe) levels were 1.6 times higher.

Monitoring results from the Comard village area of the Tutgun River revealed that in the third quarter, iron (Fe) concentrations were 1.8 times above normal levels. Similarly, assessments from the Red Bazaar settlement along the Kondelen River in the Fuzuli region indicated that Chemical Oxygen Demand (COD) levels exceeded permissible limits by 1.1 times.

Basitchay. According to the results of various sediment analyses conducted at three different points of the Basitchay River during the first eight months of 2024, the findings from the Rezdere point are presented in the table below.

Table 6. Heavy metal dynamics in the bottom depressions of Basitchay River in Rezdere region

	January	February	March	April	May	June	July	August	Permissible Limit
Mn	504	487	456	505	500	456	536	476	*100*
Co	7.01	4.88	2.56	6.16	7.05	6.77	7.12	8.96	*100*
Pb	9.0	6.77	4.56	9.76	7.8	5.08	4.89	4.88	30
Ni	28.77	23.5	2.56	26.1	20.8	29.6	34.5	18.4	*100*
Cr	27.05	30.9	22.1	34.9	30.4	34.3	30.44	33.3	350
Mo	16.55	10.04	0	0	0	0	0	0	250
Cd	0	0	0	0	0	0	0	0	*100*
Fe	28710	24560	24560	22,00	26,89	24630	26300	22400	300
Zn	66.7	50.4	41.56	35.1	40.2	35.6	47.5	48.7	1000
Cu	48.77	37.4	42.3	17.1	15.7	19.6	6.19	11.9	1000

Observations:

- **Mn** consistently exceeds the permissible limit.
- **Co**, **Ni** and **Pb** levels vary throughout the months, but **Pb** is notably high in January and April.
- **Mo** and **Cd** levels remain at zero across all months.
- **Fe** levels are significantly higher than the permissible limit, particularly in January.
- **Zn** and **Cu** levels fluctuate but remain below their respective limits.

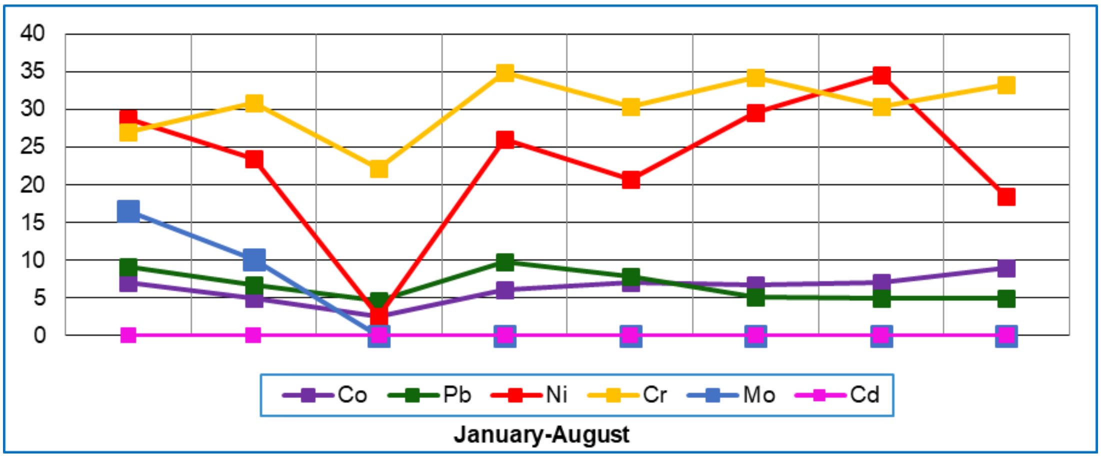

Figure 5. Co, Pb, Ni, Cr, Mo and Cd dynamics in the bottom depressions of Basitchay River in Rezdere region

Bargushad River. Based on the analysis of the results, the concentration of iron (Fe), among the heavy metals, exceeded the permissible concentration limits in several instances along the Bargushad River. Specifically, in the Gubadli area during the third decade of June, the iron concentration was 1.3 times above the limit. In the Gilijan and Aliguluugagi areas during the first decade of July, it exceeded the limit by 1.6 times, while in the Gubadli area, it was 1.4 times over the limit.

The dynamics of iron (Fe) concentration across different locations, based on the water samples collected from the Bargushad River over an eight-month period, reflect these fluctuations.

Table 7. Dynamics of change of heavy metals in the bottom depressions in the Bargusad River (Gubadli region)

	January	February	March	April	May	June	July	August
Mn	788	788	644	691	573	545	536	612
Co	6.5	4.22	2.04	12.04	8.05	5.96	6.96	6.29
Pb	2.44	3.25	4.12	18.3	14.7	11.04	9.88	12.66
Ni	9.77	6.44	5.11	2.07	5.06	3.83	8.99	4.56
Cr	7.01	4.55	3.44	26.9	31	25.4	20.4	27.4
Mo	4.55	0	0	0	0	0	0	0
Cd	0	0	0	0	0	0	0	0
Fe	24630	29360	25320	23,5	24,68	28760	21890	24780
Zn	44.4	31.7	36.05	63.6	59.8	47.8	53.6	39.5
Cu	40.55	29.7	20.04	45.6	40.3	47.6	53.4	35.6

The Bargusad River exhibits concerning levels of manganese and iron, both of which consistently exceed permissible limits, indicating potential ecological risks. Lead concentrations spike in April, warranting further investigation into possible contamination sources. Other metals remain within safe limits, suggesting localized issues rather than widespread pollution. Regular monitoring is essential to address these concerns and protect the river ecosystem.

4. Results and discussions

The rivers flowing from Karabagh and Eastern Zangezur regions are famous for their unique biodiversity. However, due to this ecological terror, the living beings here have been suffering for years and have had difficulties in developing

4.1. Fish Species and Distribution Areas

17 pieces of Carps (approximately 75% of all species), River goldfish, naked angora, naked Kura, Caucasian loach, golden loach, Caucasian catfish:

- Kondelenchay: Contains 14 different fish species;
- Gargarchay: 8 species of fish found here;
- Terterchay: Hosts 14 species of fish;
- Basitchay, Okchuchay and Hekerichay: 22 species of fish;
- Hekerichay: 10 species of fish;
- Terterchay: 6 species of fish;

4.2. Species Listed in the "Red Book" of the Republic of Azerbaijan:

- River Goldfish: Found in Zangilan, Lachin and Gubadli districts, as well as in Kelbecer;
- Zerdeper: Found in Zangilan, Lachin and Gubadli districts and in Khojaly and Fuzuli.

4.3. Water Quality and Radioactivity Analysis of Tartar River

Microbiological Contamination: Until August 2020, the microbiological contamination of Tartar River was characterized by serious issues. Analyses indicated that the river contained:

- The number of E. coli was 3-4 times higher than acceptable levels.
- Non-permissible cocci (Staphylococcus aureus), microscopic fungi (Candida, Aspergillus) and pathogenic bacteria (Salmonella) were detected in drinking water.

These results showed that Tartar River water was unsuitable for direct drinking. The microbiological contamination was linked to the discharge of organic waste from the Suqovushan reservoir, located near the Armenian armed forces.

Purification Stages: The contamination of Tartar River with organic waste required the application of both mechanical and biological purification stages. Implementing a multi-stage complete purification cycle could help make this water safer.

Post-War Changes: After the victory of the Azerbaijani Army in the 44-day Patriotic War, positive changes were observed in the microbiological indicators of Tartar River water: The number of pathogenic microorganisms significantly decreased.

4.4. Microbiological Structure of Okcuchay

In 2023, hydrobiological monitoring was conducted in the spring, summer and autumn seasons - specifically in April, June and October - to study the hydrofauna of the Okhchuchay River. During the monitoring, a total of 4 macrozoobenthos samples were collected from the upper, middle and lower reaches of the river and species identification analyses were carried out by “Azelab” LLC (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan).

According to the analysis results:

- In the samples taken in April, a total of 13 species of macroinvertebrates belonging to the Insecta and Annelida classes were identified. Among these species:
  - 4 species of meso-saprob organisms were considered adapted to live in moderately to slightly polluted waters.
  - 9 species of poly-saprob organisms were identified as organisms adapted to live in polluted waters.
- In the samples collected in June, a total of 243 macroinvertebrate species belonging to the Insecta and Annelida classes were identified. Based on the analysis of these species:
  - 3 species of oligo-saprob macroinvertebrates were found to be adapted to live in slightly polluted waters, with a total of 45 organisms.
  - 4 species of meso-saprob macroinvertebrates were identified as living in moderately polluted waters, with a total of 195 organisms.
  - 1 species of poly-saprob macroinvertebrate, belonging to the Annelida class and adapted to live in polluted waters, was found, with a total of 3 organisms.
- In the samples collected in October, a total of 57 species of macroinvertebrates belonging to the Insecta class were identified. Among these species:
  - 5 species of oligo-saprob and oligo-meso-saprob organisms, living in clean and slightly polluted waters, with a total of 23 organisms.
  - 2 species of meso-saprob organisms, living in moderately polluted waters, with a total of 26 organisms.
  - 1 species of poly-saprob organism, living in polluted waters, with a total of 8 organisms.

These analyses highlight the diversity of macroinvertebrates that are adapted to different pollution levels in the river environment. Each of these organisms has been identified as living in polluted waters. Research indicates that some organisms, such as those from the Hydropsychidae family of the Trichoptera order, which typically live in clean waters, can adapt to live in moderately polluted or polluted waters if a clean water environment is not available. This adaptive ability is a broad biological characteristic that allows organisms to adjust to changing environmental conditions.

General Observations: Factors affecting the microbiological structure include human activities, industrial waste, agricultural influences and natural conditions. Microbiological analyses of Okcuchay are essential for ensuring that the water meets sanitary standards for drinking. These analyses should be conducted regularly to monitor water quality. This situation presents a critical challenge for biodiversity conservation and fish stock management in the region. Addressing the pollution from the Okchu River, improving water quality in the Araz River and constructing fish transfer devices at the dams could help mitigate the negative impacts on the fish populations in the Hekari and Bargushad rivers.

The proposal to protect the Okchu River's ecosystem while utilizing its hydropower potential through a unified project is a promising solution. By constructing a regulatory dam at a height of 630 meters with a capacity of 5-6 million cubic meters, the highly polluted water entering the republic can be diverted and treated before it impacts downstream ecosystems. This dam would serve as both an ecological safeguard and a resource for hydropower generation. The collected water from this reservoir would be diverted via a DN 2200 mm pipe over a length of 13 km to the “Zangilan-1” Hydropower Plant (HPP), located near Zangilan city at a lower elevation of 470 meters. With an installed capacity of 9 MW, the plant could produce up to 70 million kilowatt-hours of electricity annually, making a substantial contribution to the region's energy supply.

This project would not only help reduce the pollution impacting the Araz River and surrounding ecosystems but also create a renewable energy source, enhancing environmental and economic sustainability in the region. The extension of the project to include a second Hydropower Plant (HPP), “Zangilan-2”, highlights a comprehensive approach to both environmental protection and energy generation. After the river water passes through the “Zangilan-1” HPP, it will be transported via a DN 2200 mm pipe for 17 kilometers to “Zangilan-2” HPP, situated at a lower elevation of 300 meters on the Araz River bank. This second plant, with an installed capacity of 6.5 MW, is expected to generate an additional 80 million kilowatt-hours of electricity annually (Majidli & Aliyev, 2024).

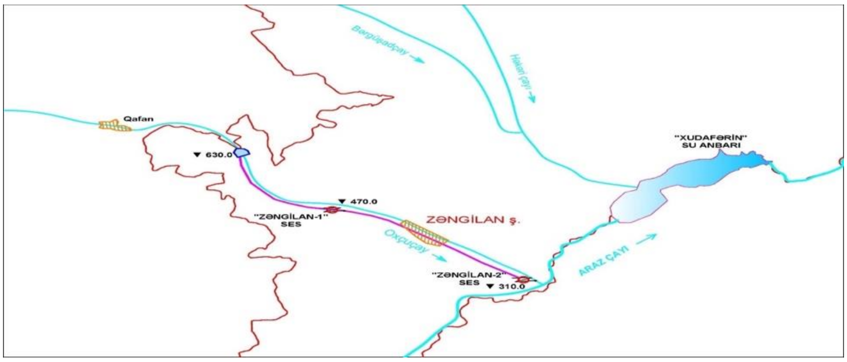

Figure 6. The location plan of HPPs planned to be built on Okchu River

Together, the two HPPs will produce a total of 150 million kWh of green energy each year, which is sufficient to provide continuous energy to over 120,000 people. This dual system also allows the river's ecosystem to recover, as the water channel will mainly carry clean water originating within the republic. This has crucial implications for the preservation of underground water resources and the overall ecological health of the Okchu River.

5. Conclusions

In this study, the characteristics of the water quality and metal concentrations in the surface water were analyzed. The Hekari River in Eastern Zangezur, with its pristine tributaries Khochaz and Shalva, offers significant untapped potential for improving water resource management and energy production in the region. Since the river's water quality meets the required standards for drinking purposes, it holds considerable importance for securing a safe water supply for the population. The river's formation in the mountainous Lesser Caucasus range, primarily fed by spring and glacier melt, contributes to its high water quality and lack of pollution. The elevation of its water catchment area creates a strategic advantage for utilizing its hydropower potential. This would allow for the generation of electricity and the use of the water in a self-flowing mode to supply major cities in the republic with water. If utilized efficiently, the Hekari River could play a critical role in improving regional infrastructure, benefiting water security and energy supply, as well as contributing to sustainable development.

The ecological balance of the Hekari and Bargushad rivers is significantly affected by their proximity to multiple reservoirs and the lack of fish transfer devices at the “Zabukh” and “Bakhtiyarli” dams. The absence of these devices disrupts the natural migration and breeding patterns of fish, limiting their ability to travel between the three existing reservoirs near the confluence of these rivers at Karalar village in the Gubadli district.7

Moreover, the pollution of the Araz River due to the entry of highly contaminated water from the Okchu River is an ongoing issue. This pollution has a severe negative impact on the aquatic ecosystems, not only of the Araz River but also indirectly on the fish stocks of the Hekari and Bargushad rivers. Research conducted by biologists from the Islamic Republic of Iran in the Khudafarin reservoir highlights the devastating effects of this pollution, with instances of mass fish die-offs attributed to the toxic influence of the Okchu River. Regarding the health risk assessment of pollutants. By diverting the polluted water and implementing “Zangilan-1” HPP “Zangilan-2” HPP hydropower solutions, the project offers a balanced approach to mitigating the environmental degradation around the river while generating a sustainable energy supply.

Given the complexities of managing pollution in the Okchu River, especially in relation to its hydropower potential, conducting more detailed investigations at a smaller scale would be essential. This would involve identifying the specific sources of pollution, analyzing the types of contaminants entering the river and developing targeted treatment and restoration measures to address them. Involving local communities, industries and other stakeholders in pollution management, raising awareness and ensuring adherence to best practices for water use and waste disposal. Implementing these targeted measures would support the broader project by not only addressing the pollution problem but also ensuring that hydropower development and river ecosystem preservation go hand in hand.

References

Al-Jabari, S., Sharkh, M.A. & Al-Mimi, Z. (2015). Assessment of runoff potential of a small watershed in Southern Palestine. In *Eighteenth International Water Technology Conference*, 194.

Eminov, Z.N., Mahmudov, R.N. & Teymurov, M.K. (2023). Modern operative-interactive methods in the assessment of water resources and their role in sustainability guarantee - the current state of water resources management in Azerbaijan. *Materials of the Scientific-Practical Conference*, 5 May, Baku.

Humbatov, F.Y., Mustafayev, I.I., Mammadzade, S.Sh., Aslanova, G.F. & Ibrahimov, Q.I. (). Assessment of Water Quality in the Rivers of Zangilan District, Liberated from Occupation - Institute of Radiation Problems of ANAS, Azerbaijan University of Architecture and Construction page 28.

Imanov, F.A., Alakbarov, A.B. (1957). *Modern Changes and Integrated Management of Water Resources of Azerbaijan*. Baku, 59. (In Azerbaijan).

Imanov, F.A., Nuriyev, A.A. & Imanov, S.F. (2021). Calculation of the main flow characteristics of Hekarichay. Emergency Risk Assessment in Liberated Areas - Scientific-Technical Conference May 21-22, 17.

Liu, J., Xue, B., A, Y., Sun, W. & Guo, Q. (2020). Water balance changes in response to climate change in the upper Hailar River Basin, China. *Hydrology Research*, *51*(5), 1023-1035.

Majidli, K.A., Aliyev, F.G. (2024). Protection of biodiversity in Bergushad and Hakary Rivers. *Research In: Agriciltural & Veterinary Sciences*, *8*(1), 13-20. https://doi.org/10.62476/ravs8113

Majidli, K.A., Mammadov, A.S. (2023). Utilization of Green Energy Potential of Rivers Located in East Zangezur Economic Region - Azerbaijan Reclamation and Water Management Open Joint Stock Company. Azerbaijan Hydrotechnics and Reclamation Science-Production Union, 201.

Mammadov, M.A. (2002). *Hydrography of Azerbaijan*. Baku, 255.

Mao, W., Yang, J., Zhu, Y., Ye, M., Liu, Z. & Wu, J. (2018). An efficient soil water balance model based on hybrid numerical and statistical methods. *Journal of Hydrology*, 559, 721-735.

Ministry of Ecology and Natural Resources of the Republic of Azerbaijan. https://web.archive.org/web/20141017031528/http://www.eco.gov.az/hid-chay-gol-suanbar.php

Nasirov E.H. (2023). Azersu OJSC, Sukanal ETL - Subject: Environmental Security of Transboundary Rivers Under Climate Change. The Current State of Water Resources Management in Azerbaijan. Materials of the Scientific-Practical Conference Baku, May 5, 500.

Rustamov, S.G., Kashkai, R.M. (1989). *Water Resources of Azerbaijan SSR*. Baku, 180. (In Russian).

Teymurov, M.A. (2023). Assessment of soil-vegetation cover and water resources based on modern scientific innovations. Scientific Advances and Innovative Approaches Proceedings, 27-32.