Water Resources of Azerbaijan: Their Quality Status and Utilization Features

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Abstract:

The presented article studies the possible causes for the mass death of red-necked grebes *(Podiceps grisegena)* near the village of Istisu (Khachmaz dist., Azerbaijan), while exploring the connections with the ecological state of water resources. The principal origins of anthropogenic pollution were identified grounded in an analysis of Azerbaijan's hydrological network, the condition of transboundary rivers, and the water quality of the Caspian Sea. The main sources include heavy metals, petroleum products, and organic compounds. Hydro chemical analysis exposed the facts about threatening pollution of the Caspian Sea, which results in bird poisoning and ecosystem disruption.The water parameters of the Oguz-Gabala-Baku water supply system were explored to conduct comparison on this issue. According to the investigation, they comply with hygiene standards and displayed a high level of environmental safety. This comparative analysis underlines the contrast between polluted transboundary water systems and better-controlled water sources, highlighting the need to strengthen environmental monitoring, promote international cooperation, as well as present modern water purification technologies. The results are of practical importance for the development of strategies to preserve biodiversity and prevent environmental disasters in the Caspian region.The article also includes a comparative study of the hydrochemical indicators of mountain rivers in northern Azerbaijan (using the example of the Gudyalchay/Gusarchay rivers) and natural «Shollar» water, as well as a discussion of how river flow influences the quality of coastal waters in the Caspian Sea. The results of field and bibliographic studies on the hydrochemistry of the region, the official technical characteristics of «Shollar» water, and reports and overviews on the ecological status of the Caspian Sea were used.

Keywords: water resources, transboundary rivers, heavy metal contamination, petroleum-derived pollutants, environmental monitoring, biodiversity conservation, aquatic pollution, mass avian mortality.

1. Introduction

Azerbaijan's river network comprises 8,359 (Ministry of Ecology and Natural Resources of Azerbaijan, n.d.) rivers, most of which are small rivers of local importance. Of these, only the two largest rivers, the Kura and the Araz, are longer than 500 kilometers and form the basis of the country's river system. It should be noted that Azerbaijan has 22 rivers between 101 and 500 kilometers long, 40 rivers between 51 and 100 kilometers long, and 107 rivers between 26 and 50 kilometers long. This structure shows that there are many small and medium-sized rivers in the country. They are important for local ecosystems and agriculture, but have little impact on the country's overall water balance. Most rivers are concentrated in the Kura River basin, which has 5,141 rivers, and the Araz River basin, which has 1,177 rivers. A total of 3,218 rivers and their tributaries flow into the Caspian Sea, making it the most important collection point and final destination of the country's water cycle. The average density of the river network is 0.36 km/km², which is relatively low compared to the mountainous countries in the region, where river density is higher due to the wetter climate and complex relief.

The 21 transboundary rivers are of particular importance to the country's hydrographic structure. The most important of these are the Kura, Araz, Ganykhchay, Gabirichay, Samurchay and Astarachay. These rivers account for the majority of the republic's water resources. However, due to their transboundary nature, water use in Azerbaijan depends on the environmental policies and economic activities of neighbouring countries. This condition attaches great importance, thus any change in water consumption or water quality outside Azerbaijan directly affects state of the country's internal ecosystems and socio-economic situation.

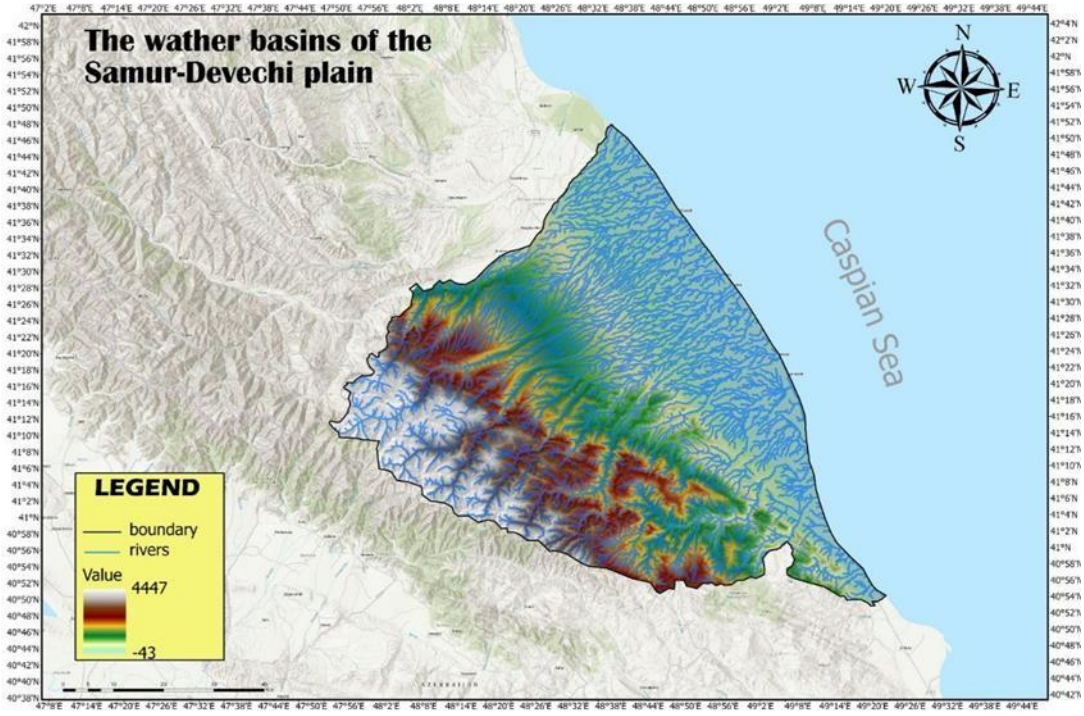

Figure 1. *Map of the watersheds of the Samur–Devechi Lowland, illustrating the hydrographic network and regional relief based on digital elevation model (DEM) data.*

The map shows the hydrographic network and relief of the Samur-Devechi plain in north-eastern Azerbaijan, along the coast of the Caspian Sea. It indicates the main watersheds and watercourses that constitute the region's surface runoff. The colour scale illustrates the differences in altitude, from the low-lying coastal areas (−43 m) to the mountainous regions in the south-west (up to 4447 m). The black line marks the boundaries of the watershed under study. The map was compiled using data from a digital terrain model (DTM) and shows the direction of watercourses and the distribution of river networks that determine the hydrological regime and ecological status of the Samur-Devechi plain.

Water status monitoring is carried out by the National Department of Hydrometeorology, which conducts stationary observations of the hydrological regime of rivers, lakes and reservoirs. There are currently 59 hydrological measuring stations in the republic, where water level, temperature, flow velocity, discharge and other important characteristics are systematically recorded. Historically, the first regular water level measuring stations were established on the Kura River at the end of the 19th century, which indicates a long tradition of investigating water resources and appreciating their significance. Gradually developing of water level network resulted in being an important tool for evaluating the dynamics of the hydrological regime and exploring the effects of human activities.

The water resources in Azerbaijan are limited, which account for only about 15% of the total water volume in the South Caucasus. Compared to its neighboring states, Azerbaijan has the lowest water supply per capita, with a total water potential of 310 billion m³ (United Nations Framework Convention on Climate Change, 2012) for the region. The total water balance of the country accounts for 30.9 billion m³, of which only 33% comes from inland waters, while 66% from transboundary rivers. This distribution sample underlines the republic's high exposure to external factors. The Kura and Araz rivers, which are the country's most important water sources, are heavily underwent to pollution in neighboring states. Industrial and agricultural wastewater containing heavy metals, pesticides, and organic compounds contaminate these water sources, leading to a deterioration in water quality and reduced suitability for drinking water and domestic use.

Rivers with a total volume from 28.5 to 30.5 km³ contain most of surface water. However, the indicated figure is prone to significant annual fluctuations. During periods of drought, the volume of surface water decreases to between 22.6 and 27.0 km³. This decline is not only due to natural causes, but also to intensive water use outside the country. The Kura and Araz rivers lose up to 20% of their water volume due to intensive water use in neighboring countries. For Azerbaijan, this means an annual water deficit of around 4 to 5 km³, which makes it really hard to supply water to the population.

The rivers of northern Azerbaijan, whose sources are in the foothills and mountains of the Greater Caucasus, contribute significantly to the hydrological regime of the Caspian Sea coastal zone. The nature and volume of river flow determine the supply of fresh water, dissolved minerals and potential pollutants to coastal ecosystems. Due to increasing anthropogenic pressure (agricultural, domestic and industrial wastewater), the potential role of these rivers in transporting pollutants to the Caspian Sea is increasing, requiring a comprehensive hydrochemical assessment (Gauthier & Reynolds, 2014; Rattner et al., 2008).

In recent decades, the situation has been further exacerbated by climate change, with an increase in average annual temperatures, and a decrease in precipitation and a stretching of drought periods. This dangerous tendency leads to a further reduction in water resources and disruption of seasonal flow patterns in rivers. As reported by the hydrological monitoring data, local stream flows decreased by 5.0 to 21.2% between 1991 and 2023, while the flow of transboundary streams reduced by 9.1 to 21%. This decline reveals a situation on deterioration of water resources because of a combination of natural and anthropogenic factors, which directly affects not only the ecological status of aquatic ecosystems, but also on the country's economy.

Complex regulatory measures are required, since Azerbaijan's water resources endure severe pressure. Although there are a lot of rivers in the territory of the country, most of them are small and cannot fully meet the population's water needs. At present, large transboundary waters depend on water supplies from neighboring countries. Pollution driven by industry and agriculture, including climate change, are aggravating the problem on water shortages and degrade water quality. Besides rivers, lakes and reservoirs also take an important part in Azerbaijan's complex hydrological system. 450 natural lakes in the territory of the republic cover a total area of about 394 km² in the country. The Lake Sarisu (the largest lake in the county-65.7 km²), contributes significantly to the surface runoff regulation and provides habitat for many waterbirds. Other crucial water systems, such as Lakes Agol, Beykshour, and Masanli, also play a vital role in managing ecosystems and climate, affecting the humidity and microclimates of neighboring regions.
Artificial reservoirs play irreplaceable role in the management of modern water resources in Azerbaijan. 136 reservoirs in the country with a total capacity of about 21,464 million cubic meters, are necessary for supplying water to the economy, households, agriculture, and energy, and also help regulate seasonal water consumption.

The Mingachevir, Jeyranbatan, Takhtakopru, Shamkirchay, Khanbulanchay and Vilajchay reservoirs, do not only provide water for human consumption and irrigation, but also constitutes the main components of the country's hydroelectric system.

In addition to their economic importance, these water bodies also fulfil ecosystem functions: they regulate groundwater levels, prevent soil salinisation and create favourable conditions for the formation of local biotopes. In recent decades, however, the influence of anthropogenic factors on water quality has increased, particularly the discharge of industrial and agricultural wastewater and transboundary pollution. The aim of this study is to compare the main hydrochemical parameters of the rivers flowing into the Caspian Sea, identify the differences between them and highlight the possible mechanisms of pollutant transport to coastal waters. Analysis of these processes makes it possible to assess the extent of anthropogenic impacts, identify ecological risks and propose measures to improve the state of aquatic ecosystems in the Caspian Sea coastal zone.

2. Materials and methods

A pathological examination of dead birds in the Caspian Sea region was carried out. The water quality of the Caspian Sea in the area around the village of Istisu was also analysed. The basic data used are the results of a comprehensive hydrochemical study of the Gudyalchay River (samples and analyses, published in Mammadova et al., 2024) (Rattner et al., 2008) and the technical characteristics of « Shollar» spring/bottled water (manufacturer's descriptions and regional documents on water sampling) (Thompson & Spurgeon, 2012). The comparison was made on the basis of the following key parameters: pH, total mineralisation (TDS), Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-} and NO_3^{-}. Additional information on the state of the coastal waters of the Caspian Sea was taken from reports and review articles (Gauthier & Reynolds, 2014; Ministry of Ecology and Natural Resources of Azerbaijan, n.d.).

3. Results and discussions

The ecological situation in the Republic is determined less by the quantity of water resources than by their quality. Over the last few decades, anthropogenic pollution of surface and groundwater has increased. The state of the Caspian Sea, into which most of the river water flows, is particularly worrying. The waters of the Kura and Araz rivers carry significant amounts of pollutants: hydrocarbons, heavy metals, nitrates and phosphates. Their accumulation leads to eutrophication of coastal areas, a decrease in oxygen content and the death of fish and water birds.

A significant indicator of these processes was the mass death of red-necked grebe (*Podiceps grisegena*) near the village of Istisu, in the Khachmaz district of Azerbaijan (Fig. 1). This aquatic bird, which lives in fresh and brackish waters, plays a key role in ecosystems by helping to regulate fish, invertebrate and plant populations. Besides, great crested grebe is also an indicator of water quality, as its population ratio and health are directly dependent on the water purity.

Figure 2*. Carcasses of red-necked grebe (Podiceps grisegena) found on the shore of the Caspian Sea on January 1, 2025*

On January 1, 2025, several dead birds were detected in the Caspian region, leading to great concern among conservationists, since such cases lay down the marker of serious habitat disturbances. Conducted

pathological examinations unveiled that there were no signs of contagious disease, rejecting viral and bacterial causes (Fig. 2). Nevertheless, characteristic poisoning lesions were discovered in the livers of the dead birds. During the laboratory analyses it was confirmed that heavy metals (lead, cadmium, and mercury) caused mass bird die-offs. Such elements are accumulated in ecosystems through water and the food chain, leading to devastating effects on species and ecosystems as a whole.

Figure 3. *Dissection of a red-necked grebe (Podiceps grisegena)*

The mass death of red-necked grebes observed in Istisu region of Azerbaijan, is not just an indicator of local tragedy, but also indicates about widespread environmental threat. This fact explicitly proves that anthropogenic pollution of transboundary rivers and the Caspian Sea has a direct negative impact on ecosystem stability and biodiversity. Though the Caspian Sea is exposed to petrochemical and industrial pollution, inland water bodies such as the Gabala-Oguz Canal suffer from pesticides. When these two examples are compared, it becomes clear that, while the sources of pollution differ, the result is the same: deterioration of water quality, decreased sustainability of aquatic communities, and the death of organisms, which are signs of ecosystem health.

As a consequence, the mass death of organisms underlines the necessity of systematic monitoring and comprehensive measures to reestablish aquatic ecosystems. Environmental protection measures and sensible use of water resources will help avoid further ecological disasters and protect biodiversity in both the Caspian Sea and the country's inland water sources.

4. Research methodology

Experts attended the field and laboratory studies, which were conducted in January 2025 at a veterinary clinic. The carcasses of red-necked grebe (*Podiceps grisegena*) found in the coastal area of the Caspian Sea, near the village of Istisu, were used as material for analysis. The collection and transport of biological material was carried out in accordance with veterinary and sanitary requirements and methodological guidelines approved by the Food Safety Agency of the Republic of Azerbaijan (AQTA) and the Ministry of Agriculture of Azerbaijan. Each specimen was placed in an individual sterile container and transported to the laboratory no later than 6 hours after discovery.

5. Pathological examination

The autopsy of the birds was performed in a specially equipped room, in compliance with biosafety and disinfection rules. The examination was carried out according to the standard veterinary protocol: an external examination was performed, and body weight, plumage, skin and mucous membrane condition were assessed. Then, the thoracic and abdominal cavities were opened one after the other. Particular

attention was paid to the condition of the internal organs, especially the liver, kidneys and lungs. Morphological changes were recorded: liver hypertrophy, changes in tissue colour and consistency.

6. Microscopic analysis

Microscopy was performed using a Leica DM500 optical microscope equipped with an ICC50 W digital camera. Examinations were performed at magnifications of ×40, ×100 and ×400. Morphological changes were recorded by microphotography and then by digital image processing. Signs of dystrophy, necrosis and degenerative changes in liver and kidney cells were analysed.

Analyses of the water quality of the Caspian Sea near the village of Istisu in January 2025 revealed the presence of a range of pollutants. The average dissolved oxygen content was 4.8 mg/l, which is at the lower end of the normal range and represents a risk of oxygen deficiency for aquatic organisms. The ammonium content (0.15 mg/l) indicates organic pollution, and the nitrate values (0.45 mg/l) are close to the upper limit. Phosphate concentrations (0.025 mg/l) are low, but already pose a risk of eutrophication. Petroleum products (0.18 mg/l, above the permitted limit) and sulphur compounds (H_2S 0.6-1.2 mg/l), which can cause mass mortality of aquatic organisms, are of particular concern. All this confirms the strong anthropogenic influence linked to both transboundary flows and local sources of pollution (Table 1).

Table 1. *Caspian Sea Water Quality (January 2025)*

Parameter	***Average Value***	***Standard / Comment***
Temperature (°C)	*18-20*	*Seasonal fluctuations*
Salinity (‰)	*12.5*	*Moderately saline water*
pH	*8.2*	*Neutral to slightly alkaline*
Transparency (m)	*4-6*	*Decrease in silted areas*
Dissolved Oxygen (mg/L)	*4.8*	*Low level, risk of hypoxia*
Ammonium (mg/L)	*0.15*	*Indicator of organic pollution*
Nitrates (mg/L)	*0.45*	*Near the upper limit*
Phosphates (mg/L)	*0.025*	*Risk of eutrophication*
Petroleum Hydrocarbons (mg/L)	*0.18*	*Exceeding, biologically hazardous*
Iron(mg/L)	*0.08*	*Within permissible limits*
Hydrogen Sulfide (mg/L)	*0.6-1.2*	*Critically high level*

In this context, the mass death of red-necked grebe (*Podiceps grisegena*) in the vicinity of Istisu seems to be a logical consequence. Birds, which are at the top of the food chain, accumulate toxins present in water and food. Pathological examinations have shown that the cause of death was heavy metal poisoning from wastewater and industrial waste entering the water.

In order to compare the state of the Caspian Sea, an analysis of water from the Oguz-Gabala-Baku water pipeline, which is an important source of drinking water, was carried out. The values for this water differ considerably from those for the Caspian Sea: the pH is within the normal range (7.69), the electrical conductivity is low (507 µS/cm for a normal value of <2500) and the total hardness is 246 mg/l $CaCO_3$ (below the permissible value of 350). The concentrations of ammonium (<0.1 mg/l), chlorides (6.4 mg/l),

sulphates (45 mg/l) and nitrates (6.9 mg/l) are well below the limit values. In addition, microbiological analysis revealed the absence of Escherichia coli and coliform bacteria, making the water safe for human consumption (Table 2).

Table 2. *Water Quality of the Oghuz–Gabala–Baku Pipeline (April 2025)*

Parameter	***Result***	***Standard (AZS 929:2023)***	***Comment***
pH	*7.69*	*6.5–9.5*	*Within normal limits*
Electrical Conductivity (µS/cm)	*507*	*<2500*	*Low mineralization*
Total Hardness (mg $CaCO_3$/L)	*246*	*350*	*Below the limit*
Ammonium (mg/L)	*<0.1*	*0.5*	*Very low level*
Chlorides (mg/L)	*6.4*	*350*	*Within permissible limits*
Nitrates (mg/L)	*6.9*	*50*	*Significantly below the limit*
Sulfates (mg/L)	*45*	*500*	*Within permissible limits*
Total Coliform Bacteria (CFU/100 mL)	*0*	*0*	*Not detected*
E. coli (CFU/100 mL)	*0*	*0*	*Not detected*

A comparison between these two bodies of water reveals a striking contrast. While the Caspian Sea suffers from complex anthropogenic pollution due to petroleum products, heavy metals, sulphur compounds and organic matter, leading to oxygen depletion and the risk of mass extinction of aquatic species and birds, the Oguz-Gabala-Baku water pipeline is characterised by a high degree of purity and meets hygiene standards. The main difference lies in the sources of pollution: the Caspian Sea is exposed to transboundary and industrial influences, while the Oguz-Gabala-Baku system, which crosses mountainous areas, is relatively isolated from industrial influences and controlled as a drinking water resource.

The study therefore highlights the need for a comprehensive approach: a combination of strict environmental controls, the introduction of purification technologies and the development of regional programmes for the preservation of the Caspian sea's ecosystems. Only such measures can prevent further cases of mass bird mortality and preserve the region's biodiversity.

According to Mammadova et al. (2024), the hydrochemical profile of the Gudyalchay river is characterised by moderate hardness, high hydrocarbon content and relatively higher concentrations of calcium and magnesium compared to typical low-mineralised spring water (Mamedov et al., 2007). According to published specifications, « Shollar» water has low mineralisation and the following indicative values: pH 6-8; Ca 6-11 mg/l; Mg 1-5 mg/l; Na 7-8 mg/l; NO3 1-2.5 mg/l; SO4 12-16.5 mg/l; Cl 2–11 mg/l; HCO3 27–60 mg/l (Mamedov et al., 2003; Costantini et al., 2020). A comparison shows that in the upper reaches of the Gudyalchai, higher concentrations of Ca (≈38-50 mg/l) and HCO_3^- (≈130-165 mg/l), with total mineralisation reaching 230-336 mg/l in typical samples and sometimes even higher in karstic and hilly areas (Mamedov et al., 2007).

The differences in composition can be explained by the geology of the basin: the leaching of carbonate rocks enriches the water with hydrocarbonates and calcium. At the same time, the « Shollar» forms as an artesian spring/well under conditions of limited interaction with these rocks and has a lower hardness (Mamedov et al., 2003; Costantini et al., 2020). These properties influence the behaviour of pollutants: fresh, low-mineralised water can dissolve and transport organic pollutants and dissolved metals in different proportions than hard carbonate water.

River runoff is one of the main vectors of pollutants in the Caspian Sea. According to regional studies and reports, accumulations of nitrogen compounds, phosphates, petroleum products and heavy metals from both river runoff and direct coastal sources are observed in coastal areas (Mammadova et al., 2024; İpeksu MMC, n.d.). Studies conducted in different parts of the Caspian Sea show that a significant proportion of heavy metals and organic pollutants accumulate in estuarine sediments, which has a negative impact on benthic and fish communities (Mammadova et al., 2024; GRID-Arendal, 2019).

The rivers of northern Azerbaijan (notably the Gudyalchay and Gusarchay) are characterised by local anthropogenic influences: agricultural wastewater, untreated or partially treated domestic wastewater, industrial waste and pollution from road traffic. This pollution results in high concentrations of nitrates, possibly in the presence of petroleum products and traces of heavy metals in estuaries, which, combined with the hydrochemical context of the rivers, determines the local level of pollution in the coastal waters of the Caspian Sea (Mamedov et al., 2007; Mammadova et al., 2024; GRID-Arendal, 2019).

It should be noted that changes in the flow regime due to climate change (changes in snowmelt patterns, increased extreme precipitation) also alter the transport of suspended solids and pollutants to the sea, as confirmed by regional studies on the state of the Caspian Sea (İpeksu MMC, n.d.; GRID-Arendal, 2019).

Assessing the state of freshwater and coastal waters requires regular monitoring of the following parameters: TDS, ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), HCO3−, SO4 2−, Cl−, NO3−, petroleum products, heavy metals (Pb, Cd, Hg, Zn, Cu) and microbiological indicators (total coliforms and E. coli). Monitoring should be carried out by a network of stations located from the upper reaches of rivers to estuaries and coastal points, with seasonal sampling.

Table 3. *Hydrochemical Characteristics of the Goychay River and "Shollar" Water*

Parameter	***Goychay River (average/range)***	***"Shollar" Water (specification)***
pH	*6.5–8.0 (neutral to slightly alkaline)*	*6.0–8.0*
TDS (mg/L)	*230–336; up to 2000 in karstic areas*	*Low mineralization (sum of ions)*
Ca (mg/L)	*≈45.5 (38–50)*	*6–11*
Mg (mg/L)	*≈15.3*	*1–5*
Na + K (mg/L)	*≈17*	*Na 7–8*
HCO_3^- (mg/L)	*≈149.6 (130–164)*	*27–60*
SO_4^{2-}, Cl^- (mg/L)	*Tens of mg/L, depending on geology*	*SO_4 12–16.5; Cl 2–11*
NO_3^- (mg/L)	*1–5 (in upper reaches)*	*1–2.5*
Temperature (°C)	*4–12 (seasonal variation)*	*Low, spring water*

Practical measures to reduce pollution in the Caspian Sea include: improving domestic and industrial wastewater treatment systems, introducing technologies to minimise agricultural runoff (fertiliser control, buffer zones), restoring coastal wetlands and developing sustainable water resource management programmes at the river basin level (Mammadova et al., 2024; İpeksu MMC, n.d.).

7. Conclusion

The results of the studies conducted allow the following conclusions to be drawn:

1. For ecology and nature conservation – The case of the coot deaths shows that constant monitoring of the Caspian Sea and early detection of ecological hazards are necessary.
2. For water management – A comparison with the Oguz-Gabala-Baku system shows that competent management and strict sanitary controls can keep water safe.
3. For biological safety – It is essential for human and animal health to prevent further accumulation of heavy metals and petroleum products in the water.
4. For strategic policy – Inter-state measures are needed to limit cross-border pollution of the Kura and Araz rivers, which are the main sources of toxins in the Caspian Sea.
5. A comparison of the hydrochemical properties of the Gudyalchay river and the «Shollar» spring shows that the river water, in a natural geological context, has higher mineralisation and Ca^{2+} and HCO_3^- content than the spring water, which is poorly mineralised. Anthropogenic sources and changes in flow rates lead to the transport of pollutants to the coastal zone of the Caspian Sea, where they accumulate in seabed sediments and have negative effects on ecosystems. In order to preserve water quality, constant monitoring and practical measures to reduce pollutant discharges are necessary.

References

1. Rattner, B. A., et al. (2008). *Environmental contaminants in aquatic ecosystems and their effects on wildlife*. Ecotoxicology, 17(6), 1231-1242.
2. Thompson, R. C., & K. A. Spurgeon (2012). *Pollution and aquatic ecosystems: The effect of heavy metals on wildlife*. Science of the Total Environment, 419, 59-68.
3. Gauthier, J. M., & S. J. Reynolds (2014). *Contamination of aquatic food webs by heavy metals: Implications for birds and other predators*. Journal of Environmental Management, 124, 173-182.
4. Мамедов Р.М., Алиев Ч.С., Фейзуллаев А.А. О роли рек в загрязнении Каспия //Известия НАНА. 2007. No 3. С. 67–74.
5. Мамедов Р.М., Агаларова Н.М., Джафарова Ш.Д., Ахмедова А.Ф. Антропогенное воздействие на реки Азербайджана, впадающие в Каспийское море //Проблемы опустынивания в Азербайджане. Баку, 2003. С. 239–247.
6. Mammadova, L., Negri, S., Tahmazova, M. K., & Mammadov, V. (2024). A Hydrological and Hydrochemical Study of the Gudiyalchay River: Understanding Groundwater–River Interactions. *Water*, *16*(17), 2480.
7. GRID-Arendal. Caspian Sea — State of the Environment (report). 2019. (State of the Caspian Sea environment report — land-based sources, pollution trends).
8. Costantini M.L., et al. Nitrogen and metal pollution in the southern Caspian Sea: evidence from macroalgae and sediment analyses. Sci Total Environ. 2020; (PMC article).
9. Ramazanova E., et al. Spatiotemporal evaluation of water quality and risk assessment in the Caspian Sea region (Kazakhstan study). Sci Total Environ. 2022.
10. Shollar-Baku water works materials: "Su ehtiyatları, hidrotexniki qurğular və ətraf mühit" (materials dedicated to 100 years of Shollar-Baku water complex). Sukanal.az / eecca-water.net. 2017.
11. https://eco.gov.az/az/fealiyyet-istiqametleri/hidrometeorologiya/yerustu-su-ehtiyatlari

12. https://az.wikipedia.org/wiki/O%C4%9Fuz%E2%80%93Q%C9%99b%C9%99l%C9%99%E2%80%93Bak%C4%B1_su_k%C9%99m%C9%99ri
13. https://az.wikipedia.org/wiki/Az%C9%99rbaycanda_su_ehtiyatlar%C4%B1
14. https://www.elibrary.az/docs/jurnal/jrn2016_235.pdf
15. https://pubs.rsc.org/en/content/articlelanding/2023/ra/d3ra00723e
16. https://nanobioletters.com/wp content/uploads/2020/10/22846808102.21482166.pdf
17. https://juniperpublishers.com/oajt/pdf/OAJT.MS.ID.555603.pdf
18. https://www.intechopen.com/chapters/60680
19. https://www.researchgate.net/publication/344872496_Water_Contamination_by_Heavy_Metals_and_their_Toxic_Effect_on_Aquaculture_and_Human_Health_through_Food_Chain
20. https://pubmed.ncbi.nlm.nih.gov/39505790/
21. https://link.springer.com/article/10.1007/s10661-024-13347-x
22. https://sciencepublishinggroup.com/article/10.11648/j.ijec.20190302.14
23. https://files.preslib.az/projects/eco/ru/eco_m5_3.pdf?utm_source=chatgpt.com
24. https://unfccc.int/ttclear/TNA/AZE-TNA-TNA_Adaptation_2012.pdf?utm_source=chatgpt.com