Water resources in Kazakhstan: analysis and challenges of environmental safety

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Abstract. This research focuses on the conservation and environmental safety of Kazakhstan's water resources. Water scarcity is a global issue, and its increase is likely to trigger a chain reaction with devastating consequences, including threats to the world's population, more than half of whom already lack access to clean drinking water. In Kazakhstan, disruptions to ecosystem stability, compounded by a lack of environmental awareness among the population, undermine sustainable development, regardless of the country's strong economic potential. Sustainable development in Kazakhstan is not only about oil production but primarily concerns the environmental safety of its population and its social stability. The authors' analysis of the environmental safety of water resources and the ongoing government conservation programs in Kazakhstan reveals troubling conclusions. Despite the implementation of legal regulations and the establishment of goals aimed at sustainable development, the level of environmental awareness and education in Kazakhstani society remains insufficient. Irregular water usage, the lack of adoption of water-saving technologies, and human activities that contribute to pollution and ecosystem degradation continue to pose significant challenges to Kazakhstan's water balance.

1 Introduction

The issue of environmental safety concerning water resources is one of the most pressing topics today. The worsening of this problem is attributed not only to natural and climatic factors but also to anthropogenic factor. Scientists have stated that salt water constitutes 97.5% of the Earth's water, while fresh water accounts for only 2.5%. It is predicted that fresh water may disappear within the next 25 years, leaving humanity with just 15 years to address this critical issue. The terms "environmental safety" and "ecological culture" first appeared in legal discourse in the 1960s. In our opinion, scientists at that time recognized that human industrial activities could become a catalyst for irreversible environmental processes, potentially leading to ecological disaster and bringing humanity to the brink of destruction. The natural ecosystem, with direct human intervention driven by specific physical and anthropological needs, has undergone significant changes. As a result, environmental problems, particularly those related to water, have worsened. Water is life, and the only alternative to its absence is death.

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The relevance of this issue is undeniable, as water is the source of life on Earth. This is why legislative efforts at both the national level and through international organizations, including the UN, have intensified. However, despite significant efforts and attempts to address legal issues concerning water safety, we continue to witness environmental catastrophes around the world, such as oil tanker spills and environmental crimes that pollute water bodies. The author's proposed research focuses on similar environmental challenges affecting Kazakhstan's water resources. In light of the current situation, the goal of this research is to analyze the environmental safety of Kazakhstan's water resources and assess the provision of clean water to the population.

2 Materials and Methods

The philosophy of scientific knowledge enables us to combine conceptual ideas and synthesize methodological tools in the investigation of global issues facing humanity. Among these, the authors consider water resources and their environmental safety to be one of the most pressing problems. Our practical research is grounded in a well-established classical methodology, which structures and organizes scientific work by defining the object, subject, and hypothesis. The interdisciplinary nature of our topic has directed attention toward specific tasks, such as understanding and analyzing the bibliography and evaluating content. In writing this article, the authors employed classical scientific research methods, including comparative analysis, observation, and abstraction, particularly when comparing statistical parameters. In this context, a systematic approach is essential.

3 Discussion

The proposed author's problems have a wide resonance in the scientific and publication space both in Kazakhstan and abroad. The shortage of water resources, as well as more than two billion people on earth who do not have the opportunity to use clean drinking water, is a global problem of mankind. The quality of drinking water is deteriorating, including in Kazakhstan [1]. Partly, the issues of ecosystem conservation and their impact on water management facilities [2], including the Aral Sea problem and the consequences of an environmental disaster in general for Kazakhstan, nearby transboundary states [2], in the western and eastern regions of Kazakhstan, there is currently a real threat of environmental pollution from waste from non-ferrous metallurgy and mining, oil industry enterprises [4, 5], was directly or indirectly touched upon in scientific publications and practical activities of Kazakhstani scientists.

From the perspective of the problem under consideration, the issues of cross-border relations between Kazakhstan and China, from where two large river streams Irtysh and Ili originate, are undoubtedly of interest, including the analysis of research groups of established trends and the likely scenario of the situation. In particular, scientists of the Institute of Geography of Kazakhstan believe that the shortage of water resources and environmental problems can exacerbate interstate relations [6], the opinion of foreign researchers correlates with the above, but it was clarified that fresh water and its shortage can cause both environmental and social upheavals [7]. The issues of environmental and economic culture of the population are touched upon in the works of the authors who devoted their research to the problem of environmental safety and sustainable development on the example of the Volga basin. The author proposes a set of measures where he considers the formation of a culture of consumption, sanity and awareness of everyday human existence to be the main one [8]

In summarizing the results of a brief thematic review of available scientific publications that address the author's research on the environmental safety of Kazakhstan's water resources, it should be noted that these issues encompass a broad range of content, both vertically and horizontally. The topic sits at the intersection of interdisciplinary scientific hypotheses and conceptual approaches. Economists, geographers, environmentalists, legal scholars, and even those in the humanities can find common ground in these research paradigms, which could lead to promising results, including potential resolutions to the identified problems.

4 Results

The issues of environmental safety of Kazakhstan's water resources occupy a special place in foreign and domestic state policy. Over the sovereign period, Kazakhstan has signed a fairly solid set of documents, both interstate and domestic, aimed at preserving the ecosystem order and shaping the country's environmental security. On February 5, 2024, Kazakhstan adopted the "Concept for the development of the Water Resources management system" of the Republic of Kazakhstan for 2024-2030. The development of this concept and its introduction into the legal field of the republic means that the government of Kazakhstan is seriously concerned about water problems and their environmental safety. According to the UN data, by 2030, a 40% shortage of water resources is expected [9] Water shortage is explained by many reasons, regarding Kazakhstan, it should be noted that the state ranks 11th in the world in terms of water consumption per capita out of 179 countries included in the Global Water monitoring [10].

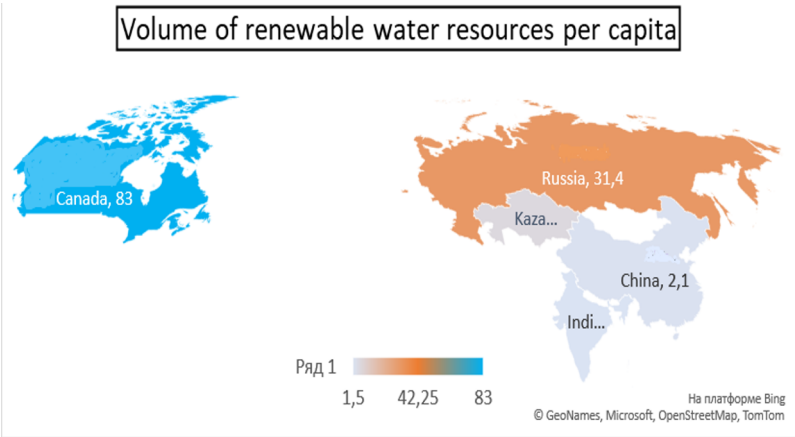

Fig. 1. Total volume of renewable water resources (in mil^{3}m) (compiled by the authors on the basis of open data. https://adilet.zan.kz/rus/docs/P2400000066).

Comparing Kazakhstan with other countries, it is clearly seen that the population does not save water at all, and low tariffs for water consumption contribute to its thoughtless and uneconomical consumption.

Currently, there is a total shortage of water supply for the population and industrial, agrotechnical needs in Kazakhstan. Transboundary river flows from China, and there are more than 20 of them, among which the Irtysh and Ili are the most important, as researchers of this problem note, almost the entire water balance of Kazakhstan is formed from the outside, at the expense of water sources from Russia, China (18.9 km^3), Uzbekistan, Kyrgyzstan. Of the eight existing water management basins in Kazakhstan, Balkhash-

Alakolsky and Irtysh, allocated in the east and northeast and bordering China, account for almost 75% of surface water resources [7].

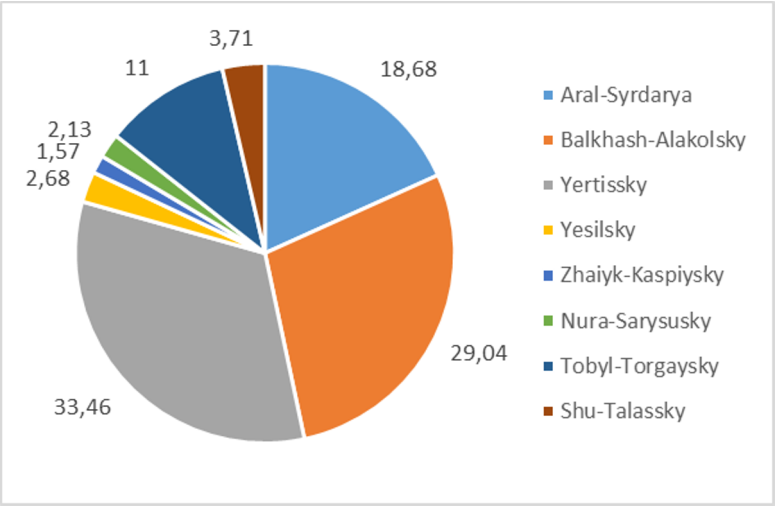

Fig. 2. Long-term average parameters of the water resource potential of the country's rivers in the context of water management basins (compiled by the authors on the basis of open data. https://adilet.zan.kz/rus/docs/P2400000066).

Kazakhstan's dependence on water from China and the Central Asian republics continues to grow. The situation is further aggravated by the ongoing crisis with the Aral Sea. Many researchers have written about the ecological catastrophe of the 20th century, marked by the disappearance of the world's fourth-largest inland body of water, primarily caused by human activity. The author's research indicates that there are technical solutions available to address this problem [3]. However, the construction of the Kush-Tepa canal in Afghanistan, which relies on the Amu Darya water resource, is leading to a potential global catastrophe. Uzbekistan, Turkmenistan, and Kazakhstan are directly affected by this development.

Fig. 3. Construction of the Kush-Tepa canal (from open sources: https://iz.ru/1489813/igor-karmazin/beshenaia-sushka-taliby-dobivaiut-glavnuiu-reku-tcentralnoi-azii).

The table below shows how the water resources of Kazakhstan in certain regions are related to external ones. It was compiled by the Institute of Geography and Water Safety. According to their data "... as of March 1, 2023, the average annual river flow in Kazakhstan decreased by 12.5 km^3 compared to 1960. Of these, 9.0 km3 or 72% of the total

reduction is accounted for by local rivers, and the share of transboundary rivers is 3.5 km3 or 28%." See table 1.

Table 1. Average annual river flow resources, km ^{3} [Concept of development of the water resources management system of the Republic of Kazakhstan for 2024-2030 // https://adilet.zan.kz/rus/docs/P2400000066].

Water management basins	Modern assessment			
	Total	including		
		neighboring countries	The Republic of Kazakhstan	
			Total	of these
				outflow from the Republic of Kazakhstan
Aral-Syrdarya	18.68	16.9	2.16	0.38
Balkhash-Alakolsky	29.04	13.5	16.5	0.96
Yertissky	33.46	8.32	26.5	1.36
Yesilsky	2.68	-	2.68	-
Zhaiyk-Kaspiysky	1.57	0.7	0.87	-
Nura-Sarysusky	2.13	0.45	1.68	-
Tobyl-Torgaysky	11	8.86	3.13	0.99
Shu-Talassky	3.71	2.77	0.94	
Total	102.3	51.5	54.46	3.69

The situation of dependence on external water sources for Kazakhstan has serious consequences related to anthropogenic environmental problems. Unfortunately, the society of Kazakhstan, despite the prospects of the water crisis, is not ready to solve the issue of the annual presence of "... a lot of water in spring and its absence in summer ...", which leads to enormous crop losses [3], afforestation and desertification, sandstorms also have an impact on the ecology of reservoirs, so affect the change in composition water [11]. On the one hand, we are witnessing desiccation, on the other hand, floods, the latter causing irreparable environmental damage to the state of water resources. In our opinion, it is necessary to develop a systematic set of measures to receive large amounts of water into prepared reservoirs. Unfortunately, at the present time it is necessary to state the irrational and essentially completely ineffective use of water resources in Kazakhstan (this includes large losses of water, the absolute absence of the use of new world technologies and reliance on existing world experience in water-saving technologies) [12, 13].

The natural, climatic, and geographical conditions of Kazakhstan result in varying levels of stress on the country's water management facilities, as shown in Figure 4, rated on a scale from one to five (low, moderate, high, very high, critical). On this scale, Central Kazakhstan's Nura-Sarysu water management facility is critically evaluated. Similarly, the Aral-Syrdarya water management facility in Southern Kazakhstan and the Kyzylorda region, the Zhaiyk-Caspian facility in Western Kazakhstan, and the Shu-Talas facility in the Zhambyl region are also facing severe water crises. These regions experience ongoing water shortages, and this year, Western Kazakhstan faced additional challenges due to severe floods. A significant portion of water resources is directed toward the industrial and agricultural sectors; however, disruptions to the hydrological system, excessive water withdrawal, and pollution from sulfates and pesticides have had a detrimental effect on the environment.

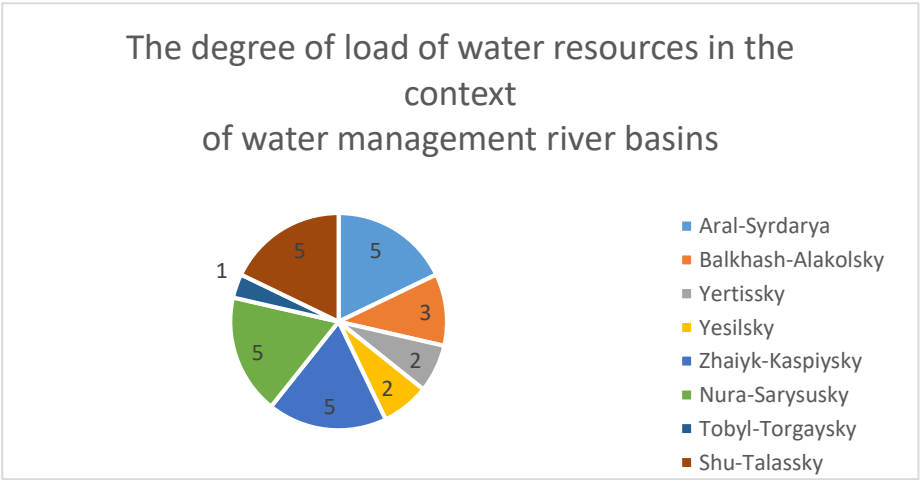

Fig. 4. The degree of load on water management facilities in Kazakhstan (Compiled by the authors on the basis of open sources: https://adilet.zan.kz/rus/docs/P2400000066).

Research by Kazakhstani scientists shows that natural water contains a wide variety of chemical elements, some of which have a beneficial effect on human health, while others may adversely affect his health. An undesirable element in the composition of water is considered to be "... sulfates – dissolved salts of sulfuric acid in the form of anions ...". According to the results obtained in the course of practical research, the scientific group noted that "More than 150 different sulfur minerals are formed in the terrestrial biosphere ... an increase in the degree of mineralization ..." leads to a gradual concentration of sulfates and an excess of the normalized values of their content in water [1, p. 66].

The quality of Kazakhstan's reservoirs, judging by the following table 2, according to the ratio of water suitability, gives an idea of the ecological state of water resources. See table 2.

Table 2. Quality of surface waters of Kazakhstan (from open sources: On approval of the Concept of development of the water Resources management system of the Republic of Kazakhstan for 2024-2030https://adilet.zan.kz/rus/docs/P2400000066).

Water quality class*	**Characteristics of water by type of water use**	**Water bodies and water quality indicators for the 1st half of 2023**
1st class (the best quality)	the water is suitable for all types of water use	11 water bodies (9 rivers, 2 reservoirs): Yesentai, Ulken Almaty, Kara Yertis, Arasan, Urzhar, Shagan rivers, Elek river of West Kazakhstan region; Usolka, Yertis of Pavlodar region; Aksu of Turkestan region; reservoirs of Buktyrma, Ust-Kamenogorsk of East Kazakhstan region
2nd class	the water is suitable for fish farming, recreation, irrigation, industry; only for domestic drinking water supply, a simple water treatment method is required.	11 water bodies (10 rivers, 1 reservoir): rivers Shilik (total phosphorus), Korgas (total phosphorus), Turgen (total phosphorus, Chemical oxygen demand (SOD)), Lepsi (total phosphorus), Aksu (total phosphorus, COD) of Almaty region; Karatal (total phosphorus), Buktyrma (manganese), Brexa (manganese), Ertis (manganese, suspended solids) East

		Kazakhstan region; Zhaiyk (suspended solids) of West Kazakhstan region; Shortandy reservoir (nickel, COD) Akmola region
3rd class	the water is suitable for recreation, irrigation, and industry;	24 water bodies (22 rivers, 2 reservoirs): the rivers Ile (magnesium), Sharyn (magnesium), Tekes (magnesium), Bayankol (total phosphorus), Kaskelen (total phosphorus), Karkara (magnesium), Talgar (total phosphorus), Temerlik (magnesium, total phosphorus), Bettybulak (Biochemical oxygen demand 5 (BPK5)), Zhabai (magnesium, BPK5), Sekisovka (ammonium ion), Silety (magnesium, BPK5), Tikhaya (ammonium ion, cadmium), Ulba (cadmium), Glubochanka (magnesium), Krasnoyarsk (magnesium, cadmium), Oba (suspended solids), Emel (magnesium), Assa (magnesium), Derkol (ammonium ion), Badam (magnesium, ammonium ion), Arys (ammonium ion), Kapshagai (magnesium), Astaninskoye reservoirs (total phosphorus, magnesium, BPK5)
	the water is suitable for breeding cyprinid fish species; it is undesirable for salmon;	
	household drinking water supply requires methods of conventional and intensive water treatment.	
> 3rd class	the water is suitable for irrigation and industry	2 water bodies (2 rivers): Shu River (phenols) and Keles River (phenols)
4th classs	the water is suitable for irrigation and industry;	37 water bodies (31 rivers, 3 canals, 3 reservoirs): rivers of Elek (ammonium ion, phenols*, chromium (6+)*), Cargaly (ammonium ion, phenols*), Emba (ammonium ion, magnesium, phenols*), Temir (ammonium ion, phenols*), Or (ammonium ion, phenols*), Aktasty (ammonium ion, phenols*), Cosestek (ammonium ion, magnesium, phenols*), Oiyl (ammonium ion, phenols*), Ulken Kobda (ammonium ion, phenols*), Kara Kobda (ammonium ion, phenols*), Yrgyz (ammonium ion, phenols*), Kishi Almaty (magnesium), Esik (suspended solids), Yesil (magnesium, suspended solids, phenols*), Shagalaly (magnesium), Zhaiyk (magnesium), Peretask tributary (magnesium), Yaik tributary (magnesium), Sharonov tributary (magnesium), Aksu (magnesium, sulfates), Karabalta (magnesium, sulfates), Toktash (magnesium, sulfates), Shyngyrlau (suspended solids), Saryozen (suspended solids), Karaozen (suspended solids), Ayet (magnesium, sulfates), Togyzak (magnesium), Uy (ammonium ion, magnesium), Gelquar (magnesium, mineralization, sulfates), Torgai (magnesium), Syrdarya (magnesium, phenols*), Nura-Yesil Canal (magnesium),

		Koshimsky Canal (suspended solids), K. K. Satpayev canal (magnesium), Samarkan (magnesium), Sergeevskoye (suspended solids, phenols), Tasotkel (sulfates, magnesium) reservoirs
	Deep water treatment methods are required for domestic drinking water supply.	
5th classs (of the worst quality)	water is suitable only for some types of industry – hydropower, mining, hydrotransport	2 water bodies (2 rivers): Makhovka (phosphates), Sarykau (sulfates) rivers

The sources of pollution in Kazakhstan's water basins include atmospheric emissions from industrial facilities and the reckless actions of humans (Homo sapiens), such as the disappearance of small riverbeds due to drying and pollution caused by large-scale mineral resource extraction. RSE Kazhydromet regularly surveys the water and adjacent coastlines, testing water and soil samples for contamination. The state of water bodies affects the ichthyofauna ecosystem, leading to imbalances due to the presence of heavy metals in water management facilities like Balkhash, Alakol, Kapshagai, Yertis, and Zhaik. There have been documented cases of mass fish and waterfowl deaths. Of all water management facilities, the Balkhash-Alakol reservoir is the most polluted, and further large-scale contamination could result in an environmental disaster comparable to the Aral Sea catastrophe [14].

4 Conclusion

Summing up the results of the author's research, we note that further forecasts are unfavorable, given the statement of the Minister of Ecology, Geology and Natural Resources that "...by 2030, water scarcity will be comparable to total water intake, and from 2040 the situation with water supply may finally deteriorate" [15].

The current situation indicates changes in the earth's climate balance, an increase in temperature is observed, as a result of gradual warming of the climate on the one hand, while moisture evaporation will be observed on the other. Accordingly, this will lead to a gradual decrease in river tributaries and a reduction in the area of the water surface. The Central Asian node on water issues may turn out to be a source of conflict and a tense situation in the struggle for survival.

The authors believe that strict measures should be taken to stop the irregular use of water resources, to intensify the implementation of the environmental code for the safety of water sources and to stop environmental barbarism. A program is needed to drastically reduce the anthropogenic factor and its impact on the environment. In particular, it is necessary to turn to the world experience of water-saving technologies, although Kazakhstan is already working on this issue by implementing subsidized agrotechnical program projects to close moisture, motivates agricultural production to use water-saving technologies, subsidizing and crediting entrepreneurs, farmers. Environmental safety of water resources is a favorable format for sustainable development of Kazakhstan.

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