Irtysh: Environmental Risks and Threats

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Abstract. Water is the source of life on Earth and a fundamental resource that plays a crucial role in environmental, economic, societal, and security-related issues. It is one of the key factors determining the stability of any state. The concept of hydro-hegemony, as used by the authors, highlights the hydropolitical dimensions of the issue and the ecological vulnerability of the Irtysh River, which flows through China, Kazakhstan, and Russia. The geographical positioning of the Irtysh River, with its source in China, allows the upstream country to control water intake levels, potentially disadvantaging the downstream nations, Kazakhstan and Russia. The ecosystem of Kazakhstan's Irtysh and Ili river basins is highly dependent on China's hydropolitical strategies, as a network of lakes-including Alakol, Zaisan, and Balkhash – as well as artificial reservoirs fed by these rivers, are at environmental risk. The aim of this research is to assess the impact of hydro-hegemony on the ecological status of the Irtysh River and the potential consequences for Kazakhstan. China's expanding agricultural policies, which include the expansion of cultivated areas and the construction of large-scale dams and reservoirs, have increased water withdrawals from rivers that flow into Kazakhstan. An analytical review of the available materials indicates that China is actively developing environmentally sustainable water management technologies, whereas Kazakhstan continues to experience water pollution from industrial enterprises, posing a potential threat to the river ecosystem.

1 Introduction

The relevance of this topic is undeniable, as nearly half of the world's population lacks regular access to drinking water. Forecasts for the next fifty years are concerning, with experts predicting that the number of people experiencing water scarcity will increase exponentially. The phrase "water is the source of life" is not merely a saying but a statement of fact, reflecting the growing water crisis and serving as a warning of a potential environmental catastrophe.

Central Asia has long faced challenges not only in terms of drinking water availability but also regarding irrigation sources. A key characteristic of Central Asia, including Kazakhstan, is its lack of direct access to the sea, which exacerbates water shortages due to

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reduced inflows from neighboring countries. This research focuses on the Irtysh River, the primary tributary of the Ob River, which flows through Kazakhstan, Russia, and China. The geopolitical significance of the Irtysh River lies in its unique geographical positioning-originating in China, where it has the shortest segment, while Kazakhstan and Russia are heavily dependent on its water flow. This asymmetry creates a situation in which China, as the upstream country, holds a strategic advantage, influencing water availability for its downstream neighbors. As a result, Kazakhstan and Russia face increasing risks of water scarcity and environmental challenges in the future.

Fig. 1. Map of the Irtysh River channel [1].

2 Methods

The proposed research is grounded in classical conceptual approaches to the analytical assessment of risks and threats. Its interdisciplinary nature is shaped by the methodological postulates of related scientific fields. Accordingly, we have applied general scientific system methods, comparative analysis, and classical methods of induction and deduction in environmental research.

In conducting this study, we considered analytical reviews, statistical and economic indicators, and visual data, all of which provided a comprehensive understanding of the issue. These sources allowed us to assess the severity of the situation regarding river resources and its broader environmental implications.

The Irtysh River channel map (Fig. 1) illustrates the concept of hydro-hegemony [2]. Adopting an approach based on realism/neorealism enables us to evaluate geopolitical dynamics, while the balance of power framework helps analyze the interdependence between Kazakhstan, the Russian Federation and the People's Republic of China (PRC) along the Irtysh River. This analysis ultimately sheds light on the potential environmental consequences for Kazakhstan.

3 Results and Discussion

3.1 Results

Kazakhstan and China share 23 transboundary watercourses. Exercising its extraterritorial rights, China claims 12.3% of the Irtysh River's waterway and actively pursues an assertive hydro-strategic policy, driven by large-scale objectives linked to the Xinjiang Uygur Autonomous Region (XUAR). In terms of water resource availability, XUAR ranks 12th among China's provinces. The region is traversed by 570 rivers, with the Tarim, Irtysh, and

Ili being the largest. XUAR's hydro-energy potential is estimated at 33.5 million kW, making it the fourth-largest in China [7].

Economic and demographic factors are the primary drivers of China's strategy in XUAR. The economic objective focuses on industrial expansion, particularly in the oil, energy, and agricultural sectors. The demographic goal involves ethnic Sinicization of XUAR, a historically contentious region. These two objectives are deeply interconnected – economic development requires labor resources, while demographic policies ensure their availability. Together, they serve the underlying purpose of stabilizing an unstable region. Amid globalization and intensifying competition in the global market, XUAR has become a strategic economic hub for China. Notably, the region covers 1.6 million km², accounting for one-sixth of China's total land area. However, only 3.8% of XUAR's territory is suitable for human habitation and economic activities [8].

The oil-producing center of XUAR is Karamay, which has proven reserves of approximately 3 billion barrels (423 million tons) [9]. The extractive industry accounts for 80% of XUAR's economy, significantly increasing water consumption. According to researchers, "The main problems of agricultural development in the area are the lack of water for irrigation in the spring, soil salinity, and natural disasters (hail, strong winds)". The expansion of irrigated farmland and water-intensive mining and processing industries has led to a steady annual increase in water consumption [9].

The available water resources are insufficient to meet the needs of XUAR's rapidly growing population, resulting in a persistent water shortage. Given that water consumption in the region continues to rise as part of China's large-scale development plans, there is a corresponding increase in China's hydro-expansion of the Irtysh River мире [10]. China is recognized as the world leader in hydropower infrastructure development, with the largest and fastest-growing hydropower sector globally. In 2011, the Chinese government adopted a comprehensive water resource management policy, titled the "Decision to Accelerate the Development of Reforms in Water Management". Under this initiative, the Chinese government allocated $62 billion annually for water management and irrigation projects until 2021, excluding additional local budget allocations [11].

China began actively diverting water from the Black Irtysh River for agricultural purposes as early as the late 1970s and early 1980s. Currently, it is estimated that China withdraws approximately 10% of the Upper Irtysh River's total runoff. Experts predict that by 2020, this figure could increase to 20–25%. According to Kazakhstani experts, China's total water withdrawal from the Irtysh River has already exceeded 35% of the levels recorded 15 years ago. At present, the Black Irtysh River supplies approximately 5 cubic kilometers of water per year from China to Kazakhstan, a decline from 7.8 cubic kilometers in 1989 [12].

In 2013, reports indicated a reduction to 4 cubic kilometers. However, with the construction of the Black Irtysh-Karamay and Irtysh-Ürümqi water channels, the total water withdrawal volume has increased significantly. Experts estimate that China will eventually withdraw between 10% and 11% of the Irtysh River's total volume for its own needs. However, recent calculations suggest that China's water intake from the Irtysh River has already increased by an average of 2 cubic kilometers. Projections indicate that this figure may further rise to 5–6 cubic kilometers, compared to the 7–8 cubic kilometers currently reaching Kazakhstan's border [13].

Kazakhstani experts suggest that, at maximum capacity, the Irtysh-Karamay and Irtysh-Ürümqi canals could transport approximately 120 cubic meters of water per second. In the Ürümqi region, two million hectares of land have already been prepared for irrigation, in addition to the existing 567,000 hectares [14].

According to some Chinese experts, China's efforts to utilize transboundary waters within its borders are justified, arguing that Kazakhstan has also historically diverted

significant river resources. For instance, in the 1960s, Kazakhstan used Ili River waters to fill the Kapchagay Reservoir [15]. Additionally, Kazakhstan continues to address water shortages in Lake Balkhash by extracting water from the Ili River.

Fig. 2. Lake Balkhash (photos from open sources [16].

Fig. 3. Map of Lake Balkhash [17].

Experts warn of a serious threat to the future of Lakes Balkhash, Alakol, and Zaisan. The collective impact of this issue could have catastrophic consequences for Kazakhstan's ecology, as the loss or reduction of these lakes would disrupt biodiversity and severely affect the surrounding environment [18]. Meanwhile, China's environmental policy prioritizes the preservation of existing water sources and the development of artificial reservoirs. The oasis sector of XUAR is a key focus, transforming desert areas through artificial irrigation to create man-made fertile lands. In this region, water is an indispensable resource, and the Chinese government regards it as too valuable to waste. Recognizing water scarcity as a critical issue, the Government of the People's Republic of China has made substantial investments in research to develop water-saving technologies for agriculture [19].

43.1% of the Irtysh River flows through Kazakhstan, passing through the East Kazakhstan, Semipalatinsk, and Pavlodar regions, while simultaneously supplying water to Karaganda and Astana via the Irtysh-Karaganda Canal. Within Kazakhstan, the Irtysh River flows into Lake Zaisan, where it is fed by numerous mountain rivers originating in Tarbagatai and Altai. The river then continues its course through the Bukhtarma and Ust-Kamenogorsk hydroelectric power stations, before reaching the Shulbinskaya hydroelectric power station, and ultimately flowing through Semey and Pavlodar. The geography of the Irtysh River highlights its strategic importance for these regions, including the more than four million people living along its course [20]. The Irtysh connects four major industrial regions of Kazakhstan, all of which have significant economic potential and house large industrial enterprises. The aforementioned hydroelectric power stations are powered by the

Irtysh River, and major industrial plants – including Ulba Metallurgical, Lead-Zinc, and Titanium-Magnesium facilities – not only utilize water for production but also contribute to river pollution. Scientists from Pavlodar report that: "...53 large enterprises discharge 260 million cubic meters of wastewater into the Irtysh. The total load on the aquatic ecosystem in the Pavlodar region is already 21% higher than the available water resources, reaching approximately 30 km³ per year. Of this, 19.0 km³ is allocated for mandatory navigable releases in the lower reaches, 6.6 km³ for agriculture, and 4.4 km³ for industrial water supply" [21]. The Kazakhstani government places particular importance on monitoring and maintaining water quality in the Irtysh water-management basin, as it serves both industrial enterprises and the population of four key regions.

Unlike neighboring China, Kazakhstan's population has not yet experienced significant water shortages, particularly in the eastern and northern regions. However, early warning signs have already emerged in East Kazakhstan. A combination of natural and human factors, including low water availability and inefficient use, has caused the Bukhtarma Reservoir to drop by nearly 10 meters. As a result, the hydroelectric power station was forced to shut down two units, leading to emergency overloads at the Ermakovskaya State Regional Power Plant. Additionally, airlock chambers were exposed, motor ships were immobilized, and water intakes in Ust-Kamenogorsk and Semipalatinsk were on the verge of collapse [22].

Of particular concern was the fact that, for the first time in history, environmental water drainage to the Pavlodar region was not carried out due to a low-snow winter in East Kazakhstan. This prevented the replenishment of floodplain meadows, which are essential for haymaking, creating a critical situation for agriculture. The lack of water supply in Pavlodar ultimately helped preserve the Bukhtarma Reservoir, preventing even more severe consequences in the East Kazakhstan region. However, potential future risks include an energy crisis, an environmental catastrophe, and a cascade of secondary issues, such as lower crop yields and the desertification of hayfields in the Irtysh floodplains.

The anthropogenic crisis of the Irtysh River has two major dimensions: on one hand, the increased water withdrawal at its source, and on the other, severe industrial pollution. Additionally, unforeseen environmental disasters have exacerbated the situation. For instance, in April 2022, six railcars carrying ore and slag fell into the Irtysh River, and as of now, no technical solution exists to retrieve them. More recently, in December 2024, a sewage spill in Pavlodar region contaminated the river, following a breakdown in Kurchatov.

Wastewater is one of the major pollutants of the Irtysh River. According to environmental experts, in 2000, wastewater discharges into the Irtysh included toxic metals from metallurgical and mining enterprises:

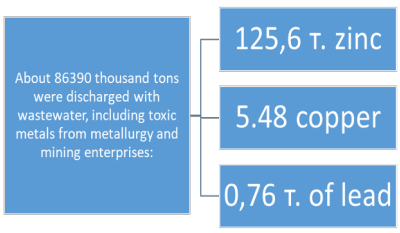

Fig. 4. Pollution of the Irtysh River [23].

Wastewater from two sewage treatment plants in Semipalatinsk is discharged into the Irtysh River: toxic metals:

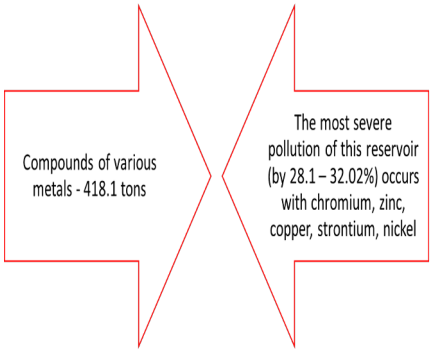

Fig. 5. Pollution of the Irtysh River [23].

The primary sources of chemical element accumulation in water systems and their components, particularly bottom sediments, within the Irtysh Basin, include exposed surfaces of mine workings, waste dumps, tailings storage facilities, and processing plant storage sites. Additional sources include waste materials and industrial effluents from metallurgical, chemical-metallurgical, chemical, machine-building, thermal power plants, and construction enterprises. Furthermore, industrial emissions released into the atmosphere eventually settle on the Earth's surface, further contributing to pollution. Heavy metal pollutants also originate from agricultural chemicals widely used in the region.

A significant environmental challenge for the Irtysh River is China's water abstraction for industrial and irrigation purposes. In early 1999, China began constructing a canal to divert water from the Black Irtysh to the Karamay oil fields in the Xinjiang Uygur Autonomous Region, supplying drinking and industrial water. More recently, reports have surfaced regarding the construction of additional reservoirs, further intensifying concerns over water resource depletion.

According to preliminary estimates, the Chinese canal will have a maximum water intake of 10–11% of the Irtysh River's total volume, which remains below the 12% threshold set by the Helsinki Agreements. The average long-term runoff of the Black Irtysh is approximately 9 km³ per year, but annual fluctuations can be significant. In high-water years, water intake may account for 20% of the runoff, whereas in low-water years, it could reach 50% or more, potentially leading to serious environmental and economic consequences.

Kazakhstani scientists warn that critical ecosystems supporting biological reproduction will be at risk. The self-purification capacity of Lake Zaisan and the Bukhtarma Reservoir will also be severely impacted, as the Irtysh River already receives water contaminated with heavy metals, nitrates, and petroleum products from China. A reduction in Irtysh River flow, while maintaining existing industrial discharges in the Ust-Kamenogorsk area, will increase pollution levels, ultimately degrading the quality of drinking water and negatively affecting public health.

Until recently, another major environmental concern was the threat of mercury contamination in the Irtysh River. However, the current concentration of mercury vapor in the atmosphere remains relatively stable, with only a slight exceedance of maximum permissible concentrations observed at the site of the former Building No. 31 of JSC Pavlodar Chemical Plant.

At present, remediation efforts are ongoing at the Pavlodar Chemical Plant to eliminate the source of mercury pollution. Due to the inefficient chlorine production technology once

used at the facility, more than 900 tons of mercury accumulated underground. According to experts, the risk of mercury entering the Irtysh River has now been effectively mitigated.

3.2 Discussion

Each new day and era brings humanity closer to a water crisis, driven not only by natural disasters but also by human activity. According to UN reports, by 2050, nearly 6 billion people will face water scarcity due to a lack of sufficient water resources [3].

The shortage of water, a fundamental source of life, poses a severe global threat. Its depletion could have catastrophic consequences, including the potential collapse of human civilization, underscoring the urgency of this research. A defining characteristic of Central Asia, including Kazakhstan, is its lack of direct access to the sea. The water deficit in the region is closely linked to the decline in water inflows from neighboring countries. This issue has been extensively studied by various researchers, particularly within the context of international collaborations on the Aral Sea crisis, the ecology of Lake Alakol, and the impact of anthropogenic factors on Kazakhstan's environment [4].

In Kazakhstan, 1,552 groundwater deposits have been explored, with a total volume of 42.2 million cubic meters per day. Of this amount, 13.7 million cubic meters are designated for domestic and drinking water supply, 2.1 million cubic meters for industrial and technical purposes, and 18 million cubic meters for irrigation. In terms of water availability, the Almaty region ranks first, followed by East Kazakhstan, Pavlodar, South Kazakhstan, and Aktobe regions. In contrast, the Akmola, West Kazakhstan, Atyrau, and Mangystau regions face significant water shortages.

Kazakhstani researchers have examined the negative impact of mining enterprises on water resources, as well as the poor technical condition of sewage networks and treatment plants. They highlight that unauthorized discharges into the Irtysh River contribute to bacterial contamination of water sources, including those used for drinking water supply [5].

This research focuses on the Irtysh River, the main tributary of the Ob River, which flows through three countries: Kazakhstan, Russia, and China. The uniqueness of this waterway lies in its total length of 4,248 km, with 47.3% (2,010 km) in Russia, 43.1% (1,835 km) in Kazakhstan, and 12.3% (525 km) in China (The percentage is calculated by the authors) [8]. The issue of hydro-hegemony is a critical factor in the resolution of water disputes between Kazakhstan and China. Many Kazakhstani researchers have examined this topic, highlighting that 24 rivers cross the 1,700-kilometer border between Kazakhstan and China, with the Irtysh and Ili Rivers being the largest transboundary watercourses. Scholars have expressed concern over China's increasing water withdrawals, particularly "for the development of oil and gas fields and cotton production in Xinjiang". A. Medeu and M. Gubaidullina emphasize that China was one of only three countries to vote against the 1997 UN Convention on the Non-Navigational Use of International Watercourses. According to these authors, China's water policies could lead to significant environmental challenges and hydropower issues for Kazakhstan in the future [6].

4 Conclusion

In conclusion, the preservation of the Irtysh River ecosystem and Kazakhstan's water resources remains a critical issue, influenced by numerous interrelated factors. Kazakhstan's urban population continues to grow annually, leading to a steady increase in water consumption. Unlike in Western countries, the local population has yet to adopt a water conservation mindset, and irrational water use remains widespread. Changing public attitudes toward water as a precious resource may take several decades or even longer.

Additionally, Kazakhstan lacks a comprehensive system for collecting and utilizing meltwater for agricultural purposes. Each year, spring floods cause widespread flooding, after which the water drains away, leaving the country to suffer from droughts in the summer months. Furthermore, water intake facilities require significant investment to improve infrastructure and efficiency.

Over the past decade, river inflows from outside Kazakhstan have declined by 17.2 km³, reaching 51.5 km³. On the Chinese side, the Irtysh River's flow has been reduced by 21.5% (2.1 km³), while in the Balkhash-Alakol basin, inflows have decreased by 15.3% (2.3 km³) due to anthropogenic activities in China. Projections indicate that by 2029, transboundary water inflows could decline by another 5 km³ [24].

It is crucial that Kazakhstan has supported key international water agreements, including the UN Convention on the Protection and Use of Transboundary Watercourses and International Lakes and the UN Convention on the Law of the Non-Navigational Uses of International Watercourses [25].

Additionally, the country is preparing to ratify the UN Protocol on Water and Health. A significant step forward will be the implementation of a national program aimed at improving water-use efficiency in agriculture, developed in cooperation with the French Development Agency.

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