Changes in the Aral Sea: Crisis and Current Situation Postprint

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Abstract

The Aral Sea was once the world' s fourth-largest lake. Beginning in the 1960s, due to agricultural irrigation demands, various regions in the Aral Sea basin diverted large volumes of water from the Amu Darya and Syr Darya rivers, leading to rapid shrinkage of the Aral Sea, declining water levels, and deteriorating water quality. By the early 21st century, the lake surface had shrunk to one-eighth of its original size, with the dried lakebed becoming highly saline salt deserts, a massive reduction in biological species, and ecological deterioration causing an ecological crisis. After the independence of Central Asian countries, water scarcity created conflicts between upstream and downstream regions of the Amu Darya and Syr Darya rivers, which subsequently severely affected inter-state relations. Although numerous negotiations were conducted, Central Asian countries ultimately failed to propose a unified solution to the Aral Sea water resources crisis. Subsequently, Kazakhstan independently implemented protection measures for the Aral Sea, rescuing portions of the water body in the northern Aral Sea; Uzbekistan has also begun to adopt a positive attitude toward Aral Sea crisis governance in recent years. Currently, the mainstream academic opinion is that the Aral Sea crisis is anthropogenic and should not be linked to global climate change. The Aral Sea crisis has been somewhat alleviated due to governance efforts and groundwater recharge; although it will not completely disappear as predicted, there remains great uncertainty regarding the extent to which it can ultimately recover. This paper provides a relatively comprehensive discussion of the history, current status, and prospects of the Aral Sea crisis, aiming to offer scientific reference for environmental governance in the arid regions of northwestern China.

Full Text

Preamble

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Evolution of the Aral Sea: Crisis and Present Situation

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Abstract: The Aral Sea was once the fourth largest lake in the world. Beginning in the 1960s, due to agricultural irrigation demands, regions in the Aral Sea basin diverted massive amounts of water from the Amu Darya and Syr Darya rivers, causing the Aral Sea to shrink rapidly, its water level to drop, and its water quality to deteriorate. By the early 21st century, the lake surface had shrunk to one-eighth of its original size, and the dried lakebed became a highly saline salt desert. Biological species decreased dramatically, and the deteriorating ecological environment created a crisis. After the independence of Central Asian countries, water shortages in the upper and lower reaches of the Amu Darya and Syr Darya rivers generated conflicts that seriously affected interstate relations. Although numerous negotiations were held, Central Asian countries ultimately failed to propose a unified solution to the Aral Sea water crisis. Subsequently, Kazakhstan independently implemented protection measures for the Aral Sea, saving part of the water body in the northern Aral Sea. In recent years, Uzbekistan has also adopted a positive attitude toward managing the Aral Sea crisis. Currently, the mainstream academic view holds that the Aral Sea crisis is anthropogenic and should not be linked to global climate change. The crisis has been somewhat alleviated through governance and groundwater recharge, and although it will not disappear completely as previously predicted, the extent of its eventual recovery remains highly uncertain. This paper provides a comprehensive discussion of the history, current status, and prospects of the Aral Sea crisis, aiming to offer scientific reference for environmental management in the arid regions of northwestern China.

Keywords: Aral Sea; crisis; water use conflicts; governance; water resources

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1 The Process of Aral Sea Changes

The Aral Sea is the most striking example among the many lakes in Central Asia that have shrunk or disappeared. Before its dramatic changes began in the 1960s, its area ranked fourth in the world after the Caspian Sea, Lake Superior, and Lake Victoria. Historical records of the Aral Sea date back approximately 10,000 years, while human documentation began around the 1st century AD. Throughout history, the Aral Sea dried up several times due to the Amu Darya's course changes, most recently in the 13th-14th centuries. Before 1575, the Amu Darya flowed into the Caspian Sea via the now-vanished Uzboy channel, while the Turgay River flowed into the Aral Sea. In the early 18th century, islands such as Vozrozhdeniya (Resurrection Island) emerged as water levels dropped. During the Russian conquest of Central Asia, systematic observations began in the mid-19th century. Until the mid-20th century, the Aral Sea's water level, area, volume, biological populations, and ecological environment remained relatively stable. This situation began to change in the mid-20th century.

In the 1960s, the Soviet Union launched large-scale water conservancy projects in the two river basins. The largest project was the Fergana Canal, which diverted water from the Syr Darya to expand irrigated area and increase agricultural output. This effort was greatly intensified in the 1970s-1980s, marked by the Karakum Canal (also called the Turkmen Canal) that began in 1954 and was officially completed in 1988. The Karakum Canal diverts water from the Amu Darya at a rate of 12-13 km^3 annually, accounting for about 20-25% of the Amu Darya' s total flow. After completion, the canal reached a total length of 1,445 km, making it the world' s longest irrigation canal. Its maximum width is 130 m, maximum depth 7.5 m, and it is navigable. Another major project is the Karshi Canal in Uzbekistan' s Karshi Steppe, with a total length of 290 km, diverting 3.30-5.25 km^3 annually from the Amu Darya. The total capacity of reservoirs built on the Amu Darya in the 1960s-1980s reached 53.8 km^3. The total length of canals and irrigation channels in the Aral Sea basin reached 21.3 km, diverting water that was primarily consumed by agriculture, with only a small portion used for industry and domestic purposes. Approximately 94.9% of the diverted water was lost to evaporation and seepage, representing enormous waste.

Due to the massive over-extraction of water from the Amu Darya and Syr Darya for farmland irrigation, the inflow to the Aral Sea decreased year by year. By the 1970s, the Syr Darya had no stable inflow to the Aral Sea, and the Amu Darya essentially stopped delivering water to the Aral Sea in the 1980s, causing the lake surface to shrink rapidly. In 1987-1988, the Aral Sea split into two parts: the northern Small Sea (also called North Aral Sea) and the southern Large Sea (also called South Aral Sea). Due to Gorbachev' s "glasnost" policy, the media began disclosing the Aral Sea' s severe ecological problems, making the public aware of another environmental crisis. In 2003, the Large Sea further divided into eastern and western parts (also called "East Sea" and "West Sea").

In 2005, Kazakhstan, recognizing that saving the entire Aral Sea was hopeless, built a dam about 13 km long at the Berg Strait—the Kok-Aral Dam—where the Syr Darya enters the lake, slightly south of the original connection between the North and South Aral Seas. The dam reduced water flow from the North Aral Sea to the South Aral Sea, accelerating the South Aral Sea's drying but helping the North Aral Sea recover. The North Aral Sea' s water level began to rise, reaching 42 m (10 m higher than the South Aral Sea), with an average depth of 8 m, and its fishing industry was restored, with current annual catches reaching 6,000 tons. In 2009, the World Wide Fund for Nature listed the Small Sea and Syr Darya Delta as a wetland of international importance under the Ramsar

Convention. The Small Sea' s transformation represents a welcome reversal in the Aral Sea crisis.

Kazakhstan subsequently proposed another plan to expand the Small Sea' s area and further improve its ecological environment and fish stocks. The plan involves building a Saryshaganak Dam and lock system at the narrow waterway connecting the Large Saryshaganak Bay in the northeastern part of the Small Sea, raising and stabilizing the bay' s water level. Simultaneously, a canal would be constructed from the lakeside to Aralsk. After completion, fishing boats could travel from the southern part of the Small Sea through the lock into the Large Saryshaganak Bay and then directly to Aralsk' s fish processing plants via the canal. This project would require 6-10 years, contingent on the Syr Darya providing 3.24 km^3 of water annually. If inflow reaches 5.0 km^3, the Small Sea' s water level could be raised to 42 m within 6-10 years; if inflow reaches 5.5 km^3, it would take 12-13 years.

Fortunately, nature has also assisted human efforts to correct mistakes and mitigate the Aral Sea crisis. The 2007 discovery of strong groundwater replenishment from the Ustyurt Plateau to the West Sea explained why the West Sea' s shrinkage was slower than expected—a positive development. After preserving the Small Sea, hope emerged for retaining part of the Large Sea. Nature has alleviated concerns about the Aral Sea' s complete disappearance and raised expectations for improving its ecological environment. However, research on the source, volume, and replenishment mechanisms of this groundwater remains insufficient.

To summarize the process: Since the early 1960s, the Aral Sea' s water level has dropped at a rate of 0.7 m annually, its area has shrunk to 8,000 km^2, and its volume has decreased to less than 100 km^3. Salinity has increased 13-25 times, exceeding the average salinity of the world' s oceans. Specific details are shown in Table 1. In 2023, the Large Sea' s water level was 29.2 m, while the Small Sea' s was 42 m; the Large Sea' s area was 3,197 km^2, while the Small Sea' s was 3,492 km^2; the Large Sea' s volume was 27.00 km^3, while the Small Sea' s was 54.72 km^3; the Large Sea' s average salinity exceeded 100 g/L, while the Small Sea' s was 6-8 g/L. It should be noted that during the Aral Sea' s desiccation, increased glacial meltwater in certain years slowed the shrinkage, notably in 2010 when the nearly dry eastern part of the South Aral Sea saw a significant water level rise due to abundant precipitation. However, this was not a stable trend, and its effects require further study.

Based on research and the current status of the Aral Sea, opinions differ regarding its future. In the 1990s, almost everyone believed the Aral Sea would disappear, but now more people think it will not, particularly the Small Sea (in Kazakhstan) and the West Sea (mainly in Uzbekistan), which can be preserved. Philip Micklin from Western Michigan University and Russian scientist Aladin believe that "if current trends continue (referring to groundwater, precipitation, meltwater, and inflow from the Small Sea), the West Sea' s water level will continue to decline and its area will shrink, potentially stabilizing at a depth of

8-10 m" [9]. The extent to which the Large Sea can recover remains difficult to predict. According to Peter Zavyalov, Deputy Director of the Russian Academy of Sciences' Institute of Oceanography, who has conducted regular expeditions to the Aral Sea since 2002, the Aral Sea has experienced five regressions in history, with the last four occurring during Ivan the Terrible' s period—making the current one the fifth and most severe. Zavyalov believes that in the foreseeable future, the West Sea (Large Sea) will not completely disappear, but its maximum depth will not exceed 30 m and may decrease to 8-10 m.

Beyond the geographic and hydrological changes listed in Table 1, the biological populations in and around the Aral Sea have also changed significantly. For example, nesting bird species in the Syr Darya Delta decreased from 319 to 180 species, total bird species from 600 to 300, and mammals from 70 to 32. Due to the withering of floodplain forests in coastal areas, 12 out of 1,500 higher plant species face extinction, including over 20 local and endangered species. According to summer field observations, the local freshwater-brackish fauna in the Aral Sea (excluding the Small Sea) has become extinct [2]. The Aral Sea crisis represents a large-scale regional environmental change centered on the water-ecological environment, causing multifaceted catastrophic consequences that require deeper historical and current status research.

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2 Causes of Aral Sea Changes

The Aral Sea lost most of its surface area and water volume in just a few decades due to human activities—primarily irrigation—causing massive changes to its own and surrounding ecosystems. The disaster' s emergence was not unexpected. When large-scale water diversion from the Amu Darya and Syr Darya began, people had considered the potentially fatal harm to the Aral Sea but underestimated its severity. Additionally, because historical changes in the Amu Darya' s course had caused the Aral Sea to disappear and naturally recover several times (in the 13th-14th centuries, the Amu Darya flowed into the Caspian Sea via the Uzboy channel, greatly shrinking the Aral Sea) without severe consequences, many believed another disappearance would merely repeat history and warranted little concern. They overlooked the fundamental difference: historical disappearances resulted from river course changes, while the current disappearance stems from excessive water consumption.

Some also argued that the Aral Sea, being large and in an arid region with vast evaporation surfaces, lost 60 km^3 of water annually to evaporation—so why not use this "wasted" precious freshwater for irrigation, industry, and domestic purposes? Under this thinking, water diversion projects from the Amu Darya and Syr Darya developed rapidly, continuously reducing inflow to the Aral Sea. During this process, Central Asia' s irrigated area expanded from 4.5$\times10^{6}$ ha to 7.0$\times10^{6}$ ha (Uzbekistan and Tajikistan increased 1.5-fold, Kazakhstan 2-fold, Turkmenistan 3-fold). High water-consumption crops like rice and cotton also expanded significantly. For instance, Uzbekistan has 4.22×10^{6} ha of irrigated land, over half for cotton cultivation. Despite large cotton acreage, Uzbekistan' s yield per unit area is very low, with various estimates suggesting 10-17$\times10^{3}$ m^3 of water consumed per hectare of seed cotton, producing only about 700 kg of cotton per hectare [5]. Such astonishing water consumption and low output are unique worldwide. Uzbekistan has long been a major cotton exporter, and because cotton plays an important role in its agriculture and exports, it has only passively reduced some cotton cultivation (due to water shortages or severe soil degradation). Turkmenistan' s situation is similar, though with less cotton cultivation, it also entered world cotton export rankings.

A special situation in Central Asian agriculture requiring attention is "field washing." After several years of irrigation, soil salinity increases, requiring fields to be flooded to dissolve salts before draining the high-salinity water. This water, containing not only salt but also pesticide and fertilizer residues, cannot be used without treatment and must be discharged into deserts. This "field washing" consumes enormous amounts of water. In the 1960s-1970s, discharging water into deserts created new massive water bodies, the largest being Sarykamysh Lake west of the Aral Sea, straddling Uzbekistan and Turkmenistan. Sarykamysh Lake began forming in 1965, with salinity at 12-13 $g \cdot L^{-1}$ and increasing at 0.6 $g \cdot L^{-1}$ annually [10]. Its area and volume are now similar to the Small Sea, but such water bodies in Central Asia, despite large volumes, cannot be used due to high harmful substance content. They cannot support plant growth or fisheries, and even if some fish survive, they contain harmful substances and are inedible. These water bodies are essentially massive contaminated pools. "Field washing" accounts for a significant portion of agricultural water use, consuming and polluting water severely, though modern agricultural technology could change this—unfortunately, this work has essentially not progressed.

Another factor requiring mention is seepage. When diverting water from the Amu Darya and Syr Darya, massive irrigation systems were built with canals up to 21.3 km in total length, most lacking concrete lining. Combined with poor maintenance, seepage is severe. Some scholars estimate that 50% of water is lost through evaporation and seepage [5]. Without systematic observation data, we question whether the proportion is this high, but substantial water loss is undeniable. Additionally, Central Asian countries have high population growth rates, affecting drinking water demand, while urban and industrial development also increases water consumption. However, these factors' impact on the Aral Sea crisis is far less than that of agricultural irrigation.

When studying the Aral Sea's changes, researchers have also examined its causes. Many scholars believe that, in addition to the aforementioned factors, global climate change is also important. As Zavyalov noted earlier, some still believe global climate change could eventually dry up the Aral Sea. However, the magnitude of climate change' s role lacks analysis based on systematic observation data, making accurate assessment difficult. Currently, proposed reasons for climate change' s impact on the Aral Sea crisis include: increased average temperatures across Central Asia due to warming, leading to increased evaporation; simultaneously, crops' water requirements increase, requiring more water from soil; and increased glacial meltwater from the Pamir and Tianshan Mountains, causing fluctuations in meltwater and precipitation and even severe droughts, which correlate with several major changes in the Aral Sea's area (Table 1). This also hinders water-saving measures. Clearly, climate change' s role is not significant and lacks convincing evidence and analysis. This paper argues that, at least when considering Aral Sea crisis governance, global climate change factors need not be heavily considered.

New mineral deposits have been discovered in the Aral Sea region, including the "West Aral Sea" oil and gas structure [12]. Reports also indicate the Aral Sea basin has natural gas reserves of 1.5-2.5$\times10^{12}$ m^3 and oil reserves exceeding 2.5$\times10^{9}$ tons, mainly distributed in Uzbekistan. This presents a dilemma: spend huge sums to restore the Aral Sea, or develop oil and gas for massive foreign exchange earnings? In 2016, the Russian Lukoil and Uzbekneftegaz companies analyzed resources in the Aral Sea waters, conducting seismic surveys in selected areas in 2017. Additionally, Rosgeologiya (a state-owned company) and Uzbekgeofizika signed an agreement to provide geological services to Uzbekistan, studying the oil and gas prospects of the Aral Sea waters and adjacent areas [14]. A possible choice is to exploit oil and gas, using increased foreign exchange earnings to compensate for export reductions caused by decreased cotton cultivation. This could increase inflow to the Aral Sea from reduced cotton fields, potentially increasing the West Sea' s area and water level and improving its ecological environment. However, no official Uzbekistan plan has been seen yet. Reports also indicate oil and gas discoveries in Kazakhstan' s Aral Sea basin. Kazakhstan' s choice will likely be less difficult than Uzbekistan' s because it has abundant oil and gas resources, the Small Sea success, and superior economic conditions and strength.

For Aral Sea crisis governance affecting all Central Asian countries in the Amu Darya and Syr Darya basins, joint consultation among basin countries is undoubtedly the most basic condition. However, with the Soviet Union' s dissolution and Central Asian countries' independence, water resources became an important factor affecting interstate relations, creating serious contradictions and even conflicts, which in turn affected water resource problem-solving, trapping interstate relations and water issues in a vicious cycle.

The five Central Asian countries can be divided hydrologically and geographically into upstream countries (Kyrgyzstan and Tajikistan) and downstream countries (Kazakhstan, Turkmenistan, and Uzbekistan). Upstream countries use water resources mainly for power generation, building multiple hydropower stations and reservoirs, while downstream countries use water primarily for irrigation, constructing most of the canals. Additionally, there is a seasonal difference: peak power generation occurs in winter when heating and industrial electricity demand is greatest, while downstream countries need water mainly during spring and summer growing seasons. This creates a problem: upstream countries must store large amounts of water during spring and summer when glacial melt and precipitation are abundant for winter power generation, but this is precisely when downstream countries critically need water for agriculture. Reduced water release would be disastrous for downstream countries. During the Soviet era, the "water-for-electricity" principle resolved upstream-downstream coordination: upstream countries released large amounts of water from reservoirs during spring and summer, reducing storage and affecting winter power generation; downstream countries then provided electricity (including natural gas) to upstream countries during winter to compensate for shortages. Water release was free, while increased electricity supply had costs, with downstream countries' economic losses addressed by the central government. This method was reasonable, but it reflected a deeper principle: water must be used with compensation. After the Soviet Union' s dissolution, the entity and function for water-energy regulation ceased to exist, becoming a sharp contradiction. Conflicts caused by upstream-downstream water-energy relations have become a major issue in interstate relations. Additionally, although upstream countries have advantages in river control, downstream countries have greater advantages in political and economic aspects, and this misaligned power balance also increases difficulty in problem-solving. The fact is that the electricity-water contradiction has worsened interstate relations since the Soviet Union' s dissolution, making a crisis that could have been mitigated more difficult to resolve.

Another reason hindering Aral Sea governance, not anticipated early on, is the discovery of promising oil and gas reserves in the Aral Sea basin, including the Aralkum Desert. This has led to the formation of numerous political and economic groups among the elite, with cronyism and corruption being important starting points for their considerations. Many interstate agreements cannot be implemented because these elite groups fear their interests will be harmed. Besides the aforementioned reasons, lack of mutual trust among Central Asian countries is also important. The Muslim identity and Turkic identity that Central Asian countries were proud of in their early independence have not played positive roles. In the process of globalization, Central Asia is actually a region moving against integration. Based on over 30 years of independence and current status, finding a comprehensive solution to Central Asia' s water resource problems in the short term is impossible, but partial solutions are hopeful. The resolution of water-energy contradictions between Kyrgyzstan and Kazakhstan regarding the Chu and Talas rivers is a convincing example.

The Aral Sea crisis has attracted widespread international attention, particularly from European countries. Multiple international institutions and organizations have established special projects, including the United Nations, World Bank, Asian Development Bank, Islamic Development Bank, Eurasian Development Bank, UNDP, UNECE, Council of Europe, Aga Khan Foundation, USAID, GIZ, DFID, and the US Office of Energy Efficiency. These organizations have provided substantial assistance to Central Asian countries in water resources through funding, technology, healthcare, services, ecological protection, and personnel training, with the EU, Germany, and Russia doing the most. The

EU has held a series of important meetings, including the representative Rome Conference on water resources, which led to strategic documents on Central Asian environment and water issues signed between the EU and Central Asian countries, demonstrating the EU' s important success in Central Asian cooperation.

Russia has also played an important role in solving Central Asia's water resource problems, inheriting research on the Aral Sea from the Tsarist and Soviet periods. Since the late 19th century, extensive research has been conducted on the Aral Sea. For example, a study led by the Russian Academy of Sciences' Institute of Oceanography and supported by the Russian Foundation for Basic Research conducted long-term observations and analysis of the Aral Sea' s Large Sea portion, collecting large amounts of first-hand data on physics, chemistry, and biology. In 2009, they published the 500-page report "The Aral Sea at the Beginning of the 21st Century: Physics, Chemistry, Biology" [3], the most comprehensive Aral Sea research report we have seen to date. On September 24, 2009, Russia held an international conference in St. Petersburg on the Aral Sea with the theme "The Aral Sea: Past, Present, and Future—A Century of Aral Sea Research." This representative conference produced important conclusions on the Aral Sea issue, concentrated in the "St. Petersburg Declaration on the Aral Sea Problem," which can be summarized as: the Aral Sea has experienced unprecedented shrinkage and salinization; irrigation is the dominant factor of degradation, using far more water than sustainable development allows; climate change is not the main cause of the Aral Sea crisis; water diversion solutions are unrealistic—instead, irrigation water use efficiency should be improved and measures taken to protect and partially restore remaining parts of the Aral Sea; Aral Sea basin countries should cooperate to solve water resource management issues, including joint water use and "water-energy conflicts" ; the most important measure for solving the Aral Sea' s ecological problems is widespread introduction of modern irrigation agricultural technologies and methods; it is premature to predict the Aral Sea' s death; and an International Commission for Comprehensive Ecological Monitoring and Research of the Aral Sea should be established.

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3 Consequences of Aral Sea Changes

The Aral Sea' s transformation has become a serious ecological crisis. UN Secretary-General António Guterres visited Nukus, Uzbekistan, in 2017, stating that seeing the world' s fourth-largest lake nearly dead was a tremendous shock, perhaps the greatest ecological disaster of our time. He believed the Aral Sea' s gradual disappearance resulted not from climate change but from improper water resource management.

The series of serious ecological and environmental problems caused by the Aral Sea crisis were introduced in a previously published article [8]. Although over 20 years have passed, the article was written during the crisis' s most severe period, and subsequent developments have not substantially changed. The consequences can be summarized in several aspects:

1) **Severe deterioration of water quality and declining groundwater levels** in the Aral Sea basin. Due to increased salinity and harmful substances in surface water, water quality in many areas no longer meets drinking standards. Some cities and settlements around the Aral Sea must import water from elsewhere for domestic use, while irrigation water quality has also significantly declined.

2) **Extensive soil salinization**. In coastal areas, particularly in the Amu Darya and Syr Darya deltas, increased water mineralization has raised soil salinity, forcing abandonment of many cultivated lands. These salinized lands and dried lakebeds have formed large salt deserts.

3) **Increased frequency and intensity of salt dust storms**. The Aral Sea region experiences frequent dust storms. With large areas of salinized land and exposed, highly saline lakebeds, salts and harmful substances from the surface are swept into the atmosphere during dust storms and spread by wind, negatively affecting plant and crop growth when they settle. Due to expanded salinized land area and climate change, salt dust storms' impact range is expanding. Salt dust storms also increase atmospheric precipitation mineralization, directly harming humans and other organisms. 资料显示, over 7.5$\times10^{6}$ tons of dust and harmful salts enter the atmosphere annually from the Aral Sea region. Aral Sea dust has been detected in Pamir and Tianshan glaciers, Greenland, Arctic glaciers, and Norwegian forests [2].

4) **Rising atmospheric temperatures and declining relative humidity**. The Aral Sea' s changes have affected the regional climate. In areas 100-150 km from the lake shore, summer temperatures have risen by 1.5°C in recent years, while relative humidity has decreased by 5-10%. These changes, caused by the Aral Sea' s shrinkage and desertification, in turn accelerate these processes. This situation has shortened frost-free periods and reduced annual accumulated temperature, causing greater harm to agriculture and animal husbandry.

5) **Reduction and change of biological species and populations**. Fisheries and hunting have been most affected. Although the Small Sea has partially restored its fishing industry, many species have not returned, and other aquatic organisms have also decreased significantly. Dense reeds and shrubbery have died off in large areas. Among 1,500 higher plant species, 12 face extinction, including over 20 local and endangered species. According to summer field observations, local freshwater-brackish fauna in the Aral Sea (excluding the Small Sea) have become extinct [2].

6) **Disaster has also befallen humans**. With 5.4$\times10^{4}$ km^2 of salinized land, wind-borne dust containing salts and harmful chemicals spreads

> up to 500 km, carrying $NaHCO_3$, Na_2SO_4, and other substances into the air. Local residents suffer from various diseases: respiratory diseases, anemia, laryngeal cancer, esophageal cancer, digestive disorders, liver and kidney diseases, and eye diseases have all increased significantly. Disease incidence in the Aral Sea region has risen sharply, birth rates have declined, infant mortality has increased, and combined with low social security levels and rising unemployment, large numbers of residents have been forced to migrate, becoming ecological refugees.

After the Aral Sea crisis emerged, relevant countries and the international community paid great attention. This paper discusses this issue from the perspectives of Central Asian countries and international society. After independence, Central Asian countries continued Soviet-era attention to the Aral Sea problem. Shortly after independence, they signed the "Agreement on Cooperation in the Joint Management and Protection of Transboundary Water Resources" (the Almaty Agreement) in Almaty on February 18, 1992, establishing the Interstate Commission for Water Coordination, which became the legal basis for Central Asian five-country coordination to solve the Aral Sea problem.

In 1994, Central Asian heads of state adopted the "Aral Sea Basin Program" through the Nukus Declaration, formulated with World Bank, UNDP, and UNEP participation. The program had three phases with total planned investment of $5.3-7.8×10ˆ{8}, marking the beginning of planned Aral Sea governance. On March 26, 2005, the third "Aral Sea Basin Program" was adopted, prioritizing ecological and socioeconomic environment improvement. On April 28, 2009, the International Fund for Saving the Aral Sea formulated the fourth "Aral Sea Basin Program," covering four aspects: integrated water resource use, ecological changes, socioeconomic changes, and improving institutional and legal mechanisms. These four programs established the framework for Aral Sea governance, under which a series of projects were established, including the "Water Resources and Environmental Management Project" with total investment of 21.5×10ˆ{6}$, involving not only the five Central Asian countries but also the Global Environment Facility, Dutch and Swedish governments, and the European Union, and the "Syr Darya River Channel Regulation and Preservation of the Northern Aral Sea" project. Kazakhstan' s work mentioned earlier was primarily conducted under these programs and projects.

Additionally, Central Asian countries held a series of meetings and signed documents, with basic information shown in Table 2. Unfortunately, numerous meetings and agreements have not played important roles in improving the Aral Sea crisis. During these meetings and agreement signings, the Aral Sea crisis continued to expand. A prominent example is that no country has basically implemented signed agreements, and no country has paid its required share to the International Fund for Saving the Aral Sea.

Central Asian countries have signed about 100 agreements on water issues, but basically none have been implemented. A special exception is that Kazakhstan and Kyrgyzstan resolved their water-energy contradictions regarding the Chu and Talas rivers, but this example did not affect similar problem-solving for the Amu Darya and Syr Darya. Regarding these agreements, a prominent problem is the lack of a special agreement on the Amu Darya, though the Amu Darya is more closely related to the Aral Sea crisis.

The reasons for non-implementation of agreements are very complex, most importantly the lack of necessary will and determination among Central Asian governments. When signing treaties, they focus more on the act of signing than on implementation content. Additionally, numerous political and economic groups have formed among the elite, with cronyism and corruption being important starting points for their considerations. Many interstate agreements cannot be implemented because these elite groups fear their interests will be harmed. Besides the aforementioned reasons, lack of mutual trust among Central Asian countries is also important. The Muslim identity and Turkic identity that Central Asian countries were proud of in their early independence have not played positive roles. In the process of globalization, Central Asia is actually a region moving against integration. Based on over 30 years of independence and current status, finding a comprehensive solution to Central Asia' s water resource problems in the short term is impossible, but partial solutions are hopeful. The resolution of water-energy contradictions between Kyrgyzstan and Kazakhstan regarding the Chu and Talas rivers is a convincing example.

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4 Conclusion

Although the international community has made many efforts to govern the Aral Sea crisis, results have been unsatisfactory. Problem resolution still depends on continuous efforts by Central Asian countries and the international community. It should be noted that after President Mirziyoyev took office, Uzbekistan' s attitude toward Aral Sea crisis governance has changed significantly, adopting a series of measures and making alleviating the Aral Sea ecological crisis and regional socioeconomic development priority measures in Uzbekistan' s "Action Strategy for 2017-2021" [19]. In September 2019, at the UN Sustainable Development Summit, Uzbekistan proposed establishing a special trust fund under UN auspices for the Aral Sea and coastal region to raise funds for Aral Sea crisis governance, receiving UN support. In June 2017, UN Secretary-General Guterres confirmed this attitude during his visit to the Aral Sea region. Subsequently, the 73rd UN General Assembly (September 2018) passed a resolution establishing the "UN Multi-Partner Human Security Trust Fund for the Aral Sea Region" [18]. The fund' s establishment will undoubtedly bring positive and obvious impacts to Aral Sea crisis governance. The Uzbekistan government decided to invest \$20×10^{6} annually in the fund.

The Aral Sea problem is the most representative among many lakes in Central Asia, powerfully demonstrating that human activities can cause severe damage to the natural environment, which in turn threatens human survival itself. In the relationship between humans and nature, people cannot consider only themselves but must respect natural laws; otherwise, they will pay the price sooner or later. The approach of sacrificing environmental quality for economic development is very dangerous, and its serious consequences may be irreparable even at high cost.

Overall, Central Asia is neither short of water nor energy. If Central Asian leaders have the will to cooperate and coordinate these issues, solving the Aral Sea problem is not extremely difficult. However, lacking this will and mutual trust among Central Asian countries, the crisis' s end remains uncertain. The 1992 Almaty Agreement was not implemented, and no new ideas have been proposed to date. With global warming, glacial melt in the Tianshan and Pamir regions is increasing, but crops' water requirements are also increasing, potentially making Central Asian water-energy problem-solving more difficult. Additionally, differing interests between upstream and downstream countries and misaligned power balances increase solution difficulty. International law' s role in coordinating transboundary river water allocation is also limited. The International Law Association' s 1966 Helsinki Rules on the Uses of the Waters of International Rivers, while influential in international water law, has no mandatory provisions on water allocation methods and principles. The UN Economic Commission for Europe' s 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention), while allowing non-UNECE members to become parties, has not yet entered into force and is not binding on Central Asian countries. These treaties and agreements contain only general principles without binding specific provisions.

Many scholars believe that water issues are not the most fundamental problem—they can be solved—but other reasons prevent solvable problems from being resolved, with Central Asia being an example. The lessons from the Aral Sea crisis should be learned not only by Central Asian countries but by the entire world.

References

[1] Former Aral Sea. March 6, 2017[EB/OL]. [2018-12-20]. https://belok.net/index.php?PHPSESSID=70395p5

[2] Kurbanbaev E, Artykov O, Kurbanbaev S. The Aral Sea and water policy of the republics of Central Asia[EB/OL]. [2018-12-22]. http://cawater-info.net/library/rus/aral_{nukus}.pdf.

[3] Zavyalov P O, Arashkevich E G, Bastida, et al. The Aral Sea at the beginning of the 21st century: Physics, biology, chemistry[EB/OL]. [2017-08-01]. http://cawater-info.net/bk/water_{{{land}}*{{resources}}*}{use}/russian_{ver}/pdf/aralskoe_{nach}.21_v.

[4] Bologov P. Why the largest part of the Aral Sea has completely dried up[EB/OL]. [2018-10-21]. https://republic.ru/posts/45839.

[5] Karakum Canal[EB/OL]. [2018-10-11]. https://dic.academic.ru/dic.nsf/ruwiki/217996.

[6] Causes and consequences of the Aral crisis[EB/OL]. [2017-02-14]. https://www.uefima.ru/nepoznannoe/vozniknovenie_{{{aralskogo}}_{{krizisa}}}.html.

[7] Yurkova A. RG correspondent reached a unique desert in Central Asia[EB/OL]. [2023-02-01]. https://rg.ru/2022/09/19/reg-ufo/korrespondent-dobralas-unikalnoj-pustyni-srednej-azii.html.

[8] Ashment B. Distribution of water resources in Central Asia: An insoluble problem?[M]. Berlin: Friedrich Ebert Foundation, 2011: 23-45.

[9] Micklin P. Possible future of the Aral Sea and its fauna[J]. Astrakhan Bulletin of Environmental Education, 2016, 36(2): 16-37.

[10] Aral Sea may begin developing hydrocarbon deposits in 2017[EB/OL]. [2018-02-09]. http://ecisnews.master.net/economy/id/1094/.

[11] Chichkin A. Aral region: Hydrocarbon geopolitics[EB/OL]. [2018-02-09]. https://www.ritmeurasia.org/news-aral-region-uglevodorodnaja-geopolitika.

[12] Rosgeologiya signed a contract for the provision of services in Uzbekistan[EB/OL]. [2021-07-07]. https://uz.sputniknews.ru/20200612/Shuster-Aralskiy-region-privlekaet-neftegazovykh-investorov-30826.html.

[13] Secretary General' s statement following his visit to the Aral Sea[EB/OL]. [2017-12-25]. https://www.un.org/sg/en/content/sg/statement/2017-06-10/secretary-general-statement-following-his-visit-aral-sea.

[14] Yang Shu, Chen Tao. Aral Sea: Its crisis and future[J]. Journal of Lanzhou University (Social Sciences Edition), 1998, 26(1): 119-126.

[15] The Aral Sea: What is left of it and what is its fate[EB/OL]. [2020-11-28]. https://dzen.ru/a/XzVBhMfs7j687m1X.

[16] Aral solution[EB/OL]. [2021-06-27]. https://review.uz/post/aralskoe-reshenie.

[17] A presentation of the fund to assist residents of the Aral Sea region took place at the UN[EB/OL]. [2021-07-31]. https://news.un.org/ru/story/2018/11/1343611.

[18] Executive directorate of the international fund for saving the Aral Sea in the Republic of Kazakhstan. Aral Sea Basin Programs[EB/OL]. [2018-11-21]. https://kazaral.org/mfsa/pbam/.

[19] Aripov E. Uzbekistan has radically changed the ideology of solving the Aral disaster[EB/OL]. [2021-06-25]. https://www.gazeta.uz/ru/2021/05/22/aral/.

Note: Figure translations are in progress. See original paper for figures.