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The Ecological, Chemical, Biological and Medical Condition of the Aral Sea Region

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Abstract: This article thoroughly examines the ecological state of the Aral Sea region and its impact on human health, particularly from medical, biological, chemical, and microbiological perspectives. The ecological crisis caused by the drying of the Aral Sea poses a serious threat not only to the environment but also to public health. As the water level has decreased and the seabed has dried up, large amounts of salt and dust have been released into the air, increasing the concentration of heavy metals, pesticides, and other toxic substances in the atmosphere. This has led to a rise in respiratory, cardiovascular, oncological, and allergic diseases. Additionally, internal diseases such as liver, kidney, and gastrointestinal disorders are frequently observed, largely due to the poor quality of drinking water and food products. Dental diseases, including caries, periodontitis, and gum inflammations, are also widespread in the region, which is linked to the deterioration in water quality, deficiency of essential microelements, and chemically-influenced oral hygiene conditions. Pollution of soil and water resources disrupts the biological balance, negatively affecting plant and animal life. Changes in the microbiological environment have also increased the risk of infectious diseases. The article provides a scientific analysis of the medical and biological consequences of environmental degradation and offers recommendations aimed at protecting public health and restoring ecological stability.

Keywords: Aral Sea region ecosystem, Biological diversity, Dust particles, Human health, Chemical pollution

Introduction

Until the mid-20th century, the Aral Sea was a vast body of water teeming with life. Covering an area of about 68,000 square kilometers, it was a unique ecosystem rich in biodiversity that helped create a moderate climate amid the vast deserts and steppes of Central Asia. The sea received water from two major rivers - the Amu Darya and the Syr Darya (Khurramov, 2025).

For the people living in the regions surrounding the Aral Sea, the sea was the main source of livelihood. The fishing industry thrived - tens of thousands of tons of fish were caught annually, and canning factories operated actively. Life was bustling in port cities such as Muynak and Aral. The sea also served as an important transportation route, used for carrying both cargo and passengers. The Aral's mild climate created favorable conditions for agriculture and livestock farming in the surrounding areas. The sea was a source of life and prosperity for the people of the region (Sharipova et al., 2024).

Method

Roots of the Tragedy

The main cause of the Aral Sea disaster lies in the massive irrigation projects launched in the 1960s to expand large-scale irrigated agriculture. Huge amounts of water from the Amu Darya and Syr Darya rivers were diverted through canals to irrigate cotton and other crop fields (Sharipova, 2022). Since most of the canals in these projects were dug directly into the soil without proper lining, a significant portion of the water - according to some estimates, between 30% and 70% - was lost through seepage and evaporation. As a result, the amount of river water flowing into the Aral Sea decreased sharply. While before 1960 the sea received an average of 50–60 cubic kilometers of water annually, by the 1980s this figure had dropped to almost zero. The halt in water inflow caused the sea level to fall rapidly, leading to its desiccation (Alikhanova et al., 2023). The drying up of the Aral Sea brought about unprecedented negative consequences for the region and the entire world.

Results and Discussion

Environmental Consequences

Disappearance of the Sea

The surface area of the Aral Sea shrank several times over, and its water level dropped by more than 20 meters. Salinity increased sharply - in some areas, several times higher than that of ocean water. The sea split into two parts (the North Aral and the South Aral), and later into three separate water bodies (Shamshetdinova, 2025). In the place of the dried-up sea, a new desert called the Aralkum emerged, covering more than 5.5 million hectares. This desert is coated with toxic salts, pesticides, and residues of chemical fertilizers (Chida, 2020).

Climate Change

The Aral Sea ceased to serve as a natural air conditioner that moderated the regional climate. As a result, the climate became sharply continental: summers grew hotter and drier, while winters became colder and longer. The growing season shortened, and precipitation levels decreased (Ignatieva, et al., 2023).

Dust and Salt Storms

Every year, millions of tons of toxic dust and salt rise from the Aralkum Desert and are carried by winds over thousands of kilometers. These pollutants spread not only across Central Asia but also reach Eastern Europe, Scandinavia, and even the Arctic glaciers. They cause severe damage to human health, agriculture, and ecosystems (Bazarbayev, et al., 2022).

Loss of Biodiversity

As the salinity of the sea increased, nearly all fish species - once numbering over 30 - became extinct. Aquatic and coastal ecosystems, including unique tugai (riparian) forests, degraded severely. Many animal and bird species disappeared or were forced to migrate to other habitats (Ivanova, 2023).

The ecological impact of the Aral Sea's desiccation affected not only human health but also the surrounding environment — particularly soil composition and the life of microorganisms within it. The reduction in soil moisture eliminated the conditions necessary for microbial life. Some beneficial bacteria, such as nitrogen-fixing and organic matter-decomposing species, perished because they could not withstand the drought (Anchitate al., 2021).

As a result, biological activity declined, and the soil's natural ability to regenerate was lost. Many beneficial bacteria and fungi perished. Microbiological diversity decreased, and the number of useful microorganisms dwindled. In the saline environment, only certain halophilic (salt-tolerant) microorganisms survive. The population of bacteria that decompose organic matter declined, slowing the formation of humus. Nitrogen cycling in the soil was disrupted, and the uptake of elements such as phosphorus and potassium deteriorated (Kirillin et al., 2025). Beneficial bacteria, such as rhizobia bacteria, live in symbiosis with plant roots. In a saline environment, plants cannot effectively absorb nutrients. As a result, crop yields decrease.

Socio-Economic Consequences

Collapse of the Fishing Industry

The fishing industry, which employed thousands of people, along with related enterprises such as canning factories and ship repair workshops, completely collapsed. This led to economic decline in cities like Muynak and many surrounding villages (Uysal et al., 2026).

Unemployment and Migration

The loss of jobs led to widespread unemployment and forced people to move to other regions (environmental migration). Many once-thriving settlements were abandoned.

Damage to Agriculture

Salty dust settled on crop fields, reducing soil fertility and lowering yields. Water shortages and secondary soil salinization created serious problems for farming. Livestock farming also suffered as the quality of pastures declined (Kumar, 2023).

Health Problems

Due to dust and salt storms, the deterioration of drinking water quality, and the overall harsh environmental conditions, the incidence of various diseases has increased, including:

Respiratory Diseases

Among the population of the Aral region, respiratory illnesses such as asthma, bronchitis, tuberculosis, and allergic conditions have become widespread.

Maternal and Child Health

Children frequently suffer from congenital defects, developmental disorders, rickets, and low birth weight.

Dental and Oral Health Issues

The effects of acidic and salty water, along with mineral and vitamin deficiencies in food, have led to numerous dental problems, including caries, fluorosis, gingivitis and periodontitis, tooth erosion and demineralization, and stomatitis.

Cardiovascular Diseases

Hypertension, ischemic heart disease, stroke risk, and atherosclerosis have become more prevalent.

Diseases of the Liver, Kidneys, and Abdominal Organs

Hepatitis (especially types A and E), liver inflammation, cirrhosis, kidney stones, pyelonephritis, and gastrointestinal disorders such as gastritis, ulcers, and dysentery.

Oncological (Cancer) Diseases

Lung, liver, skin, and colorectal cancers, as well as leukemia in children.

Skeletal and Bone System Disorders

Caused by excessive fluoride and other substances in the water. These include osteoporosis, arthritis, arthrosis, and improper bone development in children.

Ways to Mitigate the Problem and Solutions

Completely solving the Aral Sea problem - that is, restoring the sea to its former state — is currently considered nearly impossible (see Figure 1). However, comprehensive measures are necessary to mitigate its negative consequences, improve the living conditions of the regional population, and stabilize the ecosystem (Sharipova et al., 2019).

Figure 1. The current state of the Aral Sea

Today, the fate of the Aral Sea is divided into two parts. With the efforts of the Kazakh government and international organizations, the Kokaral Dam was constructed on the Syr Darya channel. This enabled the water level of the North Aral Sea (Small Aral) to rise somewhat, reduced salinity, and allowed partial restoration of the fishing industry. Although this successful project has offered a glimmer of hope, a full return of the sea to its original state remains extremely difficult (Sharipova, 2022). The South Aral Sea (Large Aral), however, has almost completely dried up, and its future remains highly uncertain. It is now divided into two extremely saline, shallow water basins - western and eastern. The eastern part remains entirely dry for most of the year. The inflow of water from the Amu Darya River to the sea is still very limited (Sharipova et al., 2023).

The government of Uzbekistan is working to reduce the amount of toxic dust and salt rising from the Aralkum Desert by creating large-scale forests on the dried seabed and planting Saxaul and other desert plants (Yusufova, 2023). Significant efforts are being made to establish these "Green Covers." Considering soil conditions, sand, and salinity, only carefully selected seedlings can survive. To maintain greenery in the western basins of the Aral region, it is necessary to study the suitability of desert plants to the dried seabed. For this purpose, seeds and seedlings of desert plants such as Kasson saxaul, Kandym, and Koraburoq are being planted because of their adaptability to the environment (Yusufova, 2023).

Efficient Water Resource Management

Strengthen cooperation among Central Asian countries for the fair and rational distribution of water resources. Widely implement water-saving technologies in agriculture, such as drip and sprinkler irrigation (Yusufova, 2023). Modernize canals and irrigation systems to reduce water losses. Shift to cultivating crops that require less water and are salt-tolerant, and diversify agricultural production.

Environmental Measures

Continue and expand afforestation programs on the dried seabed of the Aral Sea (Saxaul planting). Preserve and restore local ecosystems, including tugai forests and lakes. Support projects aimed at protecting biodiversity. Monitor dust and salt storms and implement measures to reduce their impact (Yusufova, 2023).

Socio-Economic Development

Create new jobs for the population of the Aral region and develop alternative sources of income, such as ecotourism and adapted forms of livestock farming. Improve the healthcare system and provide the population with access to clean drinking water. Support education and vocational training programs. Develop infrastructure, including roads and communication networks (Shakirova, 2023).

International Cooperation

Strengthen the activities of the International Fund for Saving the Aral Sea (IFAS). Develop cooperation with the UN, World Bank, Asian Development Bank and other international organizations and donor countries, attracting financial and technical assistance.

Support Scientific Research on the Aral Sea Problem and Facilitate the Exchange of Knowledge and Experience

There are still many challenges in mitigating the Aral Sea problem. These include regional disputes over water distribution, the negative impact of climate change on water resources (such as glacier melting), insufficient funding for project implementation, and the severity of socio-economic problems in certain areas (Shakirova et al., 2025).

The future largely depends on the unity and political will of Central Asian countries, as well as the support of the international community. While full restoration of the Aral Sea is impossible, the experience of the North Aral demonstrates that targeted efforts can bring positive changes. From now on, the main focus should shift from restoring the sea to adapting to the current situation, minimizing the consequences of the ecological disaster, ensuring sustainable development in the Aral region, and improving the lives of its people.

Conclusion

The Aral Sea disaster serves as a bitter lesson on how disastrous the consequences of humanity's thoughtless actions toward nature can be. This problem is not only ecological but also has profound social, economic, and humanitarian dimensions. Although restoring the sea to its former state may seem impossible, much remains to be done to mitigate its negative impacts, stabilize life in the region, and create a sustainable environment for

future generations. Achieving this requires strengthening regional cooperation, rational use of water resources, implementing modern technologies, and ensuring continuous support from the international community.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the authors.

Conflicts of Interest

* The authors declare no conflict of interest.

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