Aral Sea: environmental disaster and its consequences

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Abstract. The article examines the history of the Aral Sea and the environmental disaster of the twentieth century associated with the disappearance of the world's fourth sea body of water. A comprehensive author's research at the interdisciplinary level showed the role and place of the Aral Sea from the moment of its formation in the surrounding space, its influence on the socio-economic development of coastal areas. The purpose of the undertaken research was to determine the cause-and-effect relationships that determined the large-scale man-made environmental disaster that occurred on the border line of the two states of Kazakhstan and Uzbekistan. The authors tried to show how the disappearance of the sea affected the ecological state of the environment, namely the Kyzyl-Orda region, where the remains of the Aral Sea are located. The article provides statistical indicators on the topic of the research, their comparative analysis and the dynamics of the state of the environmental situation in the Aral Sea region. The authors introduce a visual representation of the changes in the Aral Sea throughout modern and recent times. In conclusion, the authors demonstrate the existence of measures taken by the state in an attempt to restore the Small Aral Sea by constructing a hydraulic structure.

1 Introduction

One of the colossal problems of the globe at the moment is environmental problem [1–3]. Climate disasters, as a consequence of human activity, are becoming more and more unpredictable and catastrophic, causing enormous damage to the environment and life on earth [4–6]. President of Kazakhstan Mr. Tokayev noted in his speech to the nation of Kazakhstan that only in 2021, more than 57 million of people people were affected in Asia [7]. According to the World Meteorological Organization (WMO), the situation in 2022–2023 has worsened even more, this is due to the melting of glaciers and rising sea levels; severe drought in Asia and a shortage of water resources, specifically drinking water, are predicted for 2024. Climate change has a negative impact on the agriculture of Asian

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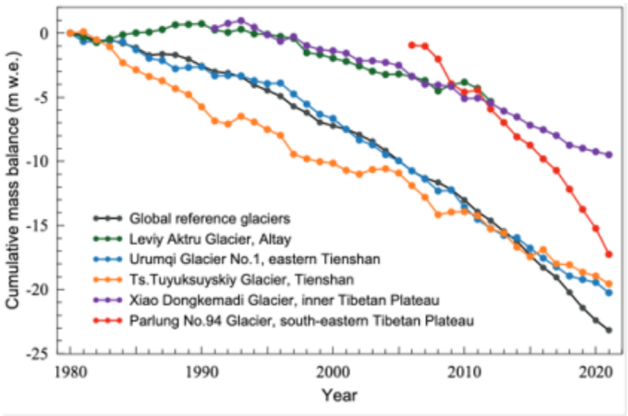
countries, causing food problems, which in turn affects migration and demographic processes.



Cumulative mass balance (in metres water equivalent (m w.e.)) of five reference glaciers in the High-Mountain Asia region and the average loss of global reference glaciers.

Fig. 1. Future water scarcity scenario [8].

Kazakhstan, being an integral part of the Asian continent, annually experiences the presence of high water in the spring and its absence in the summer, when agricultural products, including bread, die from drought. The lack of water resources is the most relevant problem at the moment; in our modern world, a catastrophe has occurred before our eyes – the Aral Sea has disappeared, having lost 97% of its life-giving moisture. Picture 2 clearly demonstrates what the area of the Aral Sea was and what area remains of what was previously called the sea and occupied 4th place in the world. How could this happen in Central Asia, where a constant global issue of water shortage has always been relevant?

The purpose of the author's research is to identify the cause-and-effect relationships that caused the environmental disaster that occurred on the border line of the two states of Kazakhstan and Uzbekistan, and also to show how the disappearance of the sea affected the ecological state of the environment, namely the Kyzyl-Orda region, where the remains of the Aral Sea are located.

Despite the fact that the development strategy of Kazakhstan outlines many priority areas for the preservation and restoration of biological diversity, the creation of conditions for the self-regulation of natural systems, the solution of environmental safety issues and the prevention of environmental disasters, we are forced to admit that the risks of disturbing the ecological balance do exist and have become the basis for author's research.

2 Materials and Methods

The authors in their study relied on common systemic general scientific blocks and approaches aimed at identifying objectively reliable knowledge in the focus of analysis of statistical parameters, knowledge and understanding of the problem in the focus of an analytical review of identified materials, synthesizing and structuring them into visual design for comparison and representation in chronological order and numerical dynamics. In writing the article, we used the concepts of the systems method, at the intersection of geography and ecology, we tried to obtain a complete picture of the problem that we were studying, which contributed to the use of methods of related sciences and resulted in the work process effectively.

3 Discussion of the results

Analysis of environmental problems in Kazakhstan is one of the current research trends of scientists professionally dealing with this topic. Researchers identify large-scale problems associated with the health of people living in an environmental disaster zone and propose solutions. The authors understand that the launched mechanism of the ecological disaster of the Aral Sea has a detrimental effect on the surrounding flora and fauna, disrupts the balance in the ecological system, which at the genetic level introduces chaos into the natural world around humans, disrupts their program, which gives rise to the "introduction of alien species of plants and animals "signifying the beginning of the coming catastrophe" [9].

Thus, the topic proposed by the authors is of current importance; unfortunately, at the moment we have several locations that have the status of environmental disaster zones, one of them is the Aral.

3.1 Origins and visualization of environmental disaster

The economic strategy of the Soviet leadership for the implementation of large-scale projects, including changing river channels in the first half of the twentieth century, became the precursor to the beginning of the disaster. For several decades, the Aral Sea served as a climatic regulator of the environment, played an important role in the system of economic production, including agricultural production, and influenced social processes and infrastructure. The daily production of the population of the border areas of the Aral Sea of Kazakhstan and Uzbekistan was closely connected with fishing production, cotton growing, crop growing, livestock farming, etc. Almost all types of human production activities required irrigation, the Syrdarya and the Amu Darya became a means of obtaining economic results and at the same time an instrument for the destruction of the Aral Sea. Water reserves exceeded consumption standards; since the 60s of the twentieth century, the Aral Sea began to shrink (Table 1).

Table 1. Dynamics of changes in the Aral Sea (taken from open sources).

Year	Water level (meters)	Surface area km^2	Mineralization
1960	53.40	65 900	9.90
1980	46.40	51 675	18.00
1990	38.24	36 800	29.00
2003	31.00	18 240	78.00

Why the area of the Aral Sea began to shrink is shown by the study of N. Novikova; we transfered her data into a diagram, which clearly shows how the area of irrigated land in the Aral Sea basin is growing between 1960 and 2000 respectively. N. Novikova points out that "the population living in this territory" in 2002 reached "40 million people, in the zone of environmental crisis, in the Aral Sea region – about 3 million people. The modern water management network includes 80 reservoirs with a capacity of more than 100 million m^3; the total length of the irrigation network is 315.8 thousand km; the total length of the collector and drainage network is 191.9 thousand km" [10].

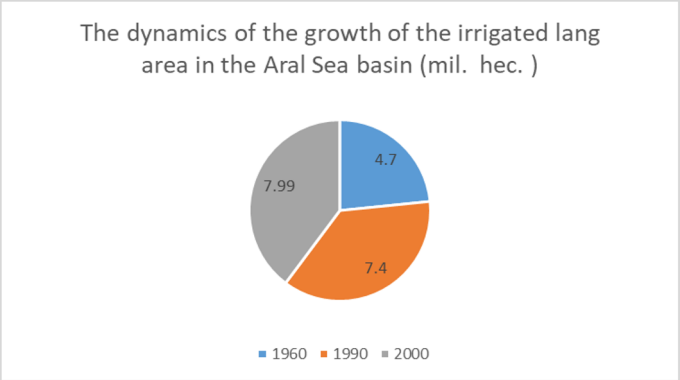


Fig. 2. Dynamics of growth of irrigated lands in the Aral Sea region [10].

Fig. 3. Dynamics of transformation of the Aral Sea (satellite images) (taken from open sources).

Figure 3 visually demonstrates the stages of drying out of the Aral Sea, thirty years are between the first and second images, twenty years are between the second and third image, fifty years are between the first and third images. The tragedy of the Aral Sea was observed by two generations, the third generation of the 21st century assesses the global environmental catastrophe, which had a large-scale impact on the human environment in the Aral Sea region.

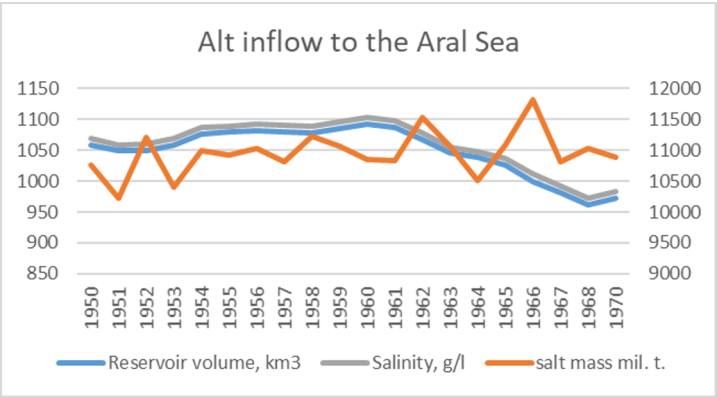


Fig. 4. Salt influx into the Aral Sea 1950-1970 (compiled by the authors based on open sources).

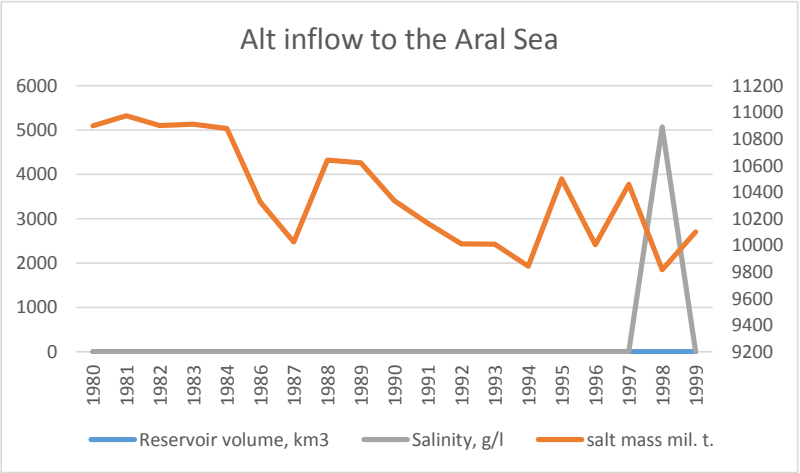


Fig. 5. Salt influx into the Aral Sea from 1980 to 1999 (compiled by the authors based on open sources).

According to the composition of the water, the salinity of the Aral exceeded the world ocean; by 2014, only 10% of the water remained from the sea, while the salinity of the water increased from 14 to 100 grams per liter [11]. According to the latest data, the area of the salt desert is more than a million hectares. Undoubtedly, the salty Aral Sea determined a reboot in the region; the qualitative composition of bio- and zoo-diversity has naturally changed.

3.2 Consequences of the environmental disaster of the Aral Sea

The environmental damage from the drying out of the Aral Sea is practically not assessable; restoration of the environment can be discussed, but, in our opinion, this is not recoverable. Previously, it was planned to turn the Siberian rivers “backwards” and replenish the Aral Sea; the restoration project had neither scientific and industrial justification nor financial support. The drying up of the Aral Sea provoked, first of all, colossal climate changes, due to the fact that it was located “on the route of a powerful jet air flow from west to east”. Dust storms have begun on a regular basis in the region, with wind speeds reaching 20–25 m/s [12]. The Aral problem concerns the entire Central Asian region; climate change has to some extent affected the territory of the population of Uzbekistan, Turkmenistan, and Kyrgyzstan.

In Kazakhstan, those affected by the environmental disaster included the Kyzylorda region, partly the areas of the South Kazakhstan, Aktobe and Karaganda regions. The growth dynamics of dust storms, which are quite usual for the Aral region, where the border lines of the Aral Sea were represented by the Karakum and Kyzylkum deserts, are only increasing. The growth of desert-sandy territory is due to the lack of water balance and the existing deficit of precipitation. The depletion of water resources has affected the soil composition of the Aral Sea region; according to archival materials, potentially fertile soils have lost significant areas of humus as a result of erosion; the reduction is felt by 30–40%. At the same time, 60% of cultivated areas contain only 1% of humus.

The sea played the role of a climate regulator, it influenced on the temperature background, humidity, an accompanying phenomenon, and it can be considered as the basis for a mild winter climate and less hot summers.

Taking into account that Kyzylorda region has the total number of stationary sources of emissions and pollutants amounted to more than 11,000 units, dust storms contribute to the active spread of harmful substances into the atmosphere, which in turn affects the health of the population. The harmful substances that were detected during the monitoring of air assessment in the Kyzylorda region: "carbon monoxide, solids, sulfur dioxide, nitrogen oxides" [13].

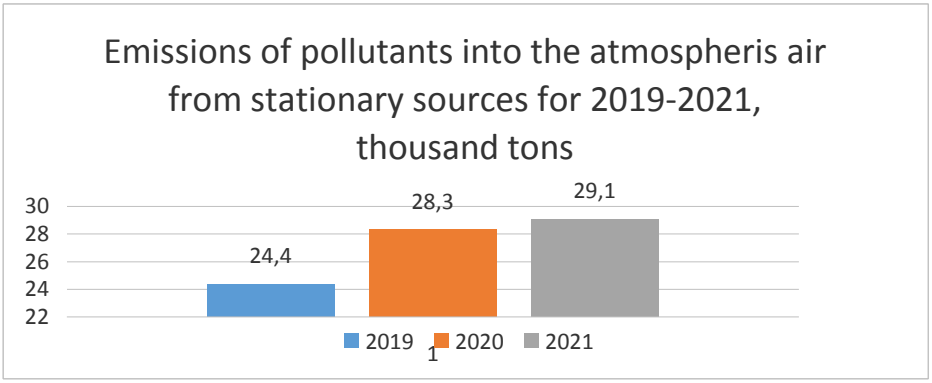


Fig. 6. Dynamics of emissions polluting the atmosphere in the Kyzylorda region.

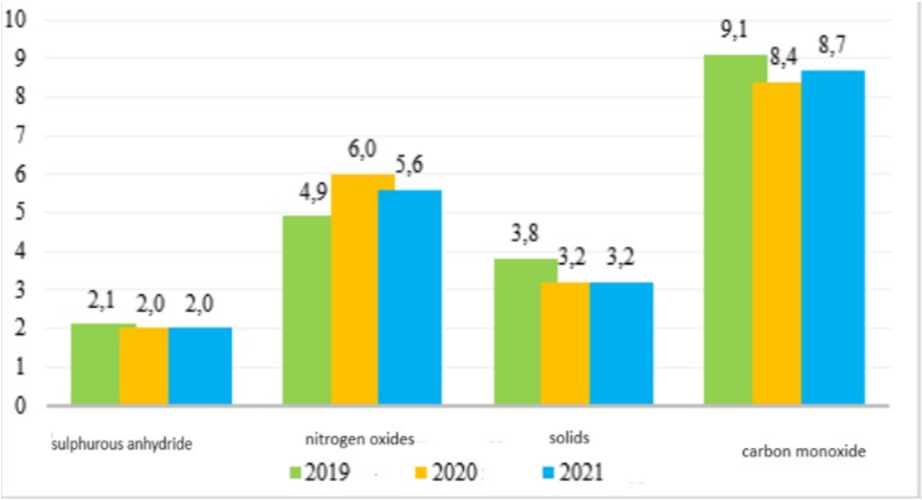


Fig. 7. Volumes of emissions of main pollutants into the atmospheric air of Kyzylorda region from 2019 to 2021, in thousand tons.

The Aral crisis caused problems with drinking water, pollution of existing water sources, and a reduction in the irrigation system. The issues of assessing pollution of water resources in Kazakhstan are dealt with by the RSE "Kazhydromet" using a specific algorithm. Pollution assessment markers include 34 physical and chemical indicators, including such indicators as water level and flow rate, the amount of sodium and potassium, hardness, suspended solids, transparency, smell, pH value, dissolved oxygen, BOD5, COD, total ions, dry residue, main ions of salt composition, biogenic (compounds of nitrogen, phosphorus, iron) and organic substances (petroleum products, surfactants, volatile

phenols), heavy metals, pesticides. In 2021, observations of surface water pollution were carried out in the Kyzylorda region in 2 water bodies – the river Syrdarya and the Aral Sea. The monitoring showed that the main pollutants in water bodies of the Kyzylorda region are sulfates, magnesium, and mineralization. Exceeding quality standards of these indicators is mainly associated with the agricultural focus of the region. See table 2 [13].

Table 2. Quality of surface waters in the Kyzylorda region for 2020–2021.

Name of water body	Water quality class		Parameters	Unit of measure	Concentration in, mg/dm^3, 2021
	2020	2021			
River Syrdarya	4 class	4 class	Sulfates	mg/dm^3	457.8
			Mineralization	mg/dm^3	1450.6
			Magnesium	mg/dm^3	34.6
			Temperature	℃	18.8
			Level of water		41.48
			Suspended solids	mg/dm^3	6.2
			PH index		7.7
			Diffused oxygen	mg/dm^3	6.3
			Transparency	sm	21
			The smell of water	point	0
			BOD	mg/dm^3	1.7
			COD	mg/dm^3	10.7
			Hydrogen carbonate	mg/dm^3	193.2
			Rigidity	mg/dm^3	7.7
			Mineralization я	mg/dm^3	1623.7
Aral Sea			Sodium + potassium	mg/dm^3	684.7
			Dry residue	mg/dm^3	1618.3
			Calcium	mg/dm^3	86.7
			Magnesium	mg/dm^3	40.7
			Sulfates	mg/dm^3	495
			Chlorides	mg/dm^3	123.5
			Phosphate	mg/dm^3	0.15
			General phosphorus	mg/dm^3	0.17
			Nitrite nitrogen	mg/dm^3	0.007
			Nitrate nitrogen	mg/dm^3	0.3
			Total iron	mg/dm^3	0.13
			Ammonium salt	mg/dm^3	0.10
			Copper	mg/dm^3	0.003
			Synthetic surfactants	mg/dm^3	0.02
			Volatile phenols	mg/dm^3	0.0
			Petrochemicals	mg/dm^3	0.0

It should be noted that in general in Kazakhstan, including the Aral Sea region, there is an unfavorable situation with the provision of clean water to the population; in many settlements there is still no centralized water supply.

Fig. 8. Monitoring the quality of surface waters of the Republic of Kazakhstan. Fragment of a map of the Kyzylorlinsk region, March 2024 (taken from open sources of Kazhydromed).

It should be noted that in comparison with the indicators in Table 2, the situation is practically unchanged and even becomes worse. Class 5 pollution of the Syrdarya river in the spring is considered to be normal, although on average, according to the experts, the level of pollution of the Syrdarya is average. The concentration of pollutants exceeds the norm from 1.5 to 4.22 times [14].

An accompanying consequence of the environmental disaster can be considered an increase in morbidity among the population of the analyzed region. Dust storms pollute the atmosphere, carrying varying amounts of pesticides, chemicals and other substances hazardous to humans. According to the experts, the Aral Sea region has a high level of diseases caused by the quality of drinking water, air and soil pollution by pesticides. Among the noted diseases, gastrointestinal and skin diseases prevail, high mortality and congenital pathologies are observed. Medical experts note that "the local population suffers from a high prevalence of respiratory diseases, anemia, cancer of the throat and esophagus, and digestive disorders. Liver and kidney diseases have become more frequent..." [15].

4 Conclusion

Summing up the results of our research, we note that the disappearance of the Aral Sea, which had the status of the fourth sea in the world, became the largest disaster of the twentieth century. The Aral Sea, which has played a key role throughout the history of its existence not only in the production processes of mankind, but also an important violin in the ecological space, has transformed its environment with its disappearance. The consequences of the death of a natural water body are irreversible and will continue to have negative consequences on bio- and zoo-diversity, and on the health of the population in the territories bordering the Aral Sea.

The disappearance of the Aral Sea was the result of man-made activities of mankind, thoughtlessly using water resources. Where the was the sea, now is a desert with the skeletons of ships that once roamed its expanses. This dead sea, which previously had rich fishing grounds, contributed to the social employment of the population living on its coastal territories, and was famous for the extraordinary diversity of flora and fauna, has an adverse effect on the territory surrounding it. In the current state, there are problems with drinking water, irrigation of agricultural land, unemployment and health.

At the same time, we still have two isolated bodies of water: the Northern (Small) and Southern (Big) Aral Sea. Modern technologies can partially solve the problems of the Aral Sea. In 2003–2005, the Kokaral dam with a hydraulic gate was built and put into operation,

which made it possible to accumulate water in the Small Aral and even revive fishing. Undoubtedly, this small beginning in the future, through the joint efforts of Kazakhstan's neighboring states, will allow to restore two reservoirs gradually.

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