CHEMICAL FIXATION AND STABILIZATION OF SOILS IN THE ARAL DESERT

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ABSTRACT

The study analyzes the dynamics of mineralization and morphometric changes in the basins of the Aral Sea during the period from 2002 to 2017. Significant differences in the salt composition of the western and eastern basins were identified, determining the specific features of bottom sediment formation. Based on expedition data, the necessity of shifting from monitoring to active landscape management has been substantiated. The research findings provide a scientific foundation for the development of technologies aimed at fixing mobile sands and salts, which is critically important for preventing toxic dust storms and stabilizing the environmental situation in Karakalpakstan.

Emphasizing environmental challenges, Shavkat Mirziyoyev, President of the Republic of Uzbekistan, noted that the disappearance of the Aral Sea, once one of the world's largest inland bodies of water, has become a global environmental catastrophe whose consequences are now felt not only within our region but far beyond its borders. The Head of State once again called upon world leaders to unite their efforts in mitigating the consequences of this crisis [1].

Despite the dedicated efforts of numerous scientists and research teams, as well as the continuing global interest in this issue, the flow of scientific information on the Aral Sea — once extensively supported by observational data — has generally declined significantly over the past twenty years. Yet it was precisely during this period that the sea underwent its most radical transformations. The main reason for this is the physical inaccessibility of the sea within its current boundaries, which have receded far from populated areas and transportation routes. A great deal of information can be obtained from instruments installed on Earth's artificial satellites that monitor the Aral Sea on a daily basis. However, they cannot reveal everything, since spacecraft observe only the water surface, while many of the secrets of the modern Aral Sea and the keys to understanding its behavior remain hidden within its saline depths. Since 2002, the Shirshov Institute of Oceanology, in cooperation with the Hydrometeorological Centre of the Russian Federation and a number of scientific organizations of Uzbekistan and Kazakhstan, and since 2012 together with the Tashkent Institute of Chemical Technology, the Hydrometeorological Service Center of the Republic of Uzbekistan, and several scientific institutions of the republic, have regularly conducted the following comprehensive studies:

- distribution of salts in groundwater and across the dried surface of the Aral Sea during the period from 1990 to 2024;
- theoretical analysis of the sequence of salt crystallization from the brine of the Western Deep-Water Part of the Large Aral Sea (WDWPLAS), including determination of changes in the $Na_2SO_4/NaCl$ and $MgCl_2/NaCl$ ratios and the construction of a cyclochronogram for the WDWPLAS;
- determination of the physicochemical properties of the WDWPLAS brine depending on temperature and salinity;
- determination of the salt composition of saline soils on the dried seabed of the Aral Sea;
- chemical and mineralogical analysis of the composition of deposited dust from the dried seabed of the Aral Sea following salt-dust storms; etc.

In 1958, at its average water level, the Aral Sea covered an area of 68,550 km². At its highest level, the area reached 69,670 km², while at its lowest level it decreased to 67,300 km². The average depth of the sea was 16.4 m, and the maximum depth was 69.5 m. At the average water level, the volume of the sea amounted to 1,122 km³; at the maximum level, 1,153 km³; and at the minimum level, 1,087 km³. The sea was 428 km long and had a maximum width of 284 km. The Aral Sea contained a considerable number of islands, with a total area of 1,276 km² [2].

Runoff from agricultural fields in the middle and lower reaches of the Sirdarya and Amudarya rivers led to the accumulation of pesticides and various other agrochemicals, which now appear in certain areas of the former seabed covering 59.31 thousand km² and coated with salt deposits. Dust storms annually carry approximately 43 million tons of salts from the Aral Sea basin over distances of up to 500 km. Sodium bicarbonate, chloride, and sulfate are transported through the atmosphere, destroying or slowing the growth of natural vegetation and agricultural crops, and are deposited over an area of 1.5–2.0 million km², causing significant damage to nearby agricultural regions. The local population suffers from a high prevalence of respiratory diseases, anemia, throat and esophageal cancer, as well as digestive disorders. The incidence of liver and kidney diseases, along with eye disorders, has also increased significantly.

Apparently, during 2009–2010, the overflow channel became filled with salt deposits. Despite the fact that the water level of the western basin was 26 m lower in 2011–2013, a certain amount of brine accumulated in the eastern basin. According to published data, the salt composition of the dry sediments in the three basins differs significantly. In the northern part of the Small Aral Sea, the composition remained practically unchanged, whereas in the eastern basin of the Large Aral it can be characterized as chloride–sulfate in nature (more than 80% sodium chlorides, with the remainder consisting of sodium sulfate and 2–6% magnesium sulfate). The western basin contains chloride–sulfate–magnesium salts (40–60% chlorides and sodium salts, 20–40% sodium sulfates, with the remainder represented by magnesium salts).

According to published sources [3–5] and the results of expeditions conducted on June 15–25, 2017, the rate of formation of the dried surface decreased from 1 to 0.15–0.20 thousand km^2 per year at a depth of 32.85 m, with a water surface area of 3.34 thousand km^2, a water mass volume of 95.95 km^3, and an average salt content of 12,595.38 million tons. During the period from 2002 to 2014, shoreline retreat was observed, resulting in the formation of 1.92 thousand km^2 of new water surface area in the Aral Sea basin.

Thus, regular expeditions and detailed chemical analysis of brine composition provide the foundation for the development of technologies aimed at stabilizing mobile sands and salt deposits on the exposed seabed. A profound understanding of salt crystallization processes makes it possible to move from passive observation to active landscape management, including the creation of sustainable protective barriers and the selection of chemical or biological soil fixation methods. This is critically important for preventing toxic dust and salt storms and for stabilizing the environmental situation in Karakalpakstan.

Ultimately, only the combination of political will with scientific methods of land reclamation and soil stabilization will make it possible to halt the aggressive expansion of desertification zones. The implementation of United Nations programs, together with precise data on mineralization, makes it possible to transform the “dust-producing” seabed into a stable and scientifically managed territory, thereby ensuring reliable protection of public health and environmental security throughout the entire Central Asia region.

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