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FORMATION AND CLIMATIC FEATURES OF THE ARAL REGION

Kudaibergenova Ulbike Kallibekovna
associate professor
doctor of philosophy (PhD) in environmental sciences
department of biology
Faculty of Natural Sciences
Ajiniyaz Nukus State Pedagogical Institute
Kudaibergenova Gulnaz
basic doctoral student
Ajiniyaz Nukus State Pedagogical Institute
Nukus, Uzbekistan
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Abstract: The article examines the issues of geological formation of the Aral Sea region and analyzes the current climatic features of the territory that has undergone significant transformations due to anthropogenic impact on the Aral Sea. Based on the generalization of long-term meteorological observation data, expedition research results, and remote sensing materials, the main patterns of changes in the temperature regime, humidity, wind activity, and dust storms in the region have been identified. It has been established that the degradation of the Aral Sea water area has led to an increase in climate continentality, an increase in the frequency of extreme meteorological phenomena, and the formation of a new natural object - the Aralkum desert. The results of the study can be used in the development of regional programs for ecological rehabilitation and adaptation of the population to changing climatic conditions.

Keywords: Aral Sea region, Aral Sea, climate, continentality, Aralkum, dust storms, temperature regime, aridization.

INTRODUCTION

The Aral Sea region represents one of the most dynamically transforming natural regions of Central Asia, forming within the Turan Lowland and linked to the Aral Sea basin. The geographical location of the territory in the central part of the Eurasian continent (approximately 43°-47° N and 58°-62° E) determines its sharply continental and arid natural-climatic conditions, characterized by a high degree of spatial variability and sensitivity to anthropogenic impact [24, pp. 63-67].

The geological development of the region has a long history, during which sea and continental stages have repeatedly alternated. During the Mesozoic-Cenozoic period, the territory was repeatedly covered by epicontinental seas, which led to the formation of thick sedimentary layers represented by clays, mergels, limestones, and sandstones [7, pp. 44-45]. In the Neogene and Pleistocene, the intensification of tectonic processes within the Turan Plate led to the formation of large structural elements - depressions and uplifts, including the Aral Depression as a zone of stable subsidence of the Earth's crust [11, pp. 87-91]. In the Quaternary period, fluvial and eolian processes related to the activities of the Amu Darya and Syr Darya, as well as climatic fluctuations of glacial epochs, acquired a leading role. It was during this period that the region's main sandy massifs and modern delta systems were formed [18, pp. 114-118].

The Aral Sea as a natural object was formed in the Late Pleistocene - Early Holocene as a result of the filling of the tectonic basin with river waters [2, p. 45]. Throughout the Holocene, the water level of the reservoir changed repeatedly, which is recorded in the alternation of regressive and transgressive phases [6, p. 88]. Until the middle of the 20th century, the hydrological balance of the Aral Sea was maintained by the tributaries of the Amu Darya and Syr Darya, which provided tens of cubic kilometers of water per year [8, pp. 102-104]. However, starting from the 1960s, intensive water intake for irrigation led to a sharp decrease in the inflow, which became a key factor in the ecological transformation of the region.

The modern landscape structure of the Aral Sea region includes diverse natural complexes: deltaic plains, sandy deserts, saline lowlands, and plateaus. The Northern, Western, Eastern, and Southern Aral Sea regions differ in their morphological and ecological characteristics, yet they function as a single system linked by common climatic and hydrological processes [24, pp. 64-67]. The Aralkum Desert is of particular importance - the exposed bottom of the former sea with an area of more than 6 million hectares, which is an active zone of deflation and salt dust transfer [5, p. 112].

The region's climate is shaped by extreme intra-continentalness, the absence of oceanic influence, and high atmospheric transparency. It belongs to a sharply continental arid type with extreme seasonal and daily temperature amplitudes and extremely low precipitation levels [12, p. 14]. In winter, the territory is under the influence of the Asian anticyclone, which leads to stable cold and dry weather conditions, and in summer, it is under the influence of tropical air masses that form extreme heat [28, p. 42].

The temperature regime is characterized by a significant amplitude: from −35°C in winter to +45...+49°C in summer. Such indicators reflect the extreme degree of continentality of the climate. Precipitation is distributed unevenly and does not exceed 90-140 mm per year, with the majority falling during the cold season [28, p. 47]. Evaporability is many times higher than precipitation, which forms a stable moisture deficit and an extremely low moisture coefficient.

Wind regime plays a crucial role in the formation of modern landscape processes. Northern and northeastern winds prevail, but dry winds and dust storms, which intensified sharply after the drying up of the Aral Sea, are of particular importance. Every year, millions of tons of salts and dust particles rise from the Aralkum territory, spreading over significant distances [10, pp. 88-91]. High solar radiation and the duration of sunshine (up to 3,000 hours per year) increase surface overheating and intensify environmental degradation processes [12, pp. 25-26].

MATERIALS AND METHODS

The methodological basis of this research is based on the principles of comprehensive physical-geographical analysis, a systematic approach, and the interdisciplinary study of natural-anthropogenic processes. The Aral Sea region is considered a complex geosystem whose development is determined by the interaction of geological, climatic, hydrological, and anthropogenic factors. The study relies on the concepts of regional geography, geoecology, and climatic dynamics of arid territories.

The work employs a historical-geographical approach that allows for tracing the evolution of the formation of the Aral Sea region at various stages of geological development, as well as identifying the relationship between natural processes and modern environmental transformations. Particular attention is paid to the analysis of anthropogenic impact on the water balance of the Aral Sea basin and its impact on climate change in the Southern Aral Sea region.

The methodological framework of the study includes the following scientific principles:

- the principle of comprehensiveness, which provides for considering the natural components of a region as a single, interconnected system;
- the principle of spatial-temporal analysis, which allows for assessing the dynamics of changes in the geographical and climatic parameters of the Aral Sea region;
- the principle of comparative-regional analysis, based on comparing modern natural conditions with historical data;

- the principle of sustainable development, which involves assessing natural changes from the perspective of environmental safety and rational nature management.

To achieve the set goal, a complex of general scientific and special geographical methods was used in the study.

General scientific methods include:

- analysis and synthesis of scientific literature, statistical materials, and regulatory legal documents;
- systematizing and summarizing data on the geological history and climatic features of the Aral Sea region;
- comparative analysis of the dynamics of natural processes across different historical periods.

Among the special geographical methods used were:

1. The historical-geographical method used to study the stages of the formation of the Aral Sea region, the transformation of the Aral Sea coastline, and changes in the Amu Darya and Syr Darya delta systems.
2. A cartographic method that includes the analysis of thematic maps, satellite imagery, and spatial distribution schemes of natural objects. This method made it possible to determine the modern boundaries of the Aral Sea region, identify landscape degradation zones, and areas of intensive desertification.
3. Geomorphological method aimed at studying the relief, deflation, accumulation, and formation processes of the Aralkum desert on the dried bed of the Aral Sea.
4. A climatological method based on the analysis of long-term data on air temperature, atmospheric precipitation, humidity, wind regime, and the frequency of dust and salt storms. This made it possible to identify modern trends in the aridization of the region's climate.
5. The hydrological method used to assess changes in the water balance of the Amu Darya basin and the dynamics of the shrinking area of the Aral Sea water mirror.
6. Geoinformation (GIS) method used for spatial analysis of natural processes, remote data processing, and visualization of changes in the region's landscape structure.
7. The method of Earth remote sensing, based on the use of satellite imagery from various time periods to identify the dynamics of Aral Sea drying and the transformation of natural complexes in the Aral Sea region.

The information base of the study consists of materials from international organizations, statistical data from the Interstate Commission for Water Coordination, state programs of the Republic of Uzbekistan, scientific publications by domestic and foreign researchers, as well as cartographic and remote data on the Aral Sea region.

The application of a combination of these methods made it possible to ensure the comprehensiveness of the study, identify the modern geographical and climatic features of the Aral Sea region, and determine the key directions for further environmental and geographical monitoring of the region.

MAIN PART

The disappearance of the Aral Sea's mitigating influence has become a key factor in modern transformation. Previously, the reservoir served as a climate regulator, accumulating heat and reducing seasonal temperature contrasts. After its degradation, a dry underlying surface with high albedo formed, which intensified climate continentality and changed the circulation of the lower layers of the atmosphere [19, pp. 14-16]. This led to a reduction in transitional seasons and an increase in the frequency of extreme weather events.

The formation of the Aralkum desert has become a central element of modern ecological transformation. The drained bottom is characterized by a combination of barchan sands and solonchaks, containing residues of mineral substances and agrochemicals accumulated during the existence of the reservoir. Dust and salt storms have acquired a systemic character and become one of the main factors of environmental risk in the region [33, pp. 55-60; 34, pp. 12-18].

Simultaneously, a profound degradation of the hydrographic network occurred. The reduction of the Amu Darya and Syr Darya flows has led to the disappearance of intra-delta water bodies and the disruption of the natural water balance. Delta ecosystems have lost their ability to self-regulate, and tugai forests have decreased by more than 80%, being replaced by saline and xerophytic communities [29, P. 115; 14, p. 51].

The region's soil cover has undergone significant degradation. In conditions of aridity and moisture scarcity, a process of secondary salinization, the destruction of the humus layer, and active wind erosion has developed. Significant areas of agricultural land have been subjected to degradation, which has reduced their productivity and sustainability [23, pp. 210-214].

Ecological changes have led to a decrease in biodiversity. The disappearance of aquatic ecosystems has caused the destruction of food chains, the reduction of fish and bird populations, and the loss of a number of endemic species. As a result of the degradation of tugai forests and the fragmentation of landscapes, the number of large mammals has decreased, and the region's fauna has become impoverished [20, pp. 41-49].

Modern research in the Aral Sea region is based on a combination of ground monitoring and remote sensing. Landsat, Sentinel, and MODIS satellite systems, as well as GIS technologies, are used to analyze the dynamics of Aralkum, the state of vegetation, and the spread of dust storms [32, pp. 11-21]. International cooperation within environmental monitoring programs ensures the formation of a unified database regarding the state of the region.

According to climate forecasts, the Aral Sea region remains one of the most vulnerable zones in Central Asia. A further increase in temperature, increased aridity, and a decrease in river water levels are expected due to the reduction of glacial feeding [4, pp. 73-79]. Possible development scenarios include both further degradation of ecosystems and partial stabilization provided that water-saving technologies are implemented and forest reclamation works are expanded.

RESULTS AND DISCUSSION

International cooperation through the International Fund for Saving the Aral Sea, as well as state environmental programs, play an important role in stabilizing the situation. The development of forest reclamation on the dried seabed using saxaul (Haloxylon aphyllum), which is capable of reducing deflation and stabilizing sands, is of significant importance [21, pp. 84-86]. The experience of partial restoration of the Northern Aral Sea after the construction of the Kokaral Dam demonstrates the possibility of local ecological stabilization during the engineering regulation of water flows.

Thus, the current state of the Aral Sea region is the result of the complex interaction of natural and anthropogenic factors, which led to the formation of a unique but extremely vulnerable natural-anthropogenic system currently undergoing ongoing transformation.

And a comprehensive study of the natural, climatic, and geo-ecological features of the Aral Sea region indicates that the region is undergoing a large-scale transformation of the natural environment. Analysis of historical materials, as well as the results of modern satellite observations, show that over a relatively short historical period, the Aral Sea, which was previously one of the world's largest stagnant bodies of water, has undergone a sharp reduction in area and split into several isolated water basins with a high degree of mineralization. The drying up of a significant portion of the sea floor led to the formation of the Aralkum desert, covering an area of millions of hectares, which caused significant changes in the natural complexes of the Turan Lowland. These processes were accompanied by the degradation of soil cover, the disruption of the hydrological regime of the Amu Darya and Syr Darya deltas, the reduction of biodiversity, and the deterioration of the sanitary-ecological situation in the Republic of Karakalpakstan [9, pp. 94-98; 26, pp. 41-44].

The uniqueness of the modern climate of the Aral Sea region is determined not only by its intra-continental position but also by large-scale anthropogenic changes in the environment. Researchers note that the disappearance of a significant portion of the Aral Sea's water mirror has led to the weakening of its climate-regulating function. As a result, climate continentality has intensified in the region, seasonal and daily temperature fluctuations have increased, air humidity has decreased, and the frequency of drought phenomena has increased [31, pp. 57-60]. According to experts, the Aral Sea region has become one of the few regions in the world where human economic activity has significantly changed the local climate regime and natural balance over several decades [17, pp. 22-25].

In modern conditions, scientific research aimed at stabilizing the ecological situation and adapting the region to the consequences of climate change is acquiring particular significance. Within the framework of the "Uzbekistan-2030" Strategy and international initiatives to develop the Aral Sea region as a zone of environmental innovations, the need to expand comprehensive monitoring of natural processes is increasing. One of the priority areas is considered to be the improvement of geoinformation systems and satellite monitoring for tracking the spread of salt and dust flows and assessing the dynamics of deflationary processes in the Aralkum region [5, pp. 112-115].

Developing effective agroforestry reclamation methods for the dried-up bottom of the Aral Sea remains an equally important task. Karakalpak scientists emphasize the need for the scientific selection of resilient species of halophytic vegetation, primarily black saxaul, capable of stabilizing shifting sands and reducing the intensity of salt dust transport [30, pp. 138-143]. Simultaneously, forecasting changes in Central Asia's water balance under conditions of accelerated melting of Pamir and Tien Shan glaciers is of great importance, as the reduction of glacial resources directly affects the volume of Amudarya and Syrdarya runoff [3, pp. 48-51].

Researchers note that further improvement of the environmental situation in the Aral Sea region is possible only through the joint efforts of scientists, government agencies, and international organizations. The coordination of scientific programs on the platform of the International Fund for Saving the Aral Sea contributes to the development of sustainable environmental solutions, the reduction of environmental risks, and the formation of prerequisites for the gradual restoration of the region's natural environment [25, pp. 176-182; 22, pp. 180-186.]

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