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Forecasting changes of hydrological and hydrochemical conditions in the Aral Sea

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Abstract: The increase of irretrievable river water withdrawals and regulation of river flow has a negative effect on the natural regime of the Aral Sea. The Amu Darya River and the Syr Darya River Basins are the largest irrigated farming areas. Their favorable soil and climatic conditions ensure guaranteed yields of various crops on irrigated lands. Since 1961, for the drastic increase of irretrievable river water withdrawal, mainly for irrigation, the inflow of river water into the Aral Sea has started to decrease significantly, accordingly the sea's hydrological and hydrochemical regimes disrupted dramatically. The sea level has continued to drop as evaporation exceeds inflow. This negatively transforms the natural environment and worsens socio-economic conditions in Priaralie as a whole, especially in the lower reaches of Amu Darya and Syr Darya, where natural conditions are largely determined by the sea's impact. At present, this causes desertification of the nonirrigated zone in the deltas, spreading to new areas as the Aral Sea dries out.

Key words: Aral Sea; hydrological condition; hydrochemical condition; river water withdrawal; natural environment

1 Introduction

Research on the Aral Sea and Priaralie problem has great scientific and practical importance for maximal mitigation of the negative consequences of sea level lowering, prevention of desertification processes, and preservation of the Aral Sea water area at a certain level by achieving efficient water use in the basin as a whole. The drying sea coast is a unique exposed Aral area, where origination, formation, and development of primary continental natural systems are observed and there is a process of formation of environmental components. In addition, the former seabed becomes the stage of aeolian processes, which typically occur in a desert zone. Deflation leads to transfer of materials, with the dust of salts accumulating in the soil because of intensive evaporation of near-surface water. The threat of further potential worsening of the geosystems in the region calls for the development of appropriate scientifically substantiated measures.

2 Research purpose and objectives

The purpose of this work is to forecast changes of the geosystems in the degrading part of the Amu Darya Delta, the drying bed of the Aral Sea and its hydrological and hydrochemical conditions by 2020, considering the progressive shrinkage of this water body and anthropogenic desertification, and finally to develop practical measures for cardinal environmental improvement of the Amu Darya Delta and of the dried bed of the Aral Sea.

To reach this goal, the following interlinked objectives need to be achieved:

1) Determine the scientific and applied relevance of forecasting changes in Priaralie geosystems and Aral Sea hydrology.

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2) Justify the scientific basis and establish the main forecasting factors.

3) Develop a forecast of changes in the geosystems of the portion of the Amu Darya Delta subjected to desertification.

4) Develop a forecast of changes in the geosystems of the dried bed of the Aral Sea within the boundaries of Uzbekistan.

5) Forecast changes in the hydrological and hydrochemical conditions of the Aral Sea by 2020.

6) Develop practical measures for cardinal environmental improvement of the Amu Darya Delta and of the dried bed of the Aral Sea.

3 Discussion and results

The major natural and anthropogenic factors of forecasting have been identified and the main natural system trends have been established. The Aral Sea and Priaralie have been scientifically substantiated as genetically single and paragenetic dynamic macro-geosystems, respectively. By taking into account the properties and features of the structural-dynamic state of the superaqual, subaqual, eluvial geosystems in Priaralie and the Aral Sea, a forecast of their transformations by 2020 was made. Practical measures for cardinal environmental improvement of the Amu Darya Delta and of the dried bed of the Aral Sea have been developed[1].

Moreover, the environmental disaster of the Aral Sea and Priaralie is now passing within the context of new geopolitical and socio-economic conditions[2]. All elaborated pre-project and scientific proposals of the past years remain mainly in place. Therefore, a revised understanding of what has transpired and its explanation are needed so that a strategy can be developed for overcoming the disaster or minimizing its consequences.

Since 1961, because of the drastic increase of irretrievable river water withdrawal, mainly for irrigation, the inflow of river water into the Aral Sea has started to decrease significantly. As a result, the sea's hydrological and hydrochemical regimes have been disrupted dramatically. The sea level has continued to drop as evaporation exceeds inflow[3]. This negatively transforms the environment and worsens socio-economic conditions in Priaralie as a whole, especially in the lower reaches of Amu Darya and Syr Darya, where natural conditions depend on the sea as well. This causes desertification of nonirrigated zone in the deltas that spreads to new areas as the Aral Sea dries out[3].

The morphometric characteristics of the sea up until 1960 were follows: water surface level = 53.4 m (above Baltic Sea level), volume = 1108 km^3, water surface area = 67700 km^2, mean depth = 16.4 m, and maximum depth = 69.4 m[3]. Such an approximate quasi-stationary state of the water body was maintained during 1900–1960[4] by the inflow of fresh river water into the sea. Since 1961, however, there has been a regular reduction in river water inflow into the sea. At present, there is virtually no inflow from the Amu Darya River, while inflow from the Syr Darya River to the Small Sea is about 3 km^3/year. According to estimations[5], approximately 80% of the reduction in inflow is caused by anthropogenic factors, while the rest of the inflow reduction depends on flow probability in rivers that have been shallow in the recent decade. Data[6] show that anthropogenic losses of flow account for 92%–95% of the total in the current period.

In general, from 1911 to 2010, the long-term average annual precipitation over the Aral Sea was 133 mm, whereas the average annual evaporation from the sea surface was 998 mm. Observations showed that the destabilization of the sea is caused by significant excess of evaporation over the sum of inflow elements[7]. As a result of the sea level lowering, the sea area decreased to 14000 km^2 by 2010 and the volume shrunk to 74 km^3. Moreover, the configuration of the sea has been significantly modified, with large shallow bays in the eastern, southeastern, and southern areas of Aral disappearing. The earlier existing islands such as Vozrozhdeniye, Barsakelmes, and Lazarev and the Muynak peninsula now form a single geographical feature together with the dried seabed.

The chemical composition of river waters flowing into the Aral Sea transformed from hydrocarbonate-calcium to sulfate-sodium. This indicates direct metamorphization of these waters. The inflow of salts with atmospheric precipitation accounts for fractions of 1% in the sea's salt balance and their contribution to formation of water salinity is estimated as minor. Currently, groundwater inflow to the Aral Sea is < 0.1–0.3 km^3/year and the