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Characteristics of dust-salt transfer from the dried bottom of the Aral Sea and the Aral region, as well as their lossout

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Abstract. This article reflects environmental changes associated with a decrease in the level of the Aral Sea, the processes of salt formation and aeolian migration on the southern coast of the Aral Sea, their distribution in the environment, their causes and possible consequences.

1 Introduction

Anthropogenic impact on nature has led to catastrophic consequences in the Southern Aral Sea region, which have dramatically changed the ecological situation in the region. Due to the scale of the disaster, the Aral problem has turned from a regional one into a global problem of our time.

As is known, the main reason for the imbalance in the nature of Central Asia is the qualitative and quantitative depletion of water resources, their pollution and scarcity. The increased intake of Amudarya water for irrigation since the sixties, the large volume of collector-drainage, industrial, agricultural, municipal and domestic wastewater discharged into the river, as well as the regulation of river flow, have negatively affected the natural conditions of the middle and lower reaches of the river.

All this is also aggravated by the consequences caused by the drying up of the Aral Sea, the level of which has dropped from 53 meters to 33 meters (2024). The mineralization of lake water approaches 300 g/l, according to the dense remainder. More than five million hectares of desert lands have formed in the deltas of the Amudarya and Syrdarya, the upper part of which is represented by salt particles and salt marshes [7].

As a result of the high intensity of weathering processes from the dried bottom of the Aral Sea, dust and salt transfer and precipitation of these particles into the environment continuously occur, thereby causing significant damage to the national economy and, above all, to human health. As studies have shown, wind removal of dust and salts from salt marshes occurs many times throughout the year. The composition of falling aerosols is dominated by sulfate and chloride salts of calcium, magnesium, and sodium [4].

The irreversible process of lake drying and its negative consequences certainly lead to natural-climatic, socio-economic and, mainly, environmental changes in this region.

The moistening effect of the Great Sea on the environment has already ceased. Also, the warm influence of the lake in winter and the cooling influence in summer disappeared. A reduction in the lake area leads to a decrease in evaporation, but an increase in water temperature causes an increase in the intensity of evaporation. As a result, the residual lake water is already turning into brine [9].

The negative impact of toxic dust and salt on the development and vital activity of the flora and fauna of the region is progressing at an increasingly rapid pace. The current extreme economic situation is causing concern for the health of the population. There is a steady increase in the number of somatic diseases, diseases of the cardiovascular system, pathologies of the gastrointestinal tract, diseases of the kidneys, liver, urinary organs, diabetes mellitus, cancer, as well as various types of diseases of the blood and hematopoietic organs. Diseases of pulmonary tuberculosis, bronchial asthma, and chronic bronchitis have especially increased. Changes in behavior and a decrease in feed consumption are observed in large and small livestock [4, 5].

Atmospheric air is an important component of the natural environment. Its pollution negatively affects not only human health, but also metal structures, structures, power lines, the condition of forest plantations, and the productivity of cultivated and wild plants.

The transfer of dust and salt particles from the dried bottom of the Aral Sea and their fallout onto the environment will continue for many decades, so further study of the dynamics of this process, the development and implementation of additional environmental measures in order to preserve biodiversity and ensure sustainable development in the region are very relevant.

In his speech at the 75th session of the UN General Assembly, the President of Uzbekistan, Sh.M. Mirziyoyev, proposed to adopt a special resolution of the United Nations General Assembly on declaring the Aral Sea region a zone of environmental innovations

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and technologies, as well as to mark the date of approval of this important document as the International Day for the Protection and Restoration of Ecological Systems.

To restore and improve the condition of the Aral Sea and the Aral Sea region, on May 18, 2021, the UN General Assembly unanimously approved a resolution declaring the Aral Sea region a "zone of environmental innovation and technology." This situation is a real merit of the President of the Republic Sh.M. Mirziyoyev.

2 Research methods

At the beginning of 1982, to conduct field studies of dust-salt fallout in the Southern Aral Sea region, almost the entire northern part of the Republic of Karakalpakstan was covered with a network of dust collection devices located along a number of sections: Muynak-Kungrad-Takhiatash (250 km); Kazakhdarya-Chimbay-Nukus (150 km), as well as on the peripheries of the irrigated zone Takhtakupyr-Karauzyak-Kegeyli-Shumanay (150 km) and on the territory of the dried bottom of the Aral Sea on an area of 300 x 400 km^2. This location of dust collection installations will make it possible to cover all directions of the wind rose adjacent to the Southern Aral Sea region. The total number of observation points for studying aerosol fallout was about 43 [4]. Throughout all these networks of salt and dust collection installations, monthly observations were carried out to study the quantitative and qualitative state of salt and dust fallout, the dynamics of changes in soil processes, the influence of wind-borne dust and salt particles on the condition of cultivated and wild plants, etc. Samples of fallen salt dust, atmospheric precipitation, soils, and plants were regularly taken for chemical analysis.

The methodology for determining salt dust concentrations in the ground layer and the amount of precipitation on the underlying surface of the earth is divided into:

- Aspiration method of forced air sampling t is measured in mg/mq for particles 1–10 μm;

- Sedimentation method of dry aerosol settling, measured in g/m^2

- Methodology for direct determination of aerosol particles per unit volume.

Depending on the purpose of the study - plant ecology, sanitary and hygienic, technical - one or another method of measuring aerosols is used [5].

Our field studies widely use the sedimentation method of collecting aerosols on salt dust collectors, consisting of metal tablets measuring 0.5 x 0.5 m (0.25 m^2), installed at a height of 1.0 m. Aerosol samples are collected on medical gauze mounted on the tablets. In addition, a prismatic vessel (made of stainless steel) with a height of 40 cm and an area of 0.06 m^2 is used, which, to compare the results, is also installed at a height of 1.0 m [5,6].

The collection of liquid and wet atmospheric precipitation is carried out according to the generally accepted methodology of the State Committee for Hydrometeorology of the Republic of Uzbekistan (Tretyakov precipitation gauge, etc.) through a network of weather stations and at some characteristic posts under the jurisdiction of the Karakalpak Hydrometeorology Department. Before collecting precipitation, precipitation gauges are washed with distilled water [4, 5].

A more detailed description of the methods for conducting individual specific investigations is provided in the relevant sections of this research work.

3 Results and discussion

To estimate the amount of salts carried away by the wind from the surface of salt marshes, in particular, in the zone of the drained lakesbed on the salt marsh, methodological experiments were carried out on the lake at Surkul, located on the Muynak Peninsula.

Control was carried out at special marked reference points installed in the middle part of the salt marsh, up to 20 in number. Along a length of 1.0 km, periodically 7–8 times a year, the height of the installation of points was measured with a level, at the same time the depth and salinity of groundwater, soil salinity, and humidity were measured. According to these observations, the removal of dust and salt from the salt marshes of the dried lakebed is 24–36 t/ha when averaged over 10 characteristic points, and the removal of salt on average will be 12–20 t/ha [4, 5].

Since the beginning of 1982, under semi-stationary conditions, we have conducted research on dust and salt fallout using dust-salt collection devices and instruments installed throughout all territories of Karakalpakstan over an area of 300 x 400 km^2.

As a result of field studies, we for the first time obtained quantitative and qualitative characteristics of the distribution of aerosol fallout throughout the entire territory of Karakalpakstan.

Based on natural field research, isohypses of dry dust-salt fallout with an interval of 1.0 t/ha and soluble salts in them with an interval of 50 kg/ha were constructed. Data for 43 points located in the Aral Sea region were averaged in time by linear interpolation using the triangle method according to a program developed at the Computer Center NPO SANIIRI and using a plotter on an ES-1035 machine, hydroisohypsum lines were obtained (Figs. 1 and 2). As can be seen from these figures, the direction of removal of dust-salt particles from the drained lakebed and salt marshes of the Amudarya delta coincides with the wind rose and the strength of the winds built in the Aral Sea region according to weather station data located on the shore of the Aral Sea, this direction prevails in the Aral Sea region from NE and N to SW and S of the Aral Sea. [5, 6].

Our field studies show that long-term data have been obtained on the specific fallout of dust-salt particles from the atmosphere throughout the territory of the Republic of Karakalpakstan using dust-salt collection devices. The total amount of dust-salt particles falls on average from 1.5–6.0 t/ha per year, of which water-soluble salts amount to 170–800 t/ha, sometimes on the dried lakebed up to 1600 kg/ha per year. Moreover, the maximum amount of deposition occurs in the area of the lake coast; in the irrigated zone, the amount of salt deposition decreases to 150–300 kg/ha. The composition of aerosols is mainly dominated by sulfate and chloride salts of calcium, magnesium, and sodium. The share of salts falling out of the total amount of aerosols is 5–16%, increasing directly near the salt marshes to 20–30% or more.

The nature of aerosol precipitation varies from year to year and significantly depends on meteorological factors, in particular, on the amount of winter and spring precipitation, as well as on the orography of the area, soil moisture, its cover with vegetation, development of the territory, etc. are seasonal. For example, in the zone of the drained bottom of the Aral Sea at point P-24, the total loss varies from 1646 to 9686 kg/ha, the average is 3886 kg/ha, of which water-soluble salts reach from 120 to 1658 kg/ha, the average is 515 kg/ha per year [4].

The amount of aerosol fallout in spring reaches from 1 to 177 summer periods, excluding fallout zones, for example P-10. The maximum amount of aerosol occurs in the fall of 7883 kg/ha. However, the largest layer of salt and dust removal is observed in the spring period of maximum wind activity. The same picture is observed in other zones in the northern part of Karakalpak [7].

The work provides data on characteristic points of the Aral Sea region on the amount of aerosol dry deposition and the composition of the main ions (HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+) of water-soluble salts by year and season.

Research from 2002 to 2016 confirms that the amount of dust and salt has increased by 15–20% compared to the past 15 years.

In the dried lakebed there is from 4000 to 11884 t/ha and an average of 7,942 t/ha of dust and salt, including water-soluble salts from 139.9 to 259.92 kg/ha and an average of 199.91 kg/ha. On the coast of the Aral Sea: from 4000 to 10373, on average 7187 t/ha and water-soluble salts from 127.97 to 163.94 kg/ha and on average 145955 kg/ha. In the non-irrigated zone, from 2.867 to 5.692 t/ha and an average of 4.280 t/ha, respectively, water-soluble salts from 73.86 to 160.50 and an average of 117.18 kg/ha.

In the irrigated zone: dry dust-salt fallout falls from 1.999 to 3.987 t/ha and an average of 2.993 t/ha and of which water-soluble salts range from 36.48 to 97.88 kg/ha and an average of 67.18 kg/ha [5, 8].

Since, the latest field research on this topic shows that during 2002–2016. The transfer of dust and salt from the drained bottom of the Aral Sea and their deposition onto the environment occurred at a relatively uniform pace. Even the visual study of 2017 was also of a similar nature.

Since 2018, abnormal dust storms, dusty drifts, haze, salt storm, and other dusty conditions began. From the beginning, experts and many scientists could not explain the main reasons for them.

Everyone knows that at this site the prevailing wind is mainly from the NE and N (up to 65–70%), which means that in most cases, the removal of dust and salt is directed from the side to the SW and S or W. The force of the wind carries away dust and salt from these directions. Here is the Ustyurt Plateau. The total height of the terrace is 200–250 meters above sea level and it retains a large number of dust and salt particles for many years. Strong winds from the north-western and western sides of the Aral Sea rarely happen; for this, dust and salt accumulate here over many years or times. As a result, anomalous strong winds raise dust and salts and are directed from populated areas, as well as neighboring states in the region.

As a result of field research during 2002–2016. We obtained quantitative and qualitative characteristics of the distribution of aerosol fallout throughout the northern territory of Karakalpakstan and constructed isohypses of dry dust-salt fallout with an interval of 1.0 t/ha and water-soluble salts of 10 kg/ha. Data on observed points (about 25 pcs.) located in the Aral Sea region were averaged over time using linear interpolation and hydroisohypses were obtained (Figs. 1 and 2).

As can be seen from these figures, the direction of removal of dust-salt particles from the dried lakebed and salt marshes of the Amudarya delta coincides with the wind rose and the strength of the winds built in the Aral Sea region. This direction prevails in the Aral Sea region from NE and N to SW and S of the Aral Sea. The same trend continued until 2016.

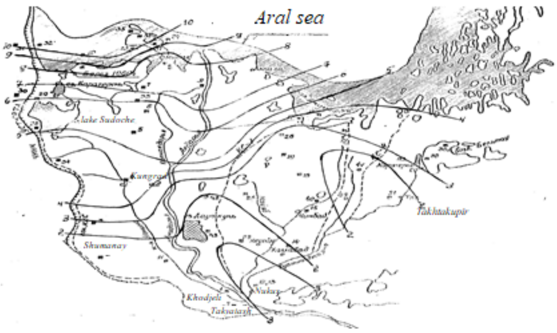

Fig. 1. Distribution of dry aerosol fallout in the Southern Aral Sea region, t/ha per year (2002–2016).

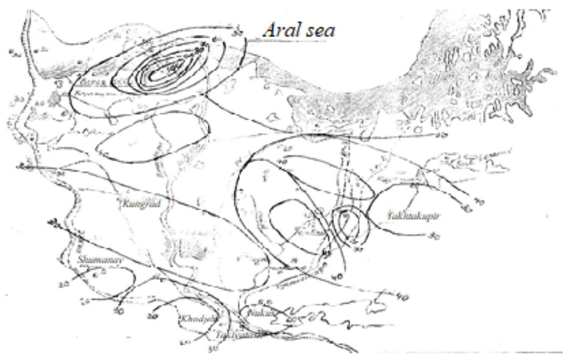

Fig. 2. Distribution of salt deposition with atmospheric dry aerosols in the Southern Aral Sea region, kg/ha per year (2002–2016).

Granulometric and chemical analysis of the composition of these May dusts and salts contain large amounts of calcium sulfate up to 40–45% (gypsum, $CaSO_4 \cdot 2H_2O$), 23–25% thenardite fluff (Na_2SO_4), 5–7% $CaCl_2$, 5–7% NaCl, 5–7% $Ca(HCO_3)_2$, 5–7% $MgSO_4$, and 5–7% $MgCl_2$, and 5–7% other elements.

4 Conclusion

1. During strong dust storms, the removal of dust and salt from the dried bottom of the Aral Sea does not occur evenly, since depending on the decrease in the groundwater level, the amount of salt decreases and the amount of dust, on the contrary, increases. In most cases, a decrease or cessation of the volume of river waters negatively affects the environment and at the same time increases the negative impact on the normal growth, development and reproduction of biotic objects in a given region.

2. To prevent the negative impact of dust and salt carryovers and their fallout from the dried bottom of the Aral Sea, it is necessary to grow salt-tolerant and drought-resistant cultivated as well as wild forage plants (for example, comb grass, reed, reed grass, yantak (algahi), and others).

These crops can be irrigated with reserve waters: collector-drainage, residual-discharge, underground, artesian and other mineralized waters.

3. To raise wild (especially predatory animals), it is necessary to organize an artificial watering hole.

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