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Study process treatment of Syrdarya and Keles rivers water of the Turkestan region

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Abstract. Over the past decade, all Central Asian countries have experienced a sharp increase in agricultural production, not only due to a reduction in investment in irrigated agriculture, but also due to a sharp deterioration in the condition of the water resources of irrigated lands. The purpose of this work is an environmental assessment of the state of the Syrdarya and Keles Rivers, as well as the development of methods for surface water purification. The results show that the water in the studied region, based on the main polar indicators, shows that irrigation water for irrigation was determined by the following chemical compounds: in Syrdarya HCO_3, SO_4, Cl, Ca, Mg, of . Cl -52.2 and Na - 73.5 in Keles rivers Cl -101.2 mg/l. A new membrane device design has been tested, which is suitable for continuous processes and solute separation, as well as for extending the life of the membrane. The relationships between water composition, operating pressure, and low velocity were established, and their effect on membrane permeability and selectivity was analyzed. With a selectivity coefficient of 0.8, the membrane system provides a capacity of 92 liters per square meter per hour. By the fifth regeneration cycle, the permeability was maintained at 70 $l/m^2 \cdot h$, an acceptable level for long-term operation. The ratio between the regeneration efficiency and the drying rate has shown that 99% recovery is possible within one hour. This study is characterized by optimal conditions and operating modes for effective water dissolution, which contribute to improving the efficiency of membranes in practice.

1 Introduction

Over the past decade, all countries of Central Asia have seen a sharp decline in the growth rate of agricultural production, not only due to reduced investment in irrigated agriculture, but also a sharp deterioration in water management and land reclamation conditions of irrigated lands [1, 2].

Water scarcity is one of the most pressing environmental and socio-economic challenges facing Central Asia today [3, 4]. The region’s arid and semi-arid climate, combined with uneven water distribution and rapidly growing populations, has created persistent tension over access to limited freshwater resources [4, 5]. Two of the largest transboundary rivers -

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the Amu Darya and Syr Darya - serve as the main sources of surface water, yet their flow regimes have been heavily altered by irrigation systems, hydropower development, and climate-related changes [6, 7].

Since the expansion of irrigation agriculture in the mid-20th century, the demand for water has increased dramatically . Large-scale diversion of river water for cotton and rice cultivation has disrupted the natural balance of regional ecosystems and led to the shrinking of the Aral Sea, one of the most severe environmental disasters of modern times. Reduced inflows, rising salinity, and the degradation of aquatic habitats have significantly affected biodiversity and local livelihoods [8, 9].

Another major factor exacerbating the crisis is inefficient water management. Aging canal infrastructure, evaporation losses, and lack of coordinated water policies among riparian states - Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan-have further intensified competition over water use. Seasonal variations in river discharge, particularly during drought periods, often cause conflicts between upstream countries that rely on water for energy generation and downstream countries that depend on it for irrigation [10, 11].

In addition, climate change is accelerating glacial melt in the Tien Shan and Pamir mountains, which provide the bulk of Central Asia's river flow. While this temporarily increases water availability, it poses long-term risks of reduced runoff and water shortages once glaciers retreat. The resulting imbalance threatens agriculture, drinking water supply, and energy security across the region.

To mitigate these problems, experts emphasize the need for integrated water resources management (IWRM), modernization of irrigation systems, and introduction of water-saving technologies. Strengthening regional cooperation and data sharing among Central Asian states is equally essential to ensure fair and sustainable use of shared river basins. Only through joint action and technological innovation can the region move toward a stable and secure water future.

The Syr Darya and Keles rivers are key watercourses of Central Asia, playing an important role in providing water resources, irrigation, ecosystems and human life. However, in recent decades, their ecological state has become increasingly alarming. The main problems are related to the deterioration of water quality, depletion of water resources, pollution by sewage, drainage and industrial waters, as well as climatic and hydrological changes. This text examines the causes of pollution, consequences, levels of risk and possible solutions to the ecological problems of the Syr Darya and Keles.

Syrdarya - one of the largest rivers in Central Asia, flowing through the territory of Tajikistan, Kyrgyzstan, Uzbekistan and Kazakhstan. It is a vital source of water for irrigation, economic needs and ecosystems of the region. In the lower reaches, the Syr Darya is subject to strong anthropogenic impact: water withdrawal, discharge of polluted sewage and drainage waters, the impact of irrigation systems .

Keles- A right tributary of the Syr Darya, flowing through the Turkestan region of Kazakhstan and the Tashkent region of Uzbekistan. The Keles basin is relatively smaller compared to the Syr Darya, but the impact on it from economic activities and pollution is also significant.

The objectives of this study are as follows:

– To identify the patterns of variation in temperature and chemical composition of the waters of the Syrdarya and Keles Rivers.
– To develop and evaluate membrane-based purification methods for improving the surface water quality of the Syrdarya and Keles Rivers.

2 Materials and methods

In order to study the membrane-based fruit extraction of mountain water affected by nitrates, chlorides, and sulfates, a custom-built experimental setup was applied, as shown in Figure 1. pumping unit (2), and passes through a coarse filtration system (3) before entering the membrane module (4).

After the water flows, the purified (filtered) portion goes to a water-covered tank (5), while the concentrated stream waste (contaminants) is combined in a separate container (6). When the pressure cross membrane reaches a predefined Tis threshold, the electric motor (7) is applied to the flexible camshaft mechanism for further processing or regeneration.

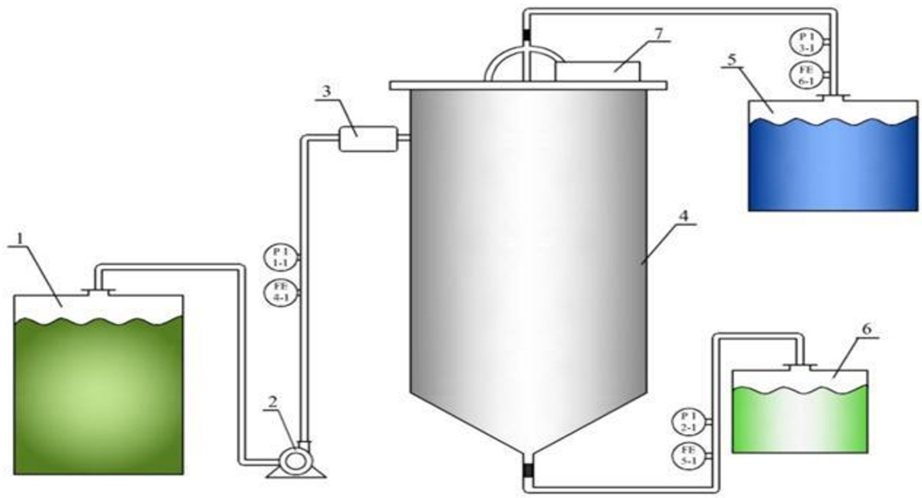

Fig. 1. Diagram of the experimental water desalination unit**:**1 – source water reservoir, 2 – pump unit, 3 – coarse pre-filter, 4 – membrane treatment module, 5 – tank for filtered (clean) water.

Table 1. Instructions for producing observations.

No. s/n	**Purpose of the well**	**Level, m**	**Temperature, 0C**	**Abbreviation for chemical analysis**
1	2	5	6	
1	observational	3 times per month	3 times a month	1 time per quarter

3 Results and discussions

The formation of ice jams both during the freezing period and at the time of the river opening causes sharp jumps in water levels, sometimes up to 2.8 meters. However, by the end of the summer period, a significant part of these temporary reservoirs dries up.

The entire territory of the work area is covered by a fine irrigation network with a depth of 1.1-2.2m.

The SyrDarya River is the main water artery that feeds the irrigation system of the Hungry Steppe, represented for the old irrigation zone by the main canal "Dostyk" (formerly named after Kirov) and distributaries of various orders branching off from it.

Water-bearing rocks are loams, sandy loams, and silty to medium-grained sands.

Water levels in July and August 2016 were found at a depth of 1.0-2.8 meters.

At high elevation, water lies at a depth of 0.5 - 2.0 meters from the surface of the earth. High elevation of the water occurs in April-July, low elevation - in October-November. The amplitude of the water fluctuation is 0.6-1.2 meters.

The total thickness of loams and sandy loams ranges within the studied area from 10.5 to 32.0 m, and the thickness of the water-saturated layer from 9.5 to 30.0 m.

The aquifer is pressure-bearing, the depth of the piezometric level varies depending on the relief from 0.5 to 3.5 m.

From a mineralization standpoint, the groundwater varies from slightly saline to highly saline, with total dissolved solids ranging between 1.05 and 14.63 g/L. Its chemical composition predominantly falls within the sulfate–chloride type, with sodium–magnesium–calcium as the main cations.

Based on regulatory parameters, the concentration of SO_4^{2-} ions averages 2087.1 mg/dm³, while HCO_3^- content ranges from 3.0 to 6.0 mg-eq/L. When evaluated using Portland cement (in accordance with GOST 10178), the water exhibits high aggressiveness toward W4-grade concrete in terms of water resistance. Conversely, when applied to slag Portland cement (as per GOST 22266), the same water is considered non-aggressive.

Considering the concentration of Cl^- ions (2111.9 mg/dm³), this water is non-aggressive toward reinforced concrete structures under constant immersion, but becomes moderately aggressive when exposure occurs through intermittent wetting.

Hydrogeologically, the region is part of the Syrdarya artesian basin. For assessment purposes, the aquifer complexes are classified by depth into three hydrogeological tiers. The upper tier consists of water-saturated Quaternary deposits, with a total thickness ranging approximately from 200 to 500 meters.

According to the sanitary and epidemiological services, the water in the Keles River is often microbiologically contaminated and cannot be used for drinking without treatment. In the lower reaches of the Syr Darya, excesses in salinity, metals, nitrites, sulfates and other pollutants are observed and show in table-2. The average annual concentrations of some elements exceed the MPC (maximum permissible concentrations) norms by several times .

The water chemistry of rivers is deteriorating: mineralization increases under the influence of returned irrigation water, evaporation, and limited fresh water inflow. During periods of low water or drought, the concentration effect is intensified and show in table-3.

Table 2. Syrdarya and Keles rivers water hydrochemical parameters.

Water body Observation point	Syrdarya rivers village of Kokbulak	Syrdarya rivers village of Azattyk	Keles rivers Estuary
Dry residue	833	856	1773
Transparency	12.0	14.0	7.0
Temperature	14.2	14.4	16.2
Weight of substance	61.2	84.2	871.6
pH	7.9	7.8	8.0
Oxygen	9.8	9.8	13.1
Magnesium	10.8	12.0	16.8
Chlorides	49.0	52.5	101.5
Sulfates	192.12	249.8	278.6
Sum of ions	591.63	649.39	802.18
Hardness, mg-eq/dm3	7.4	8.2	8.6
Hydrocarburet/ty	207.4	195.2	219.6
Sodium+Potassium	76.31	77.89	127.68
Calcium	56	62	58
CPC	10.0	9.0	10.0
BOD5	2.0	1.9	2.9
Ammonium salt	0.36	0.488	0.668

Continuation of Table 2.

Water body Observation point	Syrdarya rivers village of Kokbulak	Syrdarya rivers village of Azattyk	Keles rivers Estuary
Nitrogen nitrite	0.03	0.030	0.036
Nitrogen nitrate	2.4	2.6	2.7
Phosphates	0.038	0.035	0.092
Total phosphorus	0.085	0.097	0.156
Total iron, mg/dm3	0.053	0.025	0.081
Copper, mg/dm³	0.0009	0.0006	0.0029
Zinc, mg/dm³	0.0065	0.0070	0.0075
Nickel, mg/dm³	0.0041	0.0045	0.0046
Total chromium mg/dm³	0.0059	0.0065	0.0062
Chromium (6+) mg/dm³	0.0033	0.0032	0.0037
Lead, mg/dm³	0.0016	0.0014	0.0020
Mercury, mg/dm³	0.00	0.00	0.00
Cadmium, mg/dm³	0.0008	0.0007	0.0010
Phenols (year), mg/dm3	0.0007	0.0009	0.0010
Petroleum products, mg/dm3	0.0321	0.0322	0.0335
SPAW, mg/dm3	0.06	0.06	0.07

Today, most collectors need repair: they need to be cleaned of silt and vegetation, as well as modernized culverts, such as bridges and tubular crossings.

Table 3. Syrdarya and Keles rivers water quality.

No. n/a	Name pollutants	With pds, mg/l	PDS, g/h	Traffic, t/year
1.	Suspended matter	17.8	20342.421	178,200
2.	Mineralization,in volume numbers:	1133.5	1293946.925	11335.0
3.	-calcium	156.17	178275.864	1561.7
4.	-magnesium	46.93	53572.94	469.3
5.	-chlorides	130.82	149337.571	1308.2
6.	-sulfates	368.86	421072.133	3688.6
7.	Ammonium nitrogen	0.031	35,388	0.31
8.	Nitrate nitrogen	0.103	117.58	1.03
9.	Nitric nitrogen	0.01	11.416	0.1
10	Petroleum products	0.053	60,502	0.53
11	Phosphates	0.014	15,982	0.140
12	BODpoly	1.67	1906.389	16.7
13	Copper	0.0014	1.598	0.014
14	Zinc	0.003	3.425	0.03
15	Hexachlorocyclohexane	0.002	2.283	0.02
16	DDT and its metabolites	0.1	114.155	1.0
17	Mercury	0.0001	0.114	0.001
18	Together		824869.761	7225.875

Sewage discharges, insufficient wastewater treatment, and violations of sanitary standards lead to rivers becoming a habitat for pathogenic microflora, which threatens the health of the population. The Keles River is an example where sanitary services have recorded an excess of microbiological indicators. The Syrdarya River is also suffering from shallowing: a decrease in water volume, a change in its course, and drying out of sections. Residents note that the course used to be filled, but now in some places you can see sections that have actually dried up. This affects not only navigation and irrigation, but also the ecological balance: the river's ability to self-purify is decreasing, and biodiversity is decreasing.

In recent years, especially during periods of intense snowmelt and heavy rainfall, it has become evident that the existing drainage and sewer systems are insufficient to handle the combined discharge of stormwater, wastewater, and drainage flows. This issue is particularly pronounced during the soil-washing seasons in autumn, winter, and spring.

Before the onset of large-scale irrigation, natural subsurface flows were characterized by low velocity and limited horizontal exchange. However, irrigation activities have significantly altered these conditions. As a result, the hydrochemical properties of groundwater within the Upper Quaternary deposits, and in some areas even the Middle Quaternary strata, have undergone substantial modification. The formation and dynamics of these waters are now largely influenced by artificial hydraulic systems that generate pressure differentials between upland and lowland zones.

Enhanced vertical water exchange, stimulated by both irrigation practices and the functioning of drainage networks, has become a dominant process. This exchange is most pronounced between water in cohesive (clayey) surface layers and that within sandy strata, where vertical drainage well filters are typically installed.

A complex of artificial factors - irrigation, evaporation, flushing measures, as well as the functioning of vertical drainage and collector-drainage systems - dynamically affects the level of water mineralization. These changes are seasonal and can both increase and decrease water salinity depending on hydrological conditions.

Similar gradations of water conductivity are characteristic of the lower-middle Quaternary aquifer with a predominance of gradations of 300-500 m2/day in terms of area.

When calculating water conductivity, the calculated value of filtration coefficients was adopted as 9.3 m/day for the entire thickness of Quaternary sands.

The aquifer complex of Upper Pliocene alluvial deposits is developed throughout the studied area, however, differences in the conditions of precipitation accumulation have led to the heterogeneity of the lithological structure, both in area and in section. They are represented by interbedded sands and weak sandstones with clays and siltstones.

Water has significant pressure, the water level is set at a depth of up to 10 m. Water is directed from east to west with a slope of the piezometric surface of 0.0002-0.0003, which indicates very low movement speeds.

The aquifer complex was tested in intervals from 79.3-99.3 to 243-251 m. The well flow rates vary from 2.3 l/s with a decrease of 10.4 m to 25 l/s with a decrease of 4.4 m. The sand filtration coefficient varies from 2

Pliocene waters are fresh with a mineralization of 0.4-0.8 g/l, the type of mineralization is sulfate-sodium and hydrocarbonate-sodium. The buried alluvium is characterized by very low hardness of water.

In general, the issue of water recharge from underlying aquifers has been studied very poorly, especially in quantitative terms. When infiltration and evaporation are crucial in the water balance, sometimes the water regime is under the corrective influence of the mid-Quaternary aquifer.

Figures 2-4 illustrate the relationship between operating pressure and ion selectivity for nitrate, chloride, and sulfate salts, derived from the data in the corresponding table. pressure requirements for membrane-based desalination systems are closely tied to the salinity level of the source water. As water temperature rises, flow velocity increases, which enhances the desalination performance. Despite the fact that the efficiency of the furniture processes remains at the risk of compromising the characteristics of drinking water, which can reach maximum efficiency.

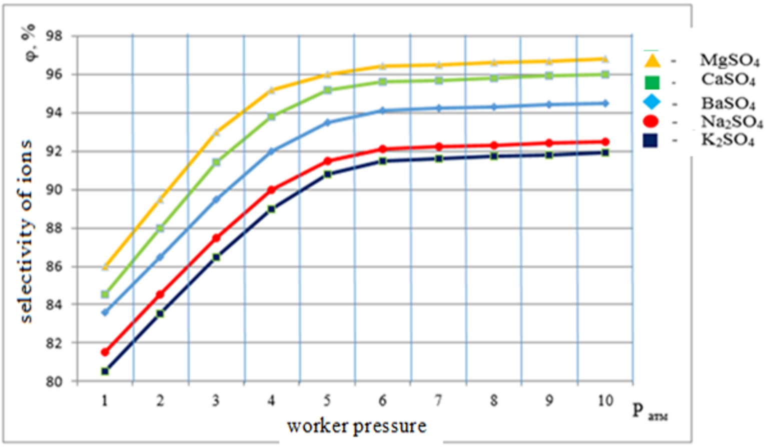

Fig. 2. Due to the operation of pressure on selectivity chloride ion separation from saline solutions.

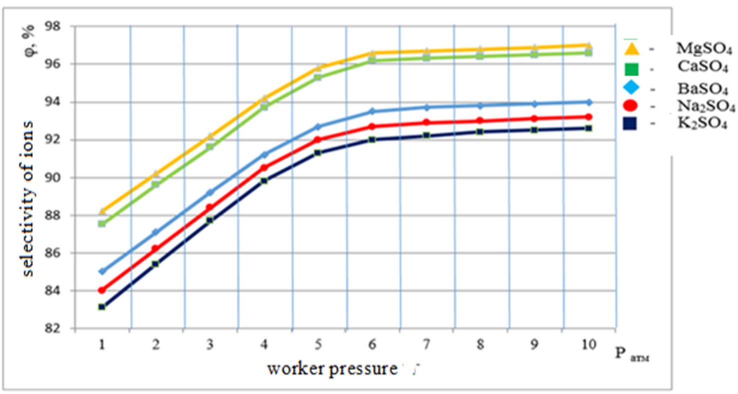

Fig. 3. Relationship between operating pressure and selective removal of sulfate ions in membrane filtration.

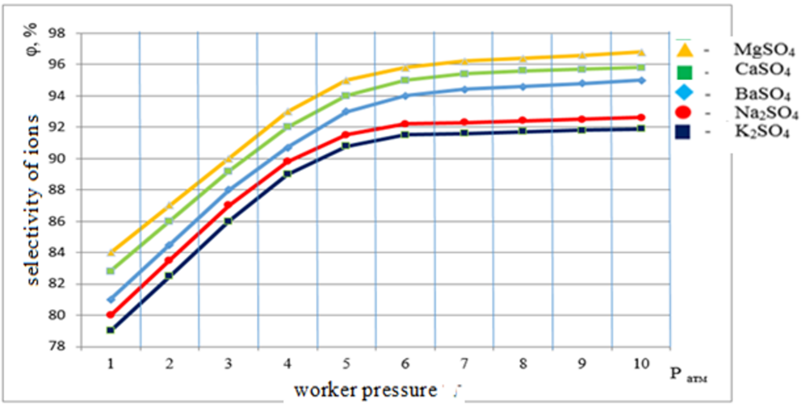

Fig. 4. Impact of system pressure on efficiency of nitrate ion separation through membrane technology.

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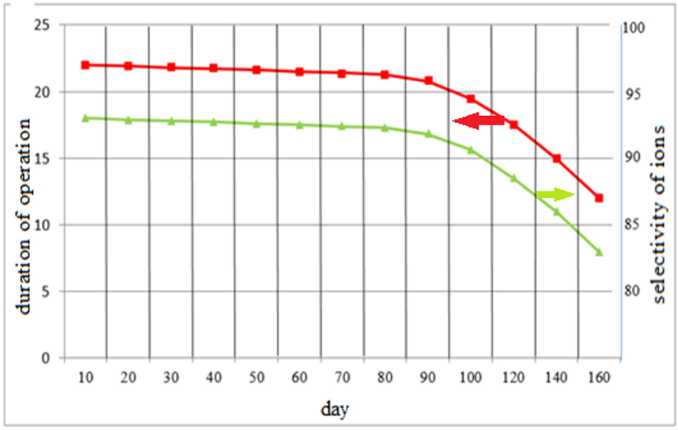

Fig. 5. Comparison between selectivity performance and membrane system operational lifespan.

The membrane working pressure required by membrane desalination systems depends largely on the salinity level of the feed water. As the water temperature increases, the flow rate increases, which leads to an increase in desalination efficiency. However, the efficiency of the membranes depends on the salinity of the incoming water. Figure 5 shows how the selectivity of the performance changes with operating time. The service life of the membrane depends largely on the water quality, temperature and the total number of operating days.

4 Conclusion

The Syr Darya and Keles rivers are currently experiencing high pressure from anthropogenic factors: pollution by sewage and industrial waters, increased mineralization, shallowing, insufficient treatment, and irrational water consumption. These processes affect not only the ecology, but also human health, the sustainability of agriculture, and the socio-economic development of regions.

To improve the condition, a comprehensive approach is needed: modernization of treatment facilities, strict regulation of discharges, participation of the state, business, society, scientific research and transboundary cooperation. Only then will it be possible to return the rivers to their vital functions and ensure a sustainable future for the inhabitants of the basin.

The study was devoted to the development of a membrane system design aimed at increasing the efficiency of desalination of water containing nitrate, chloride and sulfate compounds in the Turkestan region. The study resulted in practical recommendations for choosing the appropriate design and operating parameters of the membrane plant. A new design of the membrane apparatus was proposed, which improves both the desalination process and the separation of dissolved substances, and also increases the service life of the membrane. The relationships between the composition of water, operating pressure and flow rate were established, and their influence on the permeability and selectivity of the membrane was analyzed. At a selectivity coefficient of 0.8, the membrane system provided a throughput of 92 liters per square meter per hour. In addition, the correlation between permeability and the frequency of membrane regeneration using an elastic roller was studied. By the fifth regeneration cycle, the permeability was maintained at only 70 l/m2 h - an acceptable level for long-term operation. The relationship between the regeneration efficiency and the drying rate showed that 99% recovery was possible within one hour. It was also noted that increasing the roller rotation speed increased the regeneration efficiency. In the course of this study, the optimal conditions and operating modes for effective water desalination were determined, which contributes to increasing the efficiency of membranes in practical applications.

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