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Satbayev University

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ИЗВЕСТИЯ

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DEVELOPMENT OF METHODOLOGICAL FOUNDATIONS AND RESEARCH OF TECHNICAL SOLUTIONS TO INCREASE THE VOLUME OF THE NORTHERN ARAL SEA WITH MINERALIZATION OF THE FLOW OF THE SYRDARIA RIVER

Abstract. The article presents a study of technical solutions for increasing the volume of the North Aral Sea with mineralization of the flow of the Syrdarya River. The Syr Darya River is the source of food for the Kazakhstan part of the Aral Sea, in particular the Small Aral Sea. The Syr Darya also provides water for irrigated lands in the republics of Kyrgyzstan, Uzbekistan and Kazakhstan. The total area of agricultural land in the Syrdarya river basin is 34 million hectares, including 4.2 million hectares of arable land.

The water resources of the basin are represented by the average long-term flow of the Syrdarya River in the amount of 37.2 km3, return water from irrigation - 14.1 km3 and under-stream water reserves within 3.3 km3. The formation of natural river flow in the context of the states of the basin is extremely uneven: Kyrgyzstan - 74.2%, Uzbekistan - 13.8%, Kazakhstan - 9.3%, Tajikistan - 2.7%.

The actual use of water resources in the Syrdarya river basin by sectors of the economy in recent years amounted to: regular irrigation of agriculture - 5458.1 mln. The process of intense salinization occurred as a result of the intense evaporative capacity of the atmosphere, the bilateral salinization of soils due to the evaporation of groundwater, and the transfer or blowing of salts from the exposed dry bottom. An assessment according to the classification (Chembarisov at all, 1989) showed that the waters of the Aral Sea, in terms of mineralization, belong to weak brines. According to other data, the average annual mineralization of river runoff in the formation zone varies insignificantly within 0.35–0.40 g/l.

Despite such a large water consumption, the areas of saline and salinized irrigated lands in the Aral Sea basin did not decrease all these years and remained at the level of 55-60% of all irrigated lands. At the same time, the mineralization of water in springs, especially in the middle reaches and in river deltas, increased to 1.0–2.5 g/l, while the quality of water deteriorated, and MAC in many respects increased significantly due to the discharge of collector and drainage runoff into rivers. (12 - 14 km3 per year). To manage and stabilize the hydro-ecological state of the Aral Sea basin, comprehensive measures are needed to improve the efficiency of distribution of environmental releases, suppress emissions of salts and dust into the atmosphere, and develop technical measures to reduce the salinity of sea water.

Key words: mineralization, technical solution, river runoff, formation of natural runoff, water resources.

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СЫРДАРИЯ ӨЗЕНІНІҢ АҒЫНЫНЫҢ МИНЕРАЛДАНУЫ ЖАҒДАЙЫНДА СОЛТҮСТІК АРАЛ ТЕҢІЗІНІҢ КӨЛЕМІН ҰЛҒАЙТУ МАҚСАТЫНДА ӘДІСТЕМЕЛІК НЕГІЗДЕРДІ ӘЗІРЛЕУ ЖӘНЕ ТЕХНИКАЛЫҚ ШЕШІМДЕРІН ЗЕРТТЕУ

Аннотация. Мақалада Сырдария өзенінің ағынын минерализациялау арқылы Солтүстік Арал теңізінің көлемін ұлғайту бойынша техникалық шешімдерді зерттеу ұсынылған. Сырдария өзені Арал теңізінің қазақстандық бөлігінің, атап айтқанда Кіші Арал теңізінің азық көзі болып табылады. Сырдария сонымен қатар Қырғызстан, Өзбекстан және Қазақстан республикаларының суармалы жерлерін сумен қамтамасыз етеді. Сырдария өзені бассейніндегі ауыл шаруашылығы жерлерінің жалпы көлемі 34 млн га, оның ішінде 4,2 млн га егістік жер.

Алабынның су ресурстары Сырдария өзенінің орташа көпжылдық ағынымен 37,2 км3, суарудан қайтарылатын су – 14,1 км3 және ағын астындағы су қоры 3,3 км3 шегінде берілген. Табиғи өзен ағынының қалыптасуы мемлекеттер арасында біркелкі емес: Қырғызстан – 74,2%, Өзбекстан – 13,8%, Қазақстан – 9,3%, Тәжікстан – 2,7%. Сырдария өзені алабындағы су ресурстарын соңғы жылдары экономика салалары бойынша нақты пайдалану: ауыл шаруашылығын жүйелі суару – 5458,1 млн. Қарқынды тұздану процесі атмосфераның қарқынды булану қабілетінің, жер асты суларының булануынан топырақтың екі жақты сортаңдануы және ашық құрғақ түбінен тұздардың тасымалдануы немесе үрленуі нәтижесінде болды. Классификация бойынша бағалау Арал теңізінің сулары минералдануы жағынан әлсіз тұзды суларға жататынын көрсетті. Басқа мәліметтерге сәйкес, формация аймағындағы өзен ағынының орташа жылдық минералдануы 0,35–0,40 г/л шегінде шамалы өзгереді.

Осындай көп суды тұтынуға қарамастан, Арал теңізі алабындағы сортаңданған және сортаңданған суармалы жерлер алқаптары осы жылдар бойы азаймай, барлық суармалы жерлердің 55-60% деңгейінде қалды. Сонымен бірге бұлақтарда, әсіресе орта ағысында және өзен арналарында судың минералдануы 1,0–2,5 г/л дейін өсті, бұл ретте судың сапасы нашарлады, көп жағдайда ағынды яғни коллекторлық және дренаждық ағынды сулардың тасталуына байланысты өзендерге ШДК мәндері айтарлықтай өсті. (жылына 12 - 14 км3). Арал теңізі бассейнінің гидроэкологиялық жай-күйін басқару және тұрақтандыру үшін қоршаған ортаның шығарындыларын таратудың тиімділігін арттыру, атмосфераға тұздар мен шаң-тозаңдарды шығаруды тоқтату, теңіз суының тұздылығын төмендету бойынша техникалық шараларды әзірлеу бойынша кешенді шаралар қажет.

Түйін сөздер: минералдану, техникалық шешім, өзен ағыны, табиғи ағынның қалыптасуы, су ресурстары.

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РАЗРАБОТКА МЕТОДИЧЕСКИХ ОСНОВ И ИССЛЕДОВАНИЕ ТЕХНИЧЕСКИХ РЕШЕНИЙ УВЕЛИЧЕНИЯ ОБЪЕМА СЕВЕРНОГО АРАЛЬСКОГО МОРЯ ПРИ МИНЕРАЛИЗАЦИИ СТОКА РЕКИ СЫРДАРЬЯ

Аннотация. В статье приведены исследования технических решений увеличения объема Северного Аральского моря при минерализации стока реки Сырдарья.

Река Сырдарья является источником питания казахстанской части Аральского моря, в частности Малого Арала. Река Сырдарья обеспечивает также водой орошаемые земли в республиках Кыргызстана, Узбекистана и Казахстана. Общая площадь сельхозугодий в бассейне реки Сырдарья составляет 34 млн. га, в том числе пашни – 4,2 млн. га. Водные ресурсы бассейна представлены среднемноголетним стоком реки Сырдарья в объёме 37,2 км^3, возвратными водами от орошения – 14,1 км^3 и запасами подрусловых вод в пределах 3,3 км^3. Формирование естественного речного стока в разрезе государств бассейна исключительно неравномерно: Кыргызстан - 74,2%, Узбекистан - 13,8%, Казахстан - 9,3%, Таджикистан - 2,7%.

Фактическое использование водных ресурсов в бассейне реки Сырдарья по отраслям экономики в последние годы составило: регулярное орошение сельского хозяйства - 5458,1 млн. Процесс интенсивного засоления происходил в

результате интенсивной испарительной способности атмосферы, двустороннего засоления почв за счет испарения грунтовых вод и переноса или выдувания солей с обнаженного сухого дна. Оценка по классификации (Chembarisov at all, 1989) показала, что воды Аральского моря по минерализации относятся к слабым рассолам. По другим данным, среднегодовая минерализация речного стока в зоне формирования колеблется незначительно в пределах 0,35–0,40 г/л. Несмотря на такое большое водопотребление, площади засоленных и подверженных засолению орошаемых земель все эти годы в бассейне Аральского моря не уменьшались и оставались на уровне 55-60% всех орошаемых земель. В то же время минерализация воды в родниках, особенно в среднем течении и в дельтах рек, увеличилась до 1,0–2,5 г/л, при этом качество воды ухудшилось, а ПДК по многим показателям значительно повысились за счет сброса коллекторно-дренажного стока в реки. (12 – 14 км3 в год). Для управления и стабилизации гидроэкологического состояния бассейна Аральского моря необходимы комплексные меры по повышению эффективности распределения экологических попусков, подавлению выбросов солей и пыли в атмосферу, разработка технических мероприятий по снижению минерализации морской воды.

Ключевые слова: минерализация, техническое решение, сток реки, формирование естественного стока, водные ресурсы.

Introduction. The Syrdarya River is the main water artery of the basin, formed from the confluence of the Naryn and Kara Darya rivers, small tributaries of the Ferghana Valley, the middle reaches, and tributaries of the Akhangaran, Chirchik, Keles, Kurukkeles, and Arys. The main volume of runoff (71%) is formed in the upper part of the basin before leaving the Ferghana Valley. Downstream to the city of Shardara, the flow of right-bank tributaries (the Akhangaran, Chirchik, and Keles rivers) is 23% of the total water resources. Share of runoff The Arys and the rivers flowing down from the Karatau ridge are small - less than 6%. In the zone of formation, the distribution of flow between countries is as follows: the main flow of rivers - about 78% - is formed on the territory of Kyrgyzstan, about 15% of the river flow of the Syr Darya is formed on the territory of Uzbekistan, in Kazakhstan - about 6%, in Tajikistan - about 1%.

The Syr Darya River is the source of food for the Kazakhstan part of the Aral Sea, in particular the Small Aral Sea. The Syr Darya also provides water for irrigated lands in the republics of Kyrgyzstan, Uzbekistan, and Kazakhstan. The total area of agricultural land in the Syrdarya river basin is 34 million hectares, including 4.2 million hectares of arable land.

The water resources of the basin are represented by the average long-term flow of the Syrdarya River in the amount of 37.2 km^3, return water from irrigation - 14.1 km^3, and under-stream water reserves within 3.3 km^3 (Karlikhanov T.K. et all, 2016). The formation of natural river flow in the context of the states of the basin is extremely uneven: Kyrgyzstan - 74.2%, Uzbekistan - 13.8%, Kazakhstan - 9.3%, and Tajikistan - 2.7%.

The actual use of water resources in the Syrdarya River basin by economic sectors in recent years amounted to regular irrigation of agriculture - 5458.1 million m^3, industrial needs - 51.4 million m^3, household needs of settlements, cities, regional centers, etc. - 61.0 million m^3, fishery needs - 11.1 million m^3, bay of natural hayfields and estuary irrigation - 558.5 million m^3, forced water withdrawal - 1139.9 million m^3, releases to the Aral Sea 6619.0 million m^3. The summary requirements of water consumers in the lower reaches of the river, taking into account the inflow of the Arys River and the return flow, are shown in Table 1 (Karlikhanov T.K. et all, 2016).

Table 1 - Summary requirements for water consumption in the lower reaches of the river, km^3

Consumers and runoff costs	Average long-term value	Provision, %		
		20	50	90
Irrigation	5,50	6,10	5,45	5,00
Natural ecological systems	1,00	1,50	0,72	0,33
Delta	1,20	1,60	1,26	0,77
Losses	2,92	3,65	2,50	1,90
Inflow to the Small Aral	2,	3,70	2,53	1,70
Total	13,4	16,6	12,5	9,70

Economic and anthropogenic activity during the noted period developed at a rapid pace, which had a significant impact on many processes associated with excessive regulation and use of water resources. Under these conditions, the process of degradation began in the natural environment of the Aral Sea region. At the same time, measures were taken to regulate the flow of the river by large reservoir waterworks. In the period from 1955 to 1980, the Kairakkum (1956), Shardara (1965), Sharvak (1970), Toktogul (1975), and Andijan (1978) and other reservoirs with a total useful capacity were built about 35-36 km^3, which was commensurate with the average annual flow of the river.

Currently, more than 1,000 canals for various purposes (main, inter-farm, economic, etc.) with a total length of about 75 thousand km, an extensive network of collector-drainage networks, and waste collectors with a total length of about 55 thousand km are operated in the river basin. From 1950 to 1995, the area of irrigation in the river basin doubled and reached 10.14 million hectares. During this period, the area of irrigated land in the region increased by 94%; in the context of decades, these increases amounted to 1950-1965. - by 12%; 1965-1975 - by 20%; 1975-1985 - by 44% and 1985-995. by 25%; this is an excessive burden on ecological systems.

Based on this, now, to save and restore the ecological balance in the region, irrigation should not dominate in matters of water distribution. It should be taken into account that a huge amount of water is lost along the way as a result of the irrational use of irrigation. Thus, the Aydarkul-Arnasay wetlands and the Sarykamysh depression were formed as a result of water discharge into the lowlands. Although before it was empty places. Currently, in the Syrdarya basin on the territory of the Republic of Kazakhstan, there is 1 reservoir (Shardara, commissioned in 1965) and 1 counter-regulator (Koksarai, commissioned in 2008) with a total capacity of 8.2 km^3. The hydrological regime of the rivers of the river basin. The Syr Darya until 1961 can be considered conditionally natural; which since 1961 has been greatly distorted by economic activity.

The flow formed on the territory of the Republic of Kazakhstan is 4.7 km^3, along the river. The Syr Darya receives 14.96 km^3 from outside the Republic of Kazakhstan, in total, water resources brought to modern conditions are 19.66 km^3. Despite the implementation of a set of preventive measures to mitigate the consequences of floods, the region suffered huge economic and social damage (Zhaparkulova E.D. et all, 2021). Settlements and agricultural lands were flooded, hydraulic structures and separate sections of roads were destroyed, several thousand residents of settlements were evacuated from the flood zone, etc. The total material damage in the two regions amounted to about 2 billion tenges.

The Committee on Water Resources of the Ministry of Agriculture of the Republic of Kazakhstan agreed on the investment feasibility study for the second phase of the project «Regulation of the Syr Darya river channel and conversation of the northern Aral sea (RSRCNAS), which includes the construction of the second stage of the North Aral Sea dam», which provides for raising the water level in the Small Sea to the level of 46.0 m BS; construction of a hydroelectric power plant as part of the Aklak hydraulic structure with an annual electricity generation of up to 23 MW; rehabilitation and construction of protective dams, with a total length of 500 km; straightening the bed of the Syrdarya river; repair and restoration work at the head structure of the Kyzylorda Left-bank main canal; rehabilitation of the Aksai-Kuvandarya lake system; construction of the Raim hydroelectric complex; construction of two bridges across the Syr Darya instead of the current pontoon crossings. In addition, the issue of studying the water balance and creating a simulation model of the Syrdarya River is being considered. In this context, the issue of using the water resources of the Syr Darya, and sharing them with neighboring states on the principles of international water law, based on mutual respect and trust, and constructive cooperation, is very important for Kazakhstan.

Most of the seabed (more than 33 thousand km^2) in the period from 1960 to 1998. After drying, it was covered with salt, which, according to the Institute of Geography of the Academy of Sciences of the Russian Federation, is estimated at 10 billion tons of salts, among which salts of sodium chloride make up 56%, magnesium sulfate 26% and calcium sulfate 15%.

As the sea dries up, a huge amount of salt accumulates on its bottom. This occurs as a result of capillary uplift and subsequent evaporation of highly mineralized groundwater along the coast, seasonal fluctuations in the level that contribute to the deposition of salts due to evaporation, and winter storms bringing deposited sulfates to the coast. Therefore, at present, the most serious problem is the blowing of salts and dust from the drying seabed, as traces of them have been found 1000 km southeast of the sea in the fertile Ferghana Valley, in Georgia on the Black Sea coast and even on the Arctic coast of Russia.

The drained strip of the seabed became a source of powerful dust storms. According to some scientifically confirmed sources, dust is transported at least 150-500 km. From the southeastern coast of the Aral Sea, 15-75 chloride salts rise in a year and spread over hundreds of thousands of square kilometers, damaging the generative and vegetative organs of plants, and reducing pasture productivity and crop yields.

Materials and research methods. In the Aral Sea region, three powerful directions of entry of sand-salt aerosols into the atmosphere were formed (Abstract of diss. Tazhiyeva T.Ch., 2014). The largest of them in terms of area is the source, stretching along the eastern shore from the delta of the Syrdarya River in the north to the Aktepe archipelago in the south. The second source is the bottom of the former Saryshyganak Bay, and the third is the vast sandy bottom of the sea near the Kokaral peninsula and the former protected island of Barsakelmes. Figure 1 shows a diagram of the phased implementation of phytomeliorative measures on the dried bottom of the Aral Sea to reduce the negative impacts of sand-salt emissions in the north-south direction.

The drop in the level of the Aral Sea has led to negative changes in the sea itself and the environment in the adjacent region: its water area and biota have been reduced, the groundwater level has been lowered to 3-4.5 m in a strip of 100-120 km from the modern water line; the process of desertification covered the delta and coastal areas; the climate is changing; the deflationary processes of the dried sea bottom have been intensified, which leads to the transfer of salt dust to the territory of the Aral Sea region, the natural complex in the zone of influence of the sea has been changed.

The drying up of the sea affects the temperature regime and moisture regime in the coastal strip 50 to 100 km wide in the north, east and west and from 200 to 300 km in the south and southwest. With the change in the temperature regime of the Aral Sea region, the amount of precipitation and their intra-annual distribution have changed.

The drying part of the sea has become a source of powerful salt and dust emissions into the atmosphere. According to some estimates, up to 100 million tons of salt dust per year is blown out and carried out of the sea. Due to the decrease in the size of the sea, the increase in evaporation and the inflow of drainage-collector waters, the salinity of the water in the sea has increased, which was 9.94 g/l in 1965, and now more than 65 g/l (Martin Schmidt et all, 2018).

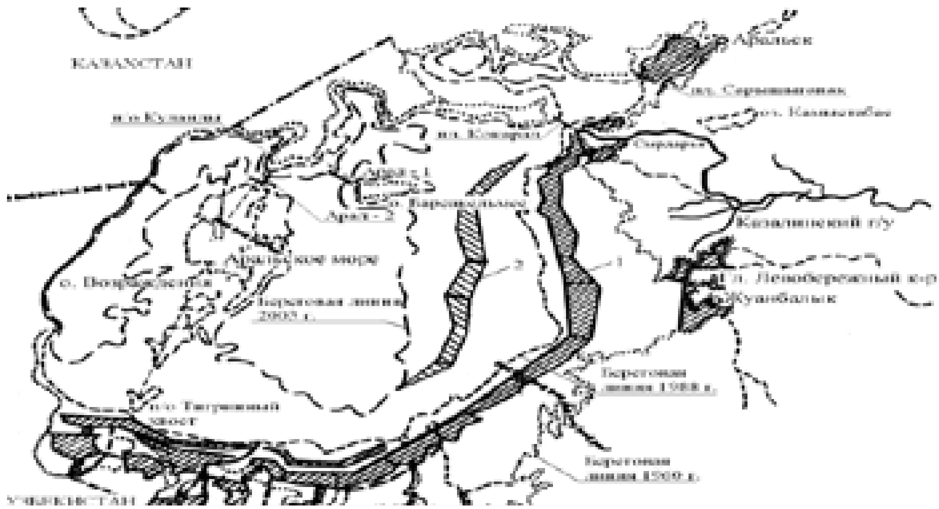

Figure 1 - Proposed measures to stabilize the environmental situation in the Aral Sea region:
1 - phytomeliorative measures of the first stage, 2 - phytomeliorative measures of the second stage

The most common pollutants in the Aral Sea include petroleum hydrocarbons, phenols, synthetic surfactants, organochlorine pesticides, and heavy metals. As a result of changes in the water balance of rivers and the resulting increase in water mineralization in the Aral basin, a unique biocenosis and several endemic animal species have been lost. Of the 319 species of avifauna, no more than 30% are mammals. Of these, 70% are rodents that have managed to master the drained bottom.

The forecast of the hydrochemical regime of the water of the Syrdarya River was carried out by the balance method according to the following equation:

$$C_{oi} = \frac{Q_1 \cdot Co_1 + \Sigma Q_2 \cdot Co_2 + \Sigma Q_3 \cdot Co_3 + \Sigma Q_4 \cdot Co_4}{Q_1 + Q_2 + Q_3 + Q_4}, \quad (1)$$

where: C_{0i} – mineralization of water in this section, g/l;

Q_1- volume of runoff in the overlying section, km^3/year;

C_{01}- mineralization of water in the overlying section, g/l;

Q_2 and C_{02} - volume of return collector-drainage waters from irrigated fields and their salinity;

Q_3 and C_{03} - volume of return wastewater from irrigated fields and their salinity;

Q_4 and C_{04} - volume of runoff and salinity of water in tributaries.

Research results. The calculation was carried out for the case that the inflow of surface waters remains at the level of recent years, and its average annual volume remains at 5.2 km^3, the volume of groundwater recharge remains at the level of 10 km^3, then the southern sea will be divided into two parts with a total area of about 12 thousand km^2, and their salinity will increase to 140 g/l.

Changes in the hydrochemical regime of groundwater in the river delta and the dry bottom of the Aral Sea are shown in Figures 2 and 3.

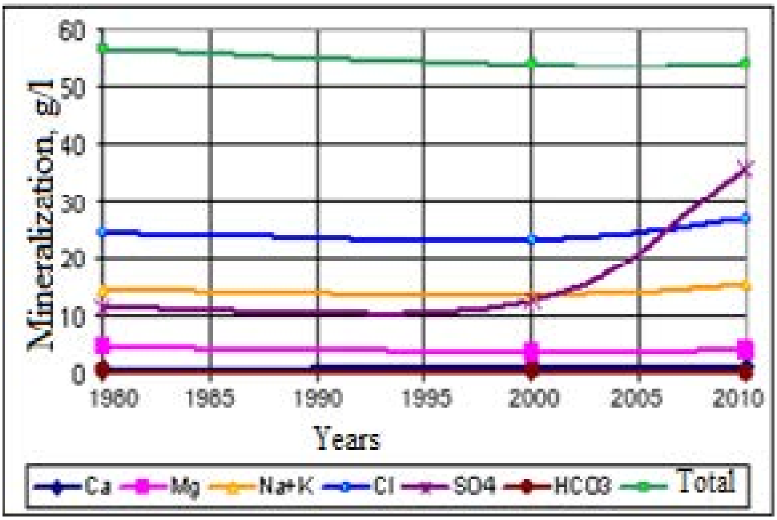

Figure 2 - Mineralization of groundwater in the delta of the Syrdarya River

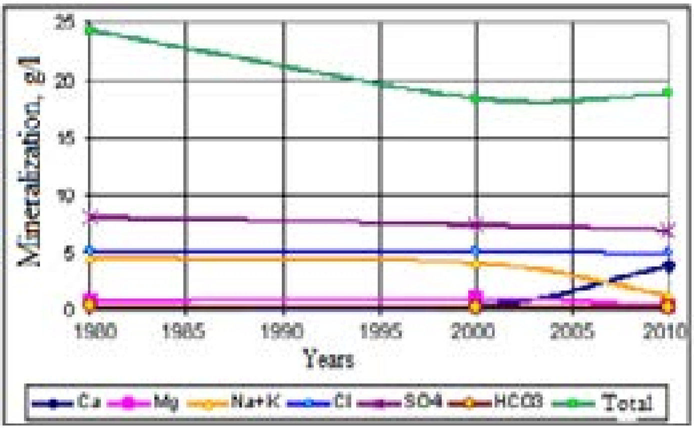

Figure 3 - Mineralization of underground waters of the dry bottom of the Aral Sea

The process of intense salinization occurred as a result of the intense evaporative capacity of the atmosphere, bilateral soil salinization due to the evaporation of groundwater and the transfer or blowing of salts from the exposed dry bottom. An assessment according to the classification (Abstract of diss. Tazhiyeva T.Ch., 2014). showed that the water of the Aral Sea, in terms of mineralization, belongs to weak brines.

According to other data (Mozheiko A.M., et all, 1958), the average annual mineralization of the river runoff in the formation zone varies insignificantly within 0.35–0.40 g/l. With the flow of collector-drainage water, the mineralization of water in the river increases downstream. For example, in the Bekabad gauge it varies from 0.44 to 1.40 g/l, and in the Kazalinsk gauge from 0.52 to 2.26 g/l (Table 2).

Table 2 - Mineralization of water in the Syrdarya river, g/l (Mozheiko A.M., et all, 1958).

Alignment	Years	C_o, g/l	Main iones, mg/l					
			Ca^{+2}	Mg^{+2}	Na^{+}	Hco_3	So_4^{-2}	Cl^{-}
Bekabad	1955	0,44						
	1975	0,64	15	65	104	204	437	82
	1985	0,97	111	66	117	195	482	84
	1995	1,38	132	90	115	219	579	123
	2005	1,40	109	60	113	195	482	84
Tomenaryk	1955	0,48	96,2	37,1	9,5	134,2	220,7	50,8
	1975	0,74	85	38	80	177	286	62
	1985	0,94	101	58	145	166	452	102
	1995	1,74	111	95	240	186	670	151
	2005	1,23	111	95	240	186	670	151
Kyzylorda	1955	0,51	71,1	28,2	61,0	148,3	246,3	48,6
	1975	0,70	94	26	74	199	246	49
	1985	0,98	99	60	155	174	455	110
	1995	1,74	110	72	226	185	615	132
	2005	1,58	113	81	236	141	466	141

Kazaly	1955	0,52	86	30	88	198	217	58
	1975	0,95	97	57	169	182	485	111
	1985	1,01	112	87	253	173	731	197
	1995	1,72	110	72	226	185	615	110
	2005	1,26	88	46	135	178	6185	102

The increase in mineralization in the Kazalinsk hydro-section is caused both by an increase in the volume of discharged collector-drainage water (CDW), and by some increase in its mineralization due to an increase in the volume of discharge of highly mineralized water from the rice paddies of the Kyzylkum, Togusken and other massifs. As can be seen from tables 1, from the analyzed indicators of water quality, the maximum permissible coefficient (MPC) was exceeded, including the following main indicators of water quality: water salinity, total hardness, the presence of petroleum products, hexochlorocyclohexane (HCCH), fluorine, dichlorodefinyl dichloroethane, dichlorophenyl dichiorethane, dichloro dephenyl trichloroethane, etc (Ibrayev T. et all, 2022).

Based on these data, it can be stated that at the current level in the lower reaches of the river, the quality of river water does not meet the requirements for the vast majority of standardized indicators (Balyuk S.A., et all, 1993). Thus, the water quality of the Syrdarya River does not meet the regulatory requirements for both fishery and household water bodies (Soroush Barkhordari et all, 2022). There is an excess of mineral and organic compounds over the maximum permissible concentrations (MPC) almost along the entire length of the river, since up to 30% of wastewater is discharged into water bodies without treatment (Chembarisov at all, 1989).

The total amount of CDW in the river basin has reached 12 to 14 km^3/year, of which 10 km^3 goes back into the river, and 2 to 4 km^3 is discharged into natural depressions. The mineralization of the CDW along the river varies within the following limits: in the upper reaches - 1.45-7.6 g/l, on average - 3.3-15.9 g/l, in the lower reaches - 5-8 g/l (Pankov V.I. et all 1985). Analysis of the deterioration of the qualitative composition of the runoff in the lower reaches of the Syrdarya River and in the Aral Sea.

The anthropogenic regime, characteristic of all the river systems of the world, had its worst effect on the qualitative composition of the water of the Syrdarya River. Increased mineralization and a gradual increase in the amount of harmful chemicals have led not only to a decrease in the productivity of agricultural landscapes, but also to a deterioration in the ecological situation in the region. This process is especially strongly observed in the delta part of the river and in the Aral Sea region. Simultaneously with an increase in the general mineralization of river water, the content of such chemical components as magnesium, copper, iron, sulfates, chlorides, etc. increases. As a result, the water of the Syrdarya River, not only in the lower, but already in the middle reaches, is not suitable for drinking water supply. Significant pollution of the river as a source of drinking water often leads to an increase in morbidity among the local population.

The assessment of the hydrochemical regime of the water in the lower reaches of the Syrdarya River shows that, for all control sections, the mineralization of water in the river increases compared to the period of 1960-1970. This is clearly shown in Figure 4, where, compared to the Naryn-Karadaria section, in the remaining sections of the river in the anthropogenic period (from 1965 to 2020), mineralization increased by 1.2-2 times, in the degraded part of the Aral Sea - hundreds of times (Fig. 4).

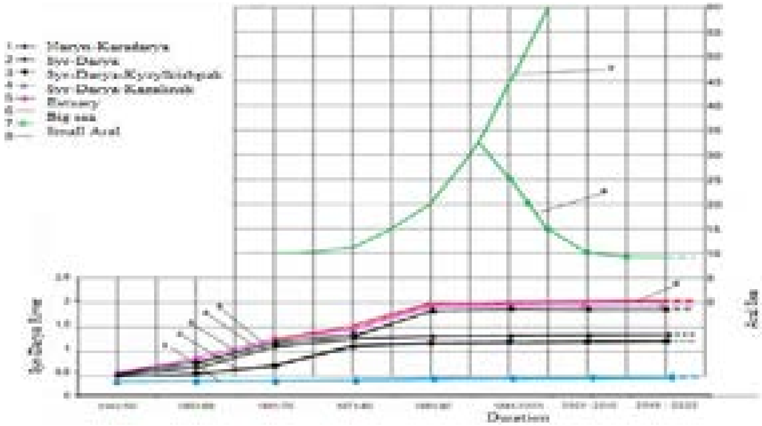

Figure 4 - Long-term trend of river runoff mineralization along the sections of the Syrdarya river and the Aral Sea (according to the GEF - 2002, N.A. Amirgaliyev - 2007, T.Ch. Tazhiyeva - 2014, Zh. Mukhtarov Zh. - 2020).

The most well-known method for assessing water quality was developed by A.M. Mozheiko and T.K. Vorotnik (Mozheiko A.M. et all, 1958), who consider water suitable for crops, if the ratio is less than 65%, if it is 66-75% - the water is dangerous, and the ratio is more than 75% indicates that the water is very dangerous, soil salinization can occur.

$$(Na + K) \cdot 100 / (Ca + Mg + Na + K)$$

According to M.F. Budanov (Budanov M.F. 1970), water is considered suitable for crops if the ratio is less than one, the ratio is less than 0.7 for waters with salinity up to 1 g/l, and for waters with salinity from 1 to 3 g/l, the quotient of dividing the sum of all ingredients by the hardness value should not exceed 4 for medium and heavy loamy soils, 5 for light loamy and 6 for sandy and sandy soils.

The most suitable for assessing the suitability of water is the formula of I. Antipov-Karataev and G. Kader (Antipov - Karataev I.N., et all 1959):

$$K = \frac{rCa + rMg}{rNa \cdot 0.23C} \cdot 0.23C, \qquad (2)$$

where rCa, rMg, rNa - content of cations in water, mg-eq; - mineralization of water, g/l.

When the water is considered suitable for irrigation, when it is unsuitable, since with a higher sodium content, soil solonetzization begins.

To assess the quality of river and waste water, you can use the method developed by the US Department of Agriculture, which takes into account the indicator of possible soil solonetzization, the so-called sodium-adsorption ratio ( ), which is determined by the formula (Nasrulin A.B., 2000).

$$SAR = Na/\sqrt{(Ca = Mg)/2} \quad (3)$$

During irrigation, an active interaction occurs between the irrigation water and the soil, as a result, a new composition of the soil solution is formed, which is taken into account when calculating the so-called «refined»:

$$SAR^{*} = SAR[1 + (8/4 - pHc)], \quad (4)$$

where $pHc = (pK_2 - pK_{CaCO_3}) + p(CA + mg) + p(AI_k)$ - is according to the table given in the manual(Pankov V.I. et all 1985).

The listed methods for determining the suitability of irrigation waters are used for a qualitative assessment of the water of the Syrdarya River and their results for the Shardara and Kazalinsk gauges for the period from 1960 to 2020 are presented in Table 2. The assessment of the suitability of the water of the Syrdarya River for irrigation shows that the water is suitable without any restrictions (Altunin V.S. et all 1991).

However, it is known that the intensity of the alkalinization process increases if magnesium predominates over calcium in the composition of the water, then both the alkalizing capacity of the water and the absolute content of cations that solonetz (Qingyu Sui et all, 2022) the soil in its increase, this must be constantly remembered by meliorators and taken into account when carrying out reclamation measures.

Table 3 - Assessment of the suitability of the water resources of the Syrdarya River

Assessment Methods	values	Shardara			Kazaly		
		1960	1975	2020	1960	1975	2020
Irrigation assessment of waters by the ratio of cations							
$100 \cdot Na^{+}/(Ca^{2+} + Mg^{2+} + Na^{+})$	≤60	41.9	33.6	39.7	52.3	55.4	58.3
$Na^{+}/(Ca^{2+} + Mg^{2+})$	≤0.7	0.71	0.48	0.66	1.03	1.24	1.40
$(Ca^{2+} + Mg^{2+})/(Na + 0.23CI)$	≤1.0	1.19	1.63	1.21	0.79	0.72	0.63
$2Na^{+}/(Ca^{2+} + Mg^{2+})$	≤10	1.42	0.96	1.32	2.19	2.48	2.79
Irrigation assessment for the danger of oversaturation of chemical elements							
$(Ca^{2+} + Mg^{2+})/Na^{+}$	≤60	1.40	2.06	1.52	0.91	0.79	0.71
$100 \cdot Mg^{2+}/(Ca^{2+} + Mg^{2+})$	≤50	33.1	33.0	42.1	37.0	43.7	35.0
$Na^{2+}/(Ca^{2+} + Mg^{2+})$	≤0.7	0.71	0.48	0.66	1.10	1.27	1.40
$Na^{+}\ Ca^{2+}$	≤1.0	1.28	0.88	0.89	1.52	1.28	1.67
Assessment of waters by the danger of soil alkalization							
pH	7.8	7.1	7.2	7.3	7.5	7.8	7.7
$(HCO_3^{-}$-$Ca^{2+})$	1.00	0.76	0.53	1.63	0.85	0.61	1.41

As is known, irrigation in the lower reaches of the Amu Darya and Syr Darya has been practiced for several millennia. In 1900, more than 3 million hectares were irrigated in the Aral Sea basin, by 1960 - 5 million hectares, and irretrievable water withdrawal reached, according to the then estimate, 40 km3. However, water withdrawal for irrigation until the 1960s was compensated by a corresponding decrease in natural evaporation, transpiration, and filtration, especially in the deltas of the Syr Darya and Amudarya, where truncated spring floods reduced floodplain flooding, the area of delta lakes, and the spread of phreatophytes. In addition, the creation of a drainage network has increased the amount of waste water entering the rivers.

By 1995, the irrigated area in the Aral Sea Basin had increased to almost 7.6 million ha [33, 34]. Water withdrawal from the Amudarya and Syrdarya was 106.4 km3 (Table 4).

Table 4 – Dynamics of irrigated areas, water withdrawals and collector-drainage flow in the Aral Sea basin

Years	К концу периода				Specific water intake, thousand m3/ha	CDS, km^3
	Irrigation area, mln.ha	% solonethic	Water intake, km^3	Water mineralization, g/l		
1900-1915	3.25	3 – 5	10-15	0.3-0.4	2-6	
1916-1931	3.071	5 -10	20	0.3-0.5	5.3	
1931-1940	4.337	16 – 20	26.1	0.3-0.5	6.0	
1941-1950	4.545	25 – 30	32.1	0.3-0.6	7.1	1-2
1951-1960	4.982	56	40.4	0.3-0.7	8.2	5-6
1961-1970	5.129	56	50.3	0.5-1.0	9.8	10-12
1971-1980	6.127	56	65.8	0.7-1.0	10.7	29-30
1981-1990	6.930	51 – 60	86.0	1.0-1.25	12.4	32-34
1986-2000	6.920	60-62	106.8	1.0-1.8	15.4	
1991-2010	7.600	62-63	106.4	1.2-1.8	14.0	29.6
1996-2020	7.990	63-64	94.7	1.4-1.8	11.9	
Perspective	7.983	64-65		1.4-1.8		

Analysis of the data shows that between 1996 and 2000 irrigation efficiency increased significantly in the sea basin, resulting in a reduction in water withdrawal from an average of 15.4 to 11.9 thousand m3/ha. This led to an increase in the irrigated area with a decrease in specific water consumption and return waters, but to reach the level before 1970. on specific water, consumption is still not successful (Luyang Y.ang et all, 2022).

The volume of the return water from irrigated fields is very large and, therefore, it plays an important role in environmental releases (Table 5).

Table 5 - Formation of return waters and water disposal in the Aral Sea basin (Nasrulin A.B., 2000).

State	Collector-drainage water	Wastewater	Total	Drainage		
				on River	into natural depressions	reuse for irrigation
Kazakhstan	1.60	0.19	1.79	0.84	0.70	0.25
Kyrgyzstan	1.70	0.22	1.92	1.85	0.00	0.07
Tadzhikistan	4.05	0.55	4.60	4.25	0.00	0.35
River Syr-Darya	1.05	0.14	1.19	0.92	0.00	0.27
River Amu-Darya	3.00	0.41	3.41	3.33	0.00	0.08
Turkmenistan	3.80	0.25	4.05	0.91	3.10	0.04
Uzbekistan	18.4	1.69	20.09	8.92	7.07	4.10
River Syr-Darya	7.60	0.89	8.49	5.55	0.84	2.10
River Amu-Darya	10.80	0.80	11.60	3.37	6.23	2.00
Total in Aral Sea Basin	29.55	2.90	32.45	16.7	10.87	4.81
River Syr-Darya	11.95	1.44	13.39	9.16	1.54	2.69
River Amu-Darya	17.60	1.46	19.06	7.61	9.33	2.12

For 20-30 years of operation of reclamation systems, it was not possible to radically get rid of the secondary salinization of lands, despite the fact that the volume of CDW during this period (1965-1985) increased from 5-6 to 32-34 km3 per year, and water withdrawal - respectively from 50.3 to 86 km3 per year.

At present, the total volume of CDW in the sea basin exceeds 33 km3/year (Table 6) [36].

Table 6-Characteristics of some large reservoirs - reservoirs of collector and drainage water

Lake	River basin	Water surface area, km^2	Volume, km^3	Water mineralization, g/l
Arnasai	Syr-Darya	1865	13.9	10.10
Kamyshlybash	Syr-Darya	78	1.00	3.40
Sarykamysh	Amy-Darya	2575	20.20	12.50
Sudachye	Amy - Darya	300	0.60	2.00

In the sea basin, more than 2000 reservoirs-accumulators of the CDW were formed with an area of 7000 km^3. Most of them are small lakes with a water surface area of up to 1 km^2, but there are also large ones.

Conclusion. The analysis shows that, despite the efforts of water engineers, maintaining the leaching irrigation regime and the use of almost annual non-vegetation irrigation on saline soils against the background of efficient drainage (vertical and horizontal) and other recommended measures, it is not possible to achieve a stable water-salt regime of soils in the region. managed.

For example, by 1960, about 5 million hectares of land were irrigated in the Aral basin, for which 40.4 km^3 of fresh river water (8.2 thousand m3/ha) with mineralization of 0.3-0.7 g/l; by 1985 - for irrigation of about 7 million hectares, water intake increased to 86 km^3 per year (12.4 thousand m^3/ha).

Despite such a large water consumption, the areas of saline and saline-prone irrigated lands did not decrease all these years in the Aral basin and remained at the level of 55-60% of all irrigated lands. At the same time, water mineralization in springs, especially in the middle reaches and in river deltas, increased to 1.0–2.5 g/l, while water quality deteriorated and MPC increased significantly in many indicators due to discharges of collector and drainage runoff into rivers (12 – 14 km3 per year).

To manage and stabilize the hydro-ecological state of the Aral basin, comprehensive measures are needed to improve the efficiency of the distribution of environmental releases, suppress salt and dust emissions into the atmosphere, and develop engineering measures to reduce the salinity of seawater.

In this regard, national experts express concern about the unsatisfactory technical condition of treatment facilities (about 60-70% of the total), which do not provide effective treatment of sewage and industrial effluents.

On the problem of improving the quality of water, the following priority measures are proposed:

- limiting the discharge of return waters into the river and the volume of discharges of certain pollutant ingredients for various sections and zones;
- introduction of the "polluter pays" principle into interstate practice (for violation of these limits);
- Strengthening water quality control measures;
- establishing the value of environmentally sound sanitary passes for different water content years and different periods for rivers of interstate significance;
- development of methods and means for monitoring the quality of water resources;
- Share participation of the interested states in financing and performance of works on prevention and liquidation of consequences of water pollution on the rivers of interstate significance.

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