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# Ion composition and qualitative indicators of water within the Chernozemelskaya water-irrigation system

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**Abstract.** In Russia, the agro-industrial complex is a large consumer of water resources, which are used to supply water to rural settlements, food and processing industries, livestock complexes and poultry farms, irrigation of land, flooding of pastures and haylands, as well as for fishing, recreation and other purposes. To a large extent, the environmentally safe, cost-effective and socially oriented development of the region depends on the state and functioning of reclamation systems. The paper presents the results of long-term monitoring of the geochemical composition and water quality indicators of the Chernozemelskaya water-irrigation system (from 2002 to 2018) located on the territory of the Caspian lowland. Irrigation and drainage and surface waste of the system are found to have a level of mineralization ranging from 1.2 to 2.3 g/l with sulfate-chloride and chloride-sulfate, sodium chemism, while the medium activity is low and intermediate-mafic (pH=7.8-8.4). It is analyzed that the high level of  $\text{Cl}^-$ ,  $\text{Na}^+$ ,  $\text{Mg}^{2+}$  ions in irrigation water can cause salinization and alcalination of all types of soils.

## 1. Introduction

Water is one of the main elements of the biosphere, without which the existence of any living organism is impossible. The civilized world is always linked to the development of water management systems and the growth of water consumption. Water, as the main natural resource, is used in various spheres – industry, agriculture and utilities, development of recreational activities and others. However, freshwater supplies on the Earth are limited (especially in the arid zone), and water scarcity is increasing every year, which in some countries has become a limiting factor along with eco-economic considerations. The current and growing shortage of fresh water resources first puts the need for water and energy-saving technologies. Therefore, there is a need for a tough focus on its strict rationalization, rational and complex use, protection against pollution using modern resource-saving technologies and environmental-system approaches and principles [1-3].

The unfavorable situation in the field of water use is related to a whole range of issues that take place at all stages of water management: harvesting, use, reproduction, protection of water resources, etc. In this regard, the issue of water efficiency improvement is particularly important [4-9].

The guaranteed supply of water in the required quality and in the necessary volumes to the population and economy becomes one of the priority tasks of the state policy aimed at preserving the health and



improving the living conditions of Russians, developing the productive and agricultural potential of the country [1-3, 6-8].

The purpose of the study is to monitor the geochemical composition of water resources that ensure the ecosystem water use in the Chernozemelskaya water-irrigation system.

## 2. Objects and methods of study

The Chernozemelskaya Water Irrigation System (CWIS) is the largest system in the territory of the Caspian lowland, which is located within the administrative boundaries of the Republic of Kalmykia. It has been in operation since the early 1970s, with a water intake limit of 536.9 million m<sup>3</sup> per year. The water source is the Chograysky reservoir, water flows into it from the Terek and Kuma rivers along the Kumo-Manychsky Channel [1]. Then, through the head structure in the reservoir dam, water is supplied to the Chernozemelskaya Main Channel (CMC), which has a length of 140.2 km and a specific flow rate in the head of 35.0 m<sup>3</sup>/s. The water from CMC gets directly to consumers by gravity through farm ditches: Gashunsky and Yashkulsky distributaries, and from Gashunsky – to the north of the region through the Priozerny channel. All channels pass through earth streams, which affects mineralization and chemical composition of water used for various needs.

The methods of quantitative chemical analysis were used to monitor the quality of water used for various needs. In the course of laboratory studies, the ion-cation composition of water was determined by gravimetric and titrimetric methods: Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, HCO<sub>3</sub><sup>-</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup>. Water mineralization was measured with a portable conductometer (Cond 340i), pH – with a portable pH meter (Cond 330i).

## 3. Results and discussion

The Chernozemelskaya WIS can provide water treatment of natural grazing lands with an area of 1167.2 thousand hectares, in the area of the system there are about 17 thousand hectares of regular and basin irrigation [1]. Several settlements of the Republic of Kalmykia (for example, the village of Yashkul, the village of Adyk) use the waters of the Chernozemelskaya WIS for drinking and communal services. Besides, water gets to replenish the water bodies.

The results of long-continued monitoring show that the mineralization level of irrigation and drainage-surface waste waters ranges from 1.2 to 2.3 g/l (sulfate-chloride and chloride-sulfate, sodium chemism) and low- and medium-temperature reaction of medium activity (pH=7.8-8.4).

Let us consider the geochemical composition and qualitative indicators of water in all the main water supply paths of the Chernozemelskaya WIS.

The *Chograysky Reservoir* is located in the valley of the East Manych River and represents the continuation of the cascade of Manychsky water bodies (Bald Lyman Lake, Lake Manych-Gudilo, Proletarian Reservoir). It is among the largest artificial water bodies not only in Russia, but in the entire planet [10, 11].

However, in recent years the environmental situation within the reservoir has dramatically deteriorated. Due to the supply of contaminated runoffs from the Kuma River, which serves as a collector for their discharge into the Caspian Sea, the mineralization of water increased to 1.40-1.89 g/l with a sulfate-chloride-hydrogen carbonate type of salinization. The concentration of toxic ions SO<sub>4</sub><sup>2-</sup> reaches 11.0 mg-equ/L and Cl<sup>-</sup> – up to 28.0 mg-equ/L (Table 1).

The assessment of water suitability of the reservoir for irrigation carried out on a zonal scale [4] made it possible to determine that intensive processes of chloride salinization, sodium and magnesium alcalination are possible in average grading soils. Besides, due to increased hydrogen ion concentration, there are problems of crop yield reduction. Water can be used for household and drinking supply during its purification. Earlier (in the 1970s-1990s) there was a water intake of Iki-Burul main water supply supplying water to the city of Elistu and 2 administrative districts of the republic. Moreover, water is also suitable for livestock watering and satisfying the technological needs of the agricultural sector of the economy.

When coming from Chograysky Reservoir, the water in the Chernozemelskaya main channel has the same indicators as in the water reservoir. However, as it progresses through the earth bed of the channel, its quality decreases.

**Table 1.** Dynamics of mineralization and chemical composition of water within Chernozemelsky water-irrigation system

Date and place of sampling	Ion concentration, g/l / mg-equ/L							Sum of salts, g/l	pH
	CO <sup>2-</sup> <sub>3</sub>	HCO <sup>2-</sup> <sub>3</sub>	Cl <sup>-</sup>	SO <sup>2-</sup> <sub>4</sub>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>		
Chograysky Reservoir									
2003	-	0.220	0.252	0.384	0.110	0.060	0.191	1.217	8.0
	-	3.60	7.20	8.00	5.50	5.00	8.30		
2011	-	0.207	0.284	0.360	0.100	0.084	0.159	1.194	7.9
	-	3.40	8.00	7.50	5.00	7.00	6.90		
2015	-	0.183	0.994	0.072	0.070	0.108	0.460	1.887	8.0
	-	3.00	28.00	1.50	3.50	9.00	20.00		
2018	-	0.262	0.206	0.528	0.110	0.120	0.129	1.355	7.9
	-	4.30	5.80	11.00	5.50	10.00	5.60		
Gashunsky distributary									
2003	-	0.189	0.277	0.552	0.050	0.144	0.182	1.394	8.0
	-	3.10	7.80	11.50	2.50	12.00	7.90		
2011	0.009	0.165	0.270	0.456	0.100	0.096	0.163	1.259	8.0
	0.30	2.70	7.60	9.50	5.00	8.00	7.10		
2018	-	0.140	0.710	0.072	0.120	0.084	0.248	1.375	7.9
	-	2.30	20.00	1.50	6.00	7.00	10.80		
Discharge channels (US-4, US-5)									
2003	-	0.214	0.298	0.600	0.090	0.084	0.297	1.583	8.2
	-	3.50	8.40	12.50	4.50	7.00	12.90		
2011	-	0.238	0.369	0.504	0.110	0.096	0.260	1.577	8.2
	-	3.90	10.40	10.50	5.50	8.00	11.30		
2018	0.006	0.256	0.178	1.080	0.005	0.003	0.722	2.250	8.4
	0.20	4.20	5.00	22.50	0.25	0.25	31.40		

The study of the chemical composition of water in the *Gashunsky distributary* over 2003-2018 shows that its mineralization was at the level of 1.259-1.394 g/l with the prevailing types of salinization – sulfate, sodium and chloride-sulfate, sodium. The deterioration of the quality of water of the Gashunsky distributary compared to the water of the source (Chograysky Reservoir) was revealed. High concentration of Cl<sup>-</sup>, Na<sup>+</sup>, Mg<sup>2+</sup> ions, which may cause salinization and alcalination of all types of soils is established (heavy, average and light). Besides, when water of this geochemical composition is used for irrigation on drip irrigation systems, the drips may be clogged. According to qualitative indicators, water is suitable for livestock watering and technological needs. The corresponding treatment is required for household and drinking purposes.

*Discharge channels (US-4 and US-5)* currently perform a double role – take drainage and surface waste from irrigated areas and, in mixture with irrigation water taken from the Chernozemelskaya Main Channel, at further advance to the east, they perform the irrigation function thus supplying water to

extensive masses of basin irrigation and some areas of regular irrigation. The accumulator of drainage-surface waste is a large array of open sands.

The mineralization of discharge channel water for the period of observations from 2001-2015 ranged from 1.5 to 2.2 g/l. The chemical composition is dominated mainly by chloride-sulfate, sodium, and sometimes sulfate-chloride, sodium salinization chemisms. Magnesium holds the second place in terms of the cation content, and the calcium content is minimal.

The nature of chemical composition dynamics contributes to the increasing danger of chloride salinization as well as sodium alkalization. In terms of the latter indicator, irrigation water often corresponds to the 2-3 class of quality (moderately dangerous and dangerous) [4]. In most cases, magnesium alkalization also varies in seasons, although its numerical values are close to moderate. At the same time, there is no danger of sodium-carbonate salinization.

#### 4. Conclusion

The monitoring of the geochemical composition of water resources of the Chernozemelsky WIS shows that usually the increase in mineralization occurs during autumn (seasonal nature) and as it is removed from the source (Chograysky Reservoir). These changes are caused by high vaporization in the area of the system and the extraction of a significant amount of water for agriculture and water supply. The increase of water mineralization is also influenced by high supply of salts in the soil profile and aeration zone, part of which is transferred from the reservoir bed and earth beds of the channels to water increasing the salt content. For ecosystem water use in the area of the Chernozemelsky water-irrigation system, in order to avoid deterioration of the melioration state of irrigated lands, the use of low and moderately dangerous quality water should necessarily be combined with a complex of special agricultural, melioration and operational measures.

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