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RECLAMATIONS

Water Resources of the Republic of Kalmykia and Measures to Improve Its Water Complex

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Abstract—This article describes the quantitative and qualitative characteristics of surface and underground water resources in the Republic of Kalmykia. A list of the major trends and optimization spheres has been determined to improve the water complex of the republic, which includes the establishment of the environmental monitoring system and the implementation of ecosystem water use in different sectors of the national economy (irrigated farming, water supply, and irrigation).

Keywords: water resources, quality, rational use, irrigation

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The area of the Republic of Kalmykia is the most arid in the southeastern part of the Russian Federation and is provided with water resources to the least extent. The main sector of the national economy of the region is the agro-industrial complex specialized in sheep and beef farming, since the natural forage lands occupy more than 5.2 million ha (69.8% of the total area of agricultural lands). The largest quantities of fresh water for different needs, such as reclamation, irrigation, and water supply (up to 90%), are taken from the adjacent areas from the basins of the Volga, Kuban, Terek, and Kuma rivers. The successful development of the agroindustrial complex of the republic requires optimization of water supply for agriculture, irrigated farming, and grazing.

METHODS

The methodological approaches were based on present-day theoretical and practical developments in the area of ecosystem water use, as well as on the agroecological principles of their organization and regulatory environmental protection documents [1, 2]. To assess the quality of irrigation water, we used a classification recommended by the All-Russia Research Institute of Hydraulic Engineering and Land Reclamation for the Volga Region, since this classification is assumed by the Monitoring Service for the Reclamative Condition of Lands and the Quality of Irrigation Waters to be a regulatory document in Kalmykia [3]. The objects of study were irrigation/water distribution systems (IWDSs), including Chernozemel'sk, Sarpinsk, Kalmyk-Astrakhan, Pravo-Egorlyksk, and Caspian systems, and irrigated sites located within the area covered by IWDSs, as well as water bodies and ponds fed by the local surface runoff.

RESULTS AND DISCUSSION

The hydrographic network of the republic has a very poor development. There is a small section of the Egorlyksk River with a length of 12 km on the western border, and there are lower reaches of the Kuma River in the south of the region (120 km); in the northeast, the territory enters the Volga River in a narrow corridor with a width of 11 km and covers a part of the Volga-Akhtubinsk floodplain with a length of 4–7 km. The channels of the Egorlyksk and Kuma rivers are used as collectors draining wastewaters from the irrigation/water distribution systems of Stavropol krai to the Proletarsk Reservoir and the Caspian Sea.

Forty-three minor rivers are water courses in the eastern and western slopes of the Ergenian highland, and they are the confluents of the Zapadnyi Manych River. A major volume of the local surface runoff is formed in them during spring flood which is then accumulated in numerous water bodies (ponds and reservoirs). An endorheic region has been formed in the lowland eastern part of the republic (within the Caspian Depression). In this region, the surface water resources are represented by the chain of numerous Sarshinsk and Sostinsk lakes with increased water mineralization. There is Proletarsk Reservoir formed in the northwest in the channel of the Zapadnyi Manych River, with its eastern edge (Lake Manych-Gudilo) adjacent to the territory of the republic, and there is also a wide range of lakes in the Manych Depression (Maloe and Bolshoe Yamaltinskoe Lakes, Aras-Emke, etc.), which have strong mineralized

General characteristic of surface water resources in the Republic of Kalmykia

Main water objects	Water source	Water volume, million m3/actual limit	Water mineralization, g/L
Sarpinsk and Kalmyk-Astrakhan IWDSs	Volga	200.0–280.0/574.8	0.4–0.6
Chernozemel'sk IWDS	Terek and Kuma rivers	375.0–415.0/536.9	1.0–2.0
Pravo-Egorlyksk IWDS	Kuban River	57.1–68.0/93.0	0.3–0.45
Caspian IWDS	Volga River	9.5–13.0/48.8	0.4–0.5
Reservoirs	IWDS channels	12.0–30.0/120.0	0.45–0.8
Reservoirs	Local flood surface runoff runoff from the Ergenian highland	80.0–140.0/170.0	0.8–6.7
Lakes	Local runoff and IWDS waste waters	2500.0–2700.0	7.0–425.5
Caspian Sea	Northwestern part of the sea	Without limitation	0.5–1.4
Local surface runoff	Ergenian and Stavropol highland slopes	1270.0–2165.0	0.10–0.43

water (from 40 to 250 g/L or more). There is a 110-kilometer coastline of the Caspian Sea in the southeast [4]. The local surface resources of the republic do not meet present-day requirements and, consequently, a specific water management complex has been established over the last 50 years (table).

The basic needs in fresh water are covered by means of the channels of five large irrigation/water distribution systems (Sarshynsk, Kalmyk-Astrakhan, Chernozemel'sk, Pravo-Egorlyksk, and Caspian systems) receiving water from the basins of the Volga, Kuban, Terek, and Kuma rivers. The volume of the annual intake is 750–800 million m^3. In 2013, the water intake decreased 23% due to the reconstruction of the Chograisk Reservoir dam and the Chernozemel'sk main channel, as well as to late water supply to the Caspian IWDS. There is also an unlimited reserve of demineralized seawaters of the northeastern Caspian Sea, whose volume is about 400 km^3 [5].

Analysis of the present-day condition of water consumption shows that the major volumes of water in the republic are consumed for the needs of irrigated farming and irrigation of natural forage lands (pastures). The total area of regularly irrigated lands is 52700 ha, and the total area of flood irrigation lands is 37200 ha. However, the degree of their use is currently very low, being equal to 17400–18900 and 23000–26000 ha, respectively. To intensify this branch, a republican target program for developing the reclamation of agricultural lands of the Republic of Kalmykia has been developed for the period of up to 2020 [6], according to which the total area of exploited irrigated lands is to grow up to 106600 ha, including the expansion of regularly irrigated lands up to 50500 ha and flood irrigation lands up to 56100 ha. This will require not less than 750 million m^3 of water annually.

The presence of the long-distance network of main and interfarm irrigation channels installed in the earthen channel causes heavy losses of water during its transport for filtration and evaporation, which reach 35–37% of the total intake. Evaluation of the qualitative indices of surface water resources makes it possible to reveal the following peculiarities. Depending on precipitation dropped out, the local spring flood runoff along minor rivers and beams can alter the chemical composition from the hydrocarbonate-calcium-magnesium to the sulfate-magnesium-sodium one at a low level of mineralization of up to 0.43 g/L and a slightly acidic level of activity (pH 7.2).

When a runoff is accumulated in reservoirs, its qualitative indices are deteriorated: the chemical composition changes for the chloride-sulfate-sodium and chloride-sodium one, and the level of water mineralization may significantly vary during the season (depending on flood volumes), reaching more than 6.0 g/L with timely increase in pH up to 8.3 (weakly alkaline reaction).

The waters of large reclamation systems have different characteristics. In the Sarshinsk IWDS, irrigation waters arriving from the Volga River at a total low level of mineralization of up to 0.7 g/L can have different chemical compositions from the hydrocarbonate-calcium to the sulfate-calcium-sodium one (pH 8.0–8.3). The draining waste runoff during rice flooding is nonsaline (the level of mineralization is 0.6–1.7 g/L) with chloride-sodium chemical composition, and the content of salts increases up to 6.0 g/L during the nonvegetation period, again with the prevalence of chloride, sulfate, and sodium ions. The pH varies from 7.9 to 8.4. Irrigation and draining wastewaters in the Chernozemel'sk IWDS with water fed from the Terek and Kuma rivers have approximately the same level of mineralization from 1.2 to 1.8 g/L (sulfate-chloride and chloride-sulfate and sodium chemical activity) and weakly alkaline reaction (pH 7.8–8.2). In the Pravo-Egorlyksk IWDS, water supplied from the basin

of the Kuban River has mineralization of up to 0.6 g/L with different chemical compositions (from the hydrocarbonate-calcium to the sulfate-calcium-magnesium one) and neutral reaction (pH 7.5). The draining wastewater has the worst quality, with mineralization of up to 3 g/L, chemical composition from the hydrocarbonate-sulfate-magnesium-calcium to the sulfate-sodium-magnesium one, and neutral pH. The irrigation waters of the Caspian IWDS that arrive from the lower reaches of the Volga River have favorable indices, with the content of salts of not more than 0.5 g/L, hydrocarbonate-calcium composition, and neutral reaction.

Within the area of the republic, there is a wide range of large and small water bodies accumulating mixed waters, i.e., wastes from irrigation systems, the local surface runoff, and sea waters. Their mineralization and chemical composition have different values. Lake Sarpa, which is a water intake of draining wastewaters from the rice irrigation systems of the Sarpinsk lowland, have large volumes (up to 200 million m^3) and an increased level of water mineralization. Depending on the volumes of waste (which may vary from 10 to 30 million m^3), the content of salts varies from 7.5 to 15 g/L in the case of chloride-sodium chemical activity and neutral activity (the pH is less than 8.0). Lake Manych-Gudilo also has very large volumes (over 2500 million m^3) and is replenished through waste from irrigation/water distribution systems of Stavropol krai and the local surface runoff. The water quality is poor, with mineralization varying from 10.5 to 45.2 g/L and having chloride-sodium chemical activity. Lake Bolshoe Yashaltinskoe fed by the waters of the local flood runoff from the slopes of the Stavropol highland has hyperhigh water mineralization exceeding 190 g/L and chloride-sodium activity. Reservoirs on the coast of the Caspian Sea, that are fed from two sources, namely, the channels of the Caspian IWDS and sea waters, and have water mineralization of up to 0.7 g/L and chloride-sulfate-sodium-calcium chemical activity. The waters of the Caspian Sea, which are mineralized in its northwestern part by the Volga River runoff, have mineralization of up to 1.5 g/L and chloride-sodium chemical activity in the coastal strip.

For the period of up to 2020, a strategy has been developed for developing the water utilization system of the agro-industrial complex of Kalmykia, which is based on the principles of ecosystem water use that provide for maintaining the functional and structural integrity, as well as the environmental safety of catchment basins, landscapes, and aquatic ecosystems [7–9] and has objectives to provide the rural population with stable drinking-water of normative quality and develop agricultural water supply; increase the efficiency of utilization of underground, sea, and mineralized waters; recover and develop land irrigation and increase the volumes of agricultural products produced in these lands; reduce and prevent negative impact on water objects; completely prohibit the discharge of polluted waste and collector and drainage waters and livestock waste into water objects; create and develop new technologies for water- and energy saving, water treatment, and waste and collector-draining water treatment; establish closed water-consumption systems; secure safety of hydraulic engineering structures; etc.

This program provides for the sequential execution of a broad range of measures. To increase water supply in the northern part of the republic (the area of the operation of Sarpinsk and Kalmyk-Astrakhan IWDSs), it is planned to reconstruct large irrigation channels (R-1, VR-1, etc.) and base pumping stations using federal funds. It is also prospective to finish the construction of the Kalmyk main chain and increase its total length up to 89.8 km (at the present time, only 19.7 km have been built). This will make it possible to additionally irrigate 90000 ha of lands with the financial requirement of more than 780 million rubles.

An urgent (very acute) problem in this region is the necessity to regulate financial issues associated with the mechanical water intake from the Volga River. The zone of rice growing for market that is established here (the planting area exceeds 5000 ha) and the vast area of irrigation of the territory require large quantities of water, reaching almost 260 million m^3. However, one constantly has problems with payment of energy costs during the operation of base pumping stations. Therefore, the volumes of supplied water annually decrease, which leads to a significant reduction of regularly irrigated and flood irrigation lands.

In the central part of the republic (the zone of the Chernozemel'sk IWDS), the main water source is the Chograisk Reservoir fed by the flood waters of the Terek and Kuma rivers. However, at the present time, it is significantly silted and the displacement does not exceed 390 million m^3. The water mineralization is 1.2–1.5 g/L. Large-scale works on reconstructing the dam of the Chernozemel'sk Reservoir and main channels are being carried out within the federal target programs. A construction of the Elistinsk Reservoir with available storage of 40–60 million m^3 is being carried out to meet water supply and irrigation needs. All these measures will make it possible to reclaim regularly irrigated areas to the level of 22000–24000 ha and expand flood irrigation lands to the area of 25000–28000 ha. In the west of the republic (the zone of the Pravo-Egorlyksk IWDS), it is also urgent to reconstruct distribution irrigation networks and sites, which will make it possible to recover regular irrigation in the area of not less than 6000 ha. The south of the region where the Caspian IWDS is located requires the reconstruction of irrigation systems fed from the Bakhtemir River and the development of irrigation based on the Caspian Sea waters mineralized at the level of not more than 3 g/L and water supplied deep into the territory through channels and pipelines.

An important issue is to enhance the efficiency of using large reservoirs fed by the IWDS fresh waters and the local runoff (with the total of more than 20 reservoirs and accumulated water volumes reaching 300 million m^3) based on the combination of different water utilization schemes, such as irrigation, water supply, watering, and fish breeding.

Lakes located in the west of the republic in the Manych Depression (Manych-Gudalo, Bol'shoe and Maloe Yashaltinskoe, Lysy Liman, etc.) have a very high degree of water mineralization and are not suitable for agricultural use. In hypersaline lakes, it is possible to extract salt and grow populations of fairy shrimp crustaceans as fishfood. The ecological situation may significantly change in the case of possible construction of the Eurasia navigation canal that will connect the Caspian and Black seas and provide the supply of desalinated waters from the northwestern Caspian Sea to this region. The chains of Sarpinsk and Sostinsk lakes that are situated in the eastern and southeastern parts of the republic and are currently fed by only a very small layer of the surface runoff have an increased water mineralization from 3 to 100 g/L.

A new concept for developing the water system of Kalmykia has been proposed, according to which it will be possible to annually improve the hydrological situation by gravity feeding fresh flood water from the Don or Volga rivers through the system of channels with the total length of more than 700 km, that connects all lakes and has a discharge into the Caspian Sea. Based on washing, all lakes will be filled with fresh water (the total volume is not more than 450 million m^3) and will then be used for various needs. However, the implementation of this project requires great financial costs. Therefore, all efforts should be made to optimize the utilization of available resources, in particular, for developing and implementing the multipurpose Ergeninsk highland water-resources scheme that makes it possible to more rationally locate water bodies (ponds and reservoirs) in its area and provide the reclamation of flood irrigation lands in the Near-Ergeninsk zone (not less than 10000–15000 ha) based on the local surface runoff that were previously withdrawn from use and transferred to dry hayfields due to water deficiency.

An important role in the water supply is also played by underground waters. Twenty-one deposits have been explored within the area of the region, which have water mineralization of up to 3 g/L and prospective reserves of 490000–760000 m^3 per day. Water reserves with mineralization from 3 to 10 g/L are almost 900000 m^3/day, with the annual intake of underground waters being steadily low (only 13.1–13.8 million m^3) [4, 5]. At the present time, a republican target program "Clean Water" is being implemented, which makes it possible to provide many rural localities with water. A construction of the Iki-Burul'sk water main from the Levokumsk underground water deposit is being finished, which will provide drinking water for two districts of Stavropol krai, as well as the Iki-Burul'sk and Priyutnensk districts and the city of Elistu in Kalmykia. It is also planned to construct special artificial groundwater recharge complexes in the Ergeninsk highland, based on a surface runoff, particularly in the Verkhne-Yashkul'sk and Bayartinsk deposits providing the city of Elistu with water. In the eastern and southern regions, the great role in irrigating pastures is played by artesian wells and shaft wells. Their number is planned to be increased in the near future; however, for this purpose, special measures on improving the water quality are required, including the application of desalination plants.

The total area of natural forage lands in Kalmykia exceeds 4 million ha; among them not more than 40% are provided with water supply. It is planned to irrigate 3.9 million ha of pastures in the near future. For this purpose, it will be necessary to annually use not less than 32 million m^3 of water from surface and underground sources.

Because the qualitative indices of water from different sources in the republic are significantly different for different years and seasons, it has become necessary to create a system of regional and local monitoring for water resources based on present-day GIS-technologies and remote sensing methods. Relevant developments are available. Electronic maps (water map and water resources map) for the Republic of Kalmykia have been created at a scale of 1 : 200000, and databases are being formed [4, 10]. Under the conditions of water resource deficiency, it is also important to develop and implement zonal water-saving technologies, i.e., differential irrigation regimes with the use of small-volume irrigation methods (drip, aerosol, and other irrigation methods) and modern irrigation installations (Kuban', Bower, etc.) for growing no-water-needed rice sorts with periodic irrigations, as well as for cultivating a wide range of companion crops using moisture reserves that have remained after rice, implementing crops reclaiming degraded lands and flood irrigation technologies, etc. The domestic experience [11, 12] has shown a high irrigation efficiency of waters with increased content of salts (5–8 g/L) and sea waters (with mineralization of up to 20 g/L) in cultivating feed crops and halophyte plants. This trend should be extensively developed in the republic.

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