Efficient use of water resources to increase agricultural production of rice

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Abstract. The construction of the Krasnodar reservoir has significantly increased the volume of replenished reserves of pressure underground water, which contributes to improving the efficiency of the use of water resources in the Kuban River basin. Relevance in improving the efficiency of water resources in the basin of the river Kuban to develop new solutions to the agricultural production of rice ensures the quality of products and crop stability. The problem of water quality is very acute. In the Kuban River basin, the annual runoff is subject to vertical zoning, and there is a regular decrease in the annual runoff modulus with a decrease in the average height of the catchment area and along the length of the watercourse. The most effective control is the construction of treatment facilities and the biological method of control in areas of reservoirs with low water exchange. Phosphates are pollutants of artificial origin. The content of phosphates in the reservoir on average exceeds the MPC 1.5-2.0 times. The analysis of available data on bacteriological and parasitological studies gives an idea of the current state of water resources. The results of laboratory tests showed that no parasitological contamination of the water was detected. Bacteriological contamination is present in all parts of the reservoir. The main type of contamination is the excess content of coliform bacteria.

1. Introduction

The construction of the Krasnodar reservoir has significantly increased the volume of replenished reserves of pressure underground water, which contributes to improving the efficiency of the use of water resources in the Kuban River basin.

Before the construction of the Krasnodar reservoir in natural conditions, the discharge of underground water was carried out in the Kuban river; the direction of the flow of underground water was south-west with a slope of 0.0018. After the construction of the reservoir, the dynamics of underground water movement is determined by numerous artificial and natural factors: water levels in the reservoir; flow rate and water levels in drains; irrigation of land; water losses from irrigation channels; discharge into the Kuban river west of the earthen dam; the amount of water turnover from pressure aquifers; the amount of precipitation, humidity and air temperature. The general direction of the movement of underground water is now western and north-western, complicated in local areas by the action of the above factors.
According to hydrogeological calculations of the Volgograd Institute of Civil Engineering [1], the drainage curtain that was subsequently sharpened along the right bank, with simultaneous clearing and deepening of the Karasun gully, was supposed to prevent flooding of the land throughout the second over-floodplain terrace. We used high values of the formal parameters of soils and the influence of irrigation, losses from irrigation canals were not taken into account; therefore, continuous drainage curtain flooding of land here after the construction of the reservoir was observed in large areas. It was necessary to build additional drains: horizontal along the airport runway; combined along the Karasun gully and the main irrigation canal of the Prigorodnaya settlement; horizontal in 0.8 km east of the irrigation canal. In general, now the depth of underground water in the territory of the second above-floodplain terrace depends mainly on the efficiency of the drains, to a lesser extent on the water levels in the reservoir and meteorological factors [2].

The depth of underground water varies from 1.5 to 8.6 m. The maximum depth is observed in the western part of the characterized territory, and the minimum – in the eastern part, so the part of the territory of the village Lenin remains flooded at the present time [3].

The problem of water quality is very acute. In the Kuban River basin, the annual runoff is subject to vertical zoning, and there is a regular decrease in the annual runoff modulus with a decrease in the average height of the catchment area and along the length of the watercourse. The most effective control is the construction of treatment facilities and the biological method of control in areas of reservoirs with low water exchange. Phosphates are pollutants of artificial origin. The content of phosphates in the reservoir on average exceeds the MPC 1.5-2.0 times.

The object of the study is the Krasnodar Reservoir, since it has significantly increased the volume of replenished reserves of pressurized groundwater, which contributes to an increase in the efficiency of the use of water resources of the river basin. Kuban. The general direction of movement of groundwater is now western and north-western, complicated at local sites by the action of the above factors.

The subject of the research is the analysis of available data on bacteriological and parasitological research, which gives an idea of the current state of water resources. The results of laboratory tests showed that no parasitological contamination of the water was detected. Bacteriological pollution is present in all parts of the reservoir. The main type of pollution is the excess of coliform bacteria.

The scientific novelty of the research lies in the development of guidelines for improving the main methods of struggle - saturation of water with oxygen (aeration), increasing the flow of biological and chemical treatment. Their content in water exceeds the permissible values from 3 to 16 times. Bacteriological pollution is mainly formed due to the runoff of large rivers flowing into the reservoir, since there is no concentration of sewage discharges into the reservoir bowl. The quality of water resources in terms of hydrochemical, bacteriological and parasitological indicators did not undergo serious negative changes after the reduction of the NRL by 90 cm. The exception is water pollution by organic compounds formed in the basin of the reservoir. The main methods of control - saturation of water with oxygen (aeration), increasing of the flow rate of biological and chemical purification.

2. Materials and methods

The aim of the work is to increase the efficiency of the use of water resources in the Kuban River basin, for the development of new solutions for agricultural rice production, which ensures an increase in the quality of the products obtained and the stability of the harvest. The problem of the quality of water resources is very acute. In the river basin In the Kuban, the value of the annual runoff is subordinated to vertical zoning; a regular decrease in the module of the annual runoff is observed with a decrease in the average height of the catchment area and along the length of the watercourse.

In the Kuban river basin, the annual runoff is subject to vertical zoning. There is a regular decrease in the annual flow modulus with a decrease in the average height of the catchment area and along the length of the watercourse. When designing the Krasnodar reservoir on the right bank, overestimated values of filtration parameters were taken. This was established in the course of experimental pumping from vertical drainage wells performed in 1998 [4]. The calculated value of the filtration coefficient of
alluvial clays is 0.005 m/day, and its average value for a layer of sand, gravel, and pebbles is 20 m/day. The value of the filtration coefficient of loess-like loams was determined during surveys on the Prigorodnaya settlement after the construction of the Krasnodar reservoir. Previously, loess-like loams were taken as a weakly permeable layer and combined with the underlying alluvial clays. The values of the filtration coefficient of loess loams vary from 1 to 5 m/day, and the calculated value is 3 m/day.

The filtration coefficients of alluvial sands, gravel, and pebbles were determined at the design stage of the reservoir and subsequently during studies for the reconstruction of its structures. The structure of a non-pressure aquifer is layered, but everywhere it can be represented as a three-layer scheme: a well-permeable layer of loess-like loam at the top and sand, gravel and pebbles at the bottom; a weakly permeable layer of clay in the center. The unpressurized aquifer is confined to the thickness of the quaternary sediments. A layer of upper Pliocene clays with a thickness of up to 20 m with a filtration coefficient of 0.001-0.0005 m/day serves as a conditional water barrier for it [5, 6].

The filtration properties of the soils were determined at the previous stages of the research using single and cluster pumping from wells. Summarizing the results of previous studies [7] and for the calculated values of the soil filtration coefficient (Fc), the following values are taken: semi-solid clay and loam -2.3-0.05 m/day; semi-solid sandy loam -4.0.5 m/day; semi-solid fine sand – 5 – 12 m/day; semi-solid medium-sized sand – 6-22 m/day; semi-solid large sand – 7 – 27 m/day; gravel soil - 35 m/day. The coefficient of total water capacity (Km) of ground water varies from 50 to 250 m²/day, and the coefficient of level conductivity (a), with active water release of cover clays and loams = 5% – from 1000 to 5000 m²/day [8].

Part of the protected area of the high floodplain of the Psekups river in natural conditions was periodically flooded with surface water and was swampy. Currently, the reclamation condition of this territory depends primarily on the operation of pumping stations 5 "d" and 7 "d", pumping surface runoff and drainage water from the protected area in the Psekups river valley, as well as on the technical condition of drainage structures [9]. The Psekups and the Krasnodar reservoir are the feeding boundaries for ground water most of the year. Additional nutrition of ground water is obtained due to the infiltration of atmospheric precipitation and man-made waters and due to the lateral inflow from the above-floodplain terraces [10].

The territory of the high floodplain is almost drainless, so most of the precipitation goes to the water saturation of the rocks of the aeration zone and the nutrition of groundwater. At the end of the cold period of the year (February-March), most of the atmospheric precipitation is spent on feeding ground water; during this period, the amount of infiltration feeding of ground water can reach 1.5 mm/day. The discharge of ground water is carried out in drains and due to evaporation from their free surface and transpiration during the warm season. It should be noted that it is also typical of other periods of the year, since its determining factor is the work of drains along the protective dam and embankments. The general direction of groundwater movement is directed from the above-floodplain terraces to the drains; the flow slopes vary from 0.0007 to 0.002 [11].

The depth of the ground water is constantly changing from 1.0 to 4.0 m. The level regime of ground water in the near-embankment and near-dam territory in a strip up to 200 m wide is hydrological, depending on the water levels in the reservoir, in drainage channels and in vertical drainage wells. The amplitude of the level fluctuation here does not exceed 1 m.

In the rest of the territory, the ground water regime is mixed with the predominance of climatic factors (precipitation, air temperature, humidity) and less influence of water levels in the open channels of the rice system and the Dysh river [12]. The high position of the ground water level here is observed in February-March, and low in October-December. The amplitude of the level fluctuation here changes as you move away from the channels from 1.5 to 3.0 m. In February – March, 30% of the territory here has a depth of ground water not exceeding 1.0 m, and 90 % - 2 m [13].

Rice sowing in the area of the Psekups river valley has not been carried out for about 20 years. Many discharge channels are silted up, overgrown, and their draining effect deteriorates.
3. Results
The supply of the Kuban river is mixed: the share of rain nutrition is 38% of the annual runoff, ground – 36%, glacial – 24%, snow – 2%. According to the flow regime, the Kuban river is a mountain river. The runoff is characterized by significant seasonal unevenness and a large amplitude of changes in the flow rates. In the area of the Krasnodar reservoir, the average river slopes are about 0.1 %, the flow rate in high water is 1.0-1.5 m/s, in low water 0.4 – 0.6 m/s [14].

In natural conditions, the Kuban river is characterized by spring-summer high water and autumn-winter low water. The average amplitude of fluctuation of levels for a year on the Kuban river in natural conditions was 4-4.5 m. The flow of the Kuban river is largely distorted by water management measures. The average restored annual flow in the line of the Krasnodar reservoir per year is 50 % of the security – 13.7 km$^3$.

The average long-term flow rate of the Kuban river near Krasnodar (for the period 1911-2016) is 437 m$^3$/s. At the reservoir site, 4 left-bank tributaries flowed into the Kuban river: Laba, Belaya, Pshish and Psekups; the mouths of three of them are currently flooded and they flow into the reservoir. The main hydrological characteristics of the Kuban river in the formation of the reservoir dam are shown in Table 1.

| Area of the catchment basin to the section of the dam, km$^2$ | Nature of the watercourse supply | Characteristics | Water flow of the security, Qm$^3$/s |
|---------------------------------------------------------------|---------------------------------|-----------------|-----------------------------------|
| 45900                                                         | mixed: rain, glacial, snow, ground | W mln.m$^3$     | 15500 13700 12100 9930           |
|                                                              |                                 | Qm$^3$/s        | 491 434 383 315                   |

The average duration of the spring-summer flood is 215 days. In the spring-summer, flood passes up to 60-70 % of the annual runoff of the Kuban river.

The greatest winter snow-rain floods are observed most often in February – March. The average duration of the flood is 22 days. Often, the decline of one flood is superimposed on the rise of the next. The maximum average daily recovered water consumption for the previous period reached 2010 m$^3$/s – 2300 m$^3$/s [15].

The maximum water consumption in the unregulated mode in Krasnodar exceeded 2000 m$^3$/s 1 time in 15-20 years; 1500 m$^3$/s – 1 time in 5 years; 1000 m$^3$/s – almost annually, in many years – several times.

The Kuban river above the Krasnodar reservoir and the Laba river are characterized by a steady winter low water. In the lower reaches of the Belaya river, the low water level is observed in the autumn-winter period and is often interrupted by rain and snow floods. The duration of individual low-water periods is 15-20 days [16].

The Pshish and Psekups rivers are characterized by a summer-autumn low-water mark. Thus, the minimum inflow to the reservoir is observed in the autumn-winter period. The minimum average monthly water consumption is observed mainly in January-February. However, over the past 30 years, due to warm winters, the minimum average monthly water consumption in the Kuban river is increasingly observed in November.

Water resources are used for water supply of the population, agricultural and industrial enterprises. Water intakes taken into account in the water balance of the reservoir are located on the Kuban river in the lower reaches. The water resources of the Krasnodar reservoir are taken for irrigation directly from the reservoir, as well as from the Kuban river and the Protoka river in the lower reaches of the reservoir.

The volume and mode of water consumption of rice irrigation systems, subject to the Krasnodar reservoir, are calculated in accordance with irrigation standards with 50% rice content in the crop
rotation, adopted in the "Scheme of integrated use and protection of water bodies of the Kuban river basin", developed by the OJSC "Kubanvodproekt" [17]. The calculated values of soil filtration parameters are presented in Table 2.

**Table 2. Calculated values of soil filtration parameters**

| Name of the soil | Filtration rate, m/day (Extreme values) | Characteristics Water efficiency, о/o |
|------------------|----------------------------------------|-------------------------------------|
| Bulk materials \( t_{Q_{iv}} \) | | |
| Clay and loams: | 0.0005 (0.001 – 0.0001) 1 | |
| a) compacted in the frame of the dam | 0.15 3 | |
| b) not sealed in the cavities between the gateway and the spillway | | |
| Sandy leems | 0.4 8 | |
| Fine and medium-sized sands | | |
| a) spillway and dam | 8.8 16 | |
| b) gateway | 3.7 14 | |
| Large and gravelly sands | 27 19 | |
| Alluvial soils \( t_{Q_{iv}} \) | | |
| Fine and medium-sized sands in the cavities of the gateway and spillway | 3.5 14 | |
| a) in the horizontal direction | | |
| b) in the vertical position | 0.35 - | |
| Fine and medium-sized sands in the frame of | 8.8 16 | |
| Alluvial quaternary deposits \( a_{Q_{IV}} \) | | |
| Clay and loams | 0.005 (0.18-0.0005) 3 | |
| Sandy leems | 0.5 8 | |
| Dusty sands | 3 13 | |
| Fine sands | 12 16 | |
| Medium-sized sands | 22 18 | |
| Large and gravelly sands | 27 19 | |
| Gravel-pebble soil | 35 19.5 | |
| Aeolian-deluvial quaternary deposits \( v_{dQ} \) | | |
| Loess-like, macroporous loams | 2 8 | |

The highest excess of MPC is observed for copper, the copper content on average exceeds the MPC 3-5 times. Copper pollution is of a natural type and is not associated with economic activity, the MPC for iron is on average exceeded 1.5-2.0 times [18]. Significant excess of the MPC for iron was observed in the basin of the former Tschik reservoir, which is associated with the low flow rate.

The excess of the MPC for the content of manganese has been observed in the last 5-10 years. Water pollution from phenols remained largely unchanged between 1990 and 2016. The content of phenols exceeds the MPC 1.5-2.0 times [19]. The reason for the contamination with phenols is the discharge of untreated industrial effluents into water bodies.

The pollution of the reservoir with sulfates is insignificant and is 1.1-1.2 MPC on average for the entire observation period (1990-2016). However, these compounds of sulfuric acid salts are the main nutrition element for algae and moisture-loving vegetation.

4. Conclusion
The most effective control is the construction of treatment facilities and the biological method of control in areas of reservoirs with low water exchange. Phosphates are pollutants of artificial origin.
The content of phosphates in the reservoir on average exceeds the MPC 1.5-2.0 times. The analysis of available data on bacteriological and parasitological studies gives an idea of the current state of water resources.

The results of laboratory tests showed that no parasitological contamination of the water was detected. Bacteriological contamination is present in all parts of the reservoir. The main type of contamination is the excess content of coliform bacteria. Their content in water exceeds the permissible values from 3 to 16 times. Bacteriological pollution is mainly formed due to the runoff of large rivers flowing into the reservoir, since there is no concentration of sewage discharges into the reservoir basin.

The quality of water resources in terms of hydrochemical, bacteriological and parasitological indicators did not undergo serious negative changes after the reduction of the NRL by 90 cm. The exception is water pollution by organic compounds formed in the basin of the reservoir. The main methods of control is the saturation of water with oxygen (aeration), increasing the flow rate of biological and chemical purification.

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