Change of hydrochemical and hydrobiological regimes of water reservoir

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Abstract. Particular attention in connection with the rational use of water resources is given to constructing reservoirs, studying their hydrobiological regime, and ensuring their reliable operation. This article evaluates reservoirs' hydrochemical and hydrobiological regimes and suggests preventing water degradation. The study was conducted on the case of the Shurtan reservoir in the northern part of the Kashkadarya region. The experiment's results showed that the openness coefficient of the Shurtan reservoir was equal to K=0.29, and since this indicator was less than 1 (K=0.29<1), the level of openness of the reservoir surface was considered low. Noteworthy, the influence of the landscape on the processes in the water reservoir was estimated based on the relative water discharge coefficient (Kwdc). In the case of the Shurtan reservoir, the coefficient of specific water discharge was Krwd= 5.99. Since this indicator was less than 10 (Krwd=5.99 < 10), the reservoir was included among water bodies with small specific water discharge Hydrobiological and morphometric indicators affecting the hydrochemical and hydrobiological regime of the reservoir have been determined. According to the change in the hydrochemical regime of the reservoir, the length of the Shortan reservoir bowl is Kel=2.62, and the water exchange coefficient in it is equal to 0.93 years, so the reservoir belongs to the II class. According to the data from 2007, 0.386 km^2 of the reservoir basin was covered with algae; by 2021, this indicator was 0.677 km^2.

1 Introduction

Rational use of water resources in the world, improvement of methods for increasing hydrological efficiency of reservoirs, and development of methods for forecasting hydrological processes in them are important issues. In this connection, the improvement of the operational reliability of water management structures and reservoirs and the improvement of methods for calculating their useful volume are of particular importance. Efficient use of water resources is carried out by constructing reservoirs of different shapes

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and purposes, designed to collect water during flood periods in river and irrigation systems. In this connection, special attention is paid to the construction of water reservoirs, a study of their hydrobiological regime, and the provision of their reliable operation.

The lack of attention to hydrobiological and ecological factors during the operation of water reservoirs, anthropogenic influences on the rivers considered as water sources, and the slowing down of the water exchange processes in the water reservoir are causing the deterioration of water quality; the resulting deficiencies are causing a decrease in the reliability of water supply of water reservoirs, in particular, an increase in its mineralization.

A.M. Nikitin, N.E.Gorelkin, V.A.Nikolaenko, F.Khikmatov, V.E.Chub and many other scientists who conducted scientific research in these directions in the reservoirs of the Central Asian region, in their works focused on the reservoirs, hydrological regime, including hydrochemical and hydrobiological regimes, and paid attention to the peculiarities of their elements [1, 2, 3,4].

Researchers A. Orlova and O. In their research, Dunin-Barkovskaya analyzed the sources affecting the quality of river water resources for each small river and put forward their proposals for the organization of water protection zones for these rivers [5], R. Razakov and L. Yaroshenko conducted their research in the direction of developing engineering and biotechnical measures that improve the quality of water resources of small rivers [6], A. As part of Krutov's research, efforts were made to develop simulation models of water resources and their quality management in small rivers [7-8], O.A. Kayumov, F. Gapparov, and S. In the studies conducted by the Mamatovs, proposals were developed for evaluating the water mineralization level and the hydro-ecological conditions of the water reservoir to assess the ecological condition of the water reservoir [9 -11].

Hydrochemical observations aim to study the regularities of a water body's hydrochemical regime and determine the impact of various anthropogenic impacts (wastewater discharge, watershed reclamation, construction of hydraulic structures) on the natural hydrochemical regime. As part of these tasks, seasonal observations of water's physical and chemical properties are carried out.

For proper assessment of water quality, characterization of its chemical and biological state, and degree of pollution, at least two conditions are required: satisfactory analysis of a certain minimum of water samples from a particular water body and their representativeness [12]. Hydrobiological observations include studying the development of phytoplankton, zooplankton, macrophytes, periphyton, zoobenthos, and other groups of the aquatic population, as well as monitoring changes in biodiversity and getting an assessment of the trophic status of a water body. River observations occur at least thrice a year [13].

The mentioned cases justify the need to increase the reliability of seasonally managed water reservoirs in the specific conditions of Uzbekistan, considering hydrological and ecological factors, and confirm that conducting research in this direction is important for the country's economy. Therefore, this research aimed to evaluate the influence of hydrological and morphometric parameters of the reservoir on changes in the hydrochemical and hydrobiological regimes of the reservoirs.

2 Methods and Materials

2.1. Study area

The Shortan reservoir in the Kashkadarya region was taken as a research site. Shurtan reservoir has been used for more than 10 years. According to the data of observations during the use of the reservoir, the volume of water collected in the reservoir during the year is 7.8-10.9 million m3, and the absolute level varies between 420- 422 m. The design full volume of the Shurtan reservoir was 13.4 mln m^3 (Fig. 1).

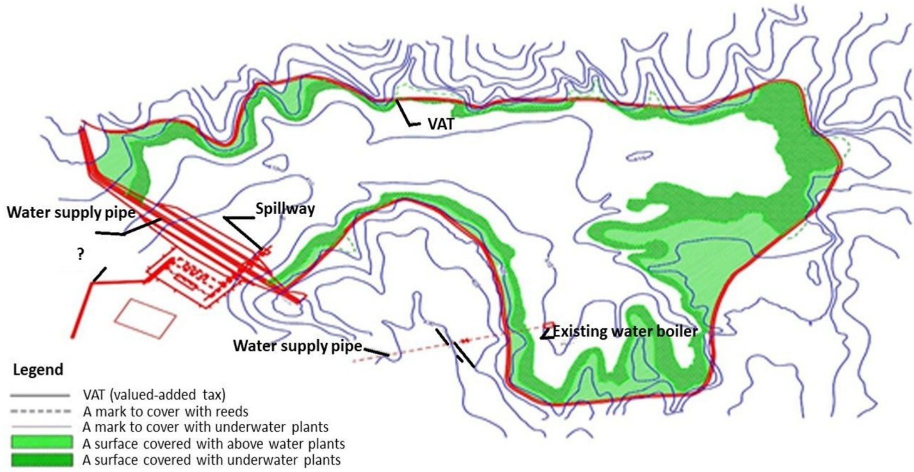

Fig.1. Vegetation status of Shortan reservoir.

The banks of the reservoir and the bottom of the banks are covered with various algae. If the shores of the reservoir are mainly covered with reeds and partially with reeds (Typha spp.), in the near-shore areas of the reservoir basin, algae such as Chara (Chara spp.) Vardest (Potamogeton) is strongly developed. Water and aquatic plants cover a distance of 10-15 meters to 100 meters, and they mainly grow at an absolute height of 418-422 m. Underwater grasses are widespread in the zone where the absolute level is below 418.5 m. Vegetated areas were mostly observed in the southern and southeastern parts of the reservoir basin, where the depth was shallow. Vegetation is less common in the northern part of the reservoir (Fig. 1).

2.2 Methods

Three small streams flow into the northern part of the reservoir. Water flow from the streams increases mainly during rain, especially when floods occur, and their water dries up during the dry summer and autumn periods. As evidenced by the data of the observations, a lot of vegetation remains, and silt are brought from these streams to the reservoir during floods. The hydrological and morphometric indicators of the reservoir serve as the basis for the analysis and prediction of the hydrochemical and hydrobiological regimes of the reservoir (Table 1). Accordingly, the following were calculated, such as S_{sdl} water surface area at standard damped level (SDL) of the reservoir, km^2, followed by S_{sh} the area of the reservoir which shallow than 2 meters, km^2, h_{dk} relative depth coefficient, K_{open} coefficient of openness, K_{rwd} relative water discharge coefficient, K_{el} - coefficient of elongation, $K_{in\ out}$ ratio of the amount of water flowing into the reservoir during the year to the volume of water in the reservoir. Clearly, its inverse magnitude ($1/K_{in\ out}$) shows how much of the year the water in the reservoir was completely replaced.

Furthermore, the highest values of water mineralization in the reservoir occurred before the river water was added, but it did not increase significantly. Furthermore, sampling took into account the specificity of the water body (morphology, hydrology, watershed character), all that determines the selection of sampling place and frequency, and the specificity of determined substances (dissolved, suspended, colloidal), i.e., all that determine finally physical, chemical and biological properties of water body [14].

In this study, the basic rule was to analyze samples as soon as possible after sampling. This was especially important when determining low concentrations of substances and when an error due to the adsorption of the substance on the container walls during storage can be quite large. Furthermore, the determination of pH in the waters under study was carried out using a universal ionometer EV-74, based on measuring the electromotive force of circuits composed of an indicator electrode and a reference electrode.

The method of determining bicarbonate ion (HCO_3) was based on the interaction of bicarbonates with hydrochloric acid (HCl) using the indicator methyl orange. The alkalinity was analyzed by the amount of acid consumed in the titration. Besides, calcium and magnesium ions (hardness) were determined by titrating the water sample with trilon B using chromogen black and fluorexone indicators. In determining the value of the total hardness of the test water is titrated with a solution of Trilon B with the indicator chromogen black until the transition of the red-violet coloring of the test water into the blue. A prerequisite for calculating the total hardness is determining the normality of Trilon B [15].

Determination of chlorine ions (Cl-) in the analysis of undyed and colored water was carried out by argentometric method using silver nitrate for titration, by the used volume of which the chlorine content. Nitrite ions (NO_2-) are a form of nitrogen compounds necessary for the life of terrestrial and aquatic organisms. The method is based on determining nitrite using Griess reagent, which colors the test water pink with different intensities depending on the concentration (NO_2). The calibration curve found nitrite content [16-17].

The methodology of hydrobiological research was mainly limited to recording the qualitative and quantitative composition of plants in water bodies, direct observation of the life of hydrobionts in natural or artificial conditions, and setting up an experiment.

Forms occurring frequently and in significant numbers are called dominant or leading; those of lesser importance are subdominant or characteristic; those occurring even more rarely are secondary and very rarely are incidental. The dominance index refers to the percentage of the number (weight) of all individuals of a given species to the number (weight) of individuals of all species in the sample. To establish the degree of generality of the species composition of organisms at the compared sites, the coefficient of species generality (K) is calculated according to the formula [18]:

$$K = C \cdot \frac{100}{D} \quad (1)$$

Where: C is number of common species, D is total number of species in the areas.

In addition, soil samples were washed through sieves with the right mesh, and organisms from the washed sample were selected, counted, and weighed [19].

3 Results and Discussion

It was reported that the relative depth coefficient of the reservoir (hr) allows to estimate the area of the shallow part of the basin. In the case of the Shurtan reservoir, the relative depth coefficient was hr=3.24, and this condition is considered at the standard level [3]. The impact of physical-geographical and climatic factors affecting the reservoir regime through the water surface on the water mass is estimated using the coefficient of openness of the reservoir surface. The experiment's results showed that the openness coefficient of the

Shurtan reservoir was equal to K=0.29, and since this indicator was less than 1 (K=0.29<1), the level of openness of the reservoir surface was considered low [10]. Noteworthy, the influence of the landscape on the processes in the water reservoir was estimated based on the relative water discharge coefficient (Kwdc). In the case of the Shurtan reservoir, the coefficient of specific water discharge was Krwd= 5.99. Since this indicator was less than 10 (Krwd=5.99 < 10), the reservoir was included among water bodies with small specific water discharge (Table 1).

Table 1. The main morphometric parameters of the Shortan reservoir

S_{mds},km^2	S_{sh}, km^2	h_r	K_{open}	K_{wdc}	K_{el}	$K_{in\ out}$, (in full volume)
2.17	0.67	3.24	0.29	5.99	2.62	1.08

Furthermore, the coefficient of elongation of the Shurtan reservoir was equal to Kel=2.62, and this indicator shows that the reservoir basin had a shape closer to a circle (in the form of lakes). In circular lakes, the mixing of water resources usually occurs completely. This condition prevents the occurrence of unpleasant hydrochemical conditions in the reservoir basin. The ratio of the amount of water flowing into the reservoir during the year to the volume of water in the reservoir shows the water exchange in the reservoir. In the case of the Shurtan reservoir, the inflow coefficient - Kin out = 1.08, which means that the water exchange in the reservoir is estimated at an average level. The reverse value of this indicator (1/Kin out) shows how much of the year the water in the reservoir is completely replaced. Thus, the water in the Shortan reservoir was completely renewed in 0.93 years or 11.3 months.

Furthermore, winds in the area play an important role in the exchange of water in the reservoir. In the area where Shurtan Reservoir is located, there are many easterly winds from September to May and northerly and north-westerly winds from June to August, with an average speed of 4.4 m/s. In some periods, the wind speed reaches 20-22 m/s. It was observed that the wind exchange of water occurred during the warm months of the year when the wind moved following the longitudinal profile of the reservoir. During the summer, wind-driven water exchange covers more of the shallow parts of the extended reservoir. During this period, the shallow part of the reservoir (depth 1-2 m, area 11-20%) was cloudy due to the mud rising from the bottom of the water.

The research experiments on reservoir water clarity were undertaken. Accordingly, due to the relative depth (hr) of Shortan Reservoir and the relative size of its shallow parts, the water clarity in the reservoir was lower than in the Tallimarjon Reservoir. Besides, clarity was 3-4 m in the deep part of the reservoir, whereas it was 0.5-1.0 m in the shallow parts. However, water clarity was especially reduced during the saturation period in the summer months. This situation serves to prevent the development of various algae and phytoplankton. Turbidity and biogenic elements were not increased in the front of the dam when the reservoir works in emergency mode. Because the turbidity moving from the southern part also decreased following the decrease in the water level.

Reservoir water temperature change: Due to the shape of the Shortan reservoir bowl, the temporary thermobar that occurred in the summer season limits the exchange of water between the northern deep part and the southern shallow part of the reservoir and limits the increase of biogenic elements and the growth of algae in the front of the dam, that is, it prevents them.

Dissolved oxygen in the reservoir water: In the area where the Shortan reservoir is located, the acceleration of the water exchange process under the strong influence of the wind factor prevents the formation of oxygen-free zones in the reservoir bowl and ensures an optimal hydrochemical regime in the reservoir.

Reservoir water mineralization and major ions content: Changes in the hydrochemical regime of reservoirs are usually classified by factors such as water mineralization and major ion changes, as well as water exchange in the reservoir basin and basin elongation. The length of the Shortan reservoir bowl was Kel=2.62, and its water exchange coefficient was equal to 0.93 years, so the reservoir belongs to the II class [20, 21].

Due to the constant outflow of water from the reservoir and the constant mixing of the water by the wind (in depth, length, and width), the mineralization of the water in the reservoir and the changes in the indicators of the main ions in its content will not be significant or will always be the same. An increase in water mineralization was observed in very small amounts near the surface and bottom parts of the water. Still, these changes exceeded the normative indicators established for water bodies used for drinking water purposes. The water quality indicators of the reservoir are shown in Table 2.

Table 2. The water quality indicators of the reservoir

Elements for analysis	Cl_3, mg/l	SO_4, mg/l	Ca, mg/l	Mg, mg/l	Na+K, mg/l	Hard Residue
Upstream	136.6	241.3	3.8	1.6	233	614.7
Exit from the reservoir	189.1	254.3	4.15	2.2	240	689.95

The experiments were undertaken on biogenic elements in reservoir water. It was observed that the number of biogenic elements in reservoir water determined the activity of biological processes in water and specific aspects of the hydrobiological regime. Nitrogen and phosphorus compounds in water form the basis of biogenic elements. Algae appear in reservoir water depending on the amount of phosphates in the water. The increase of algae in the water content caused the deterioration of water's physical and chemical properties and the creation of biological barriers. Deterioration of water quality is negatively affected by plankton, periphyton, and various types of grass growing in the water (macrophyte); that was, biological organisms and grasses die after completing their life cycle and cause secondary water pollution. Rain and flood waters can be shown as providing biogenic elements to the water reservoir. In cases the areas where this water flow formed are agricultural fields, industrial and residential areas, the introduction of biogenic elements into the water reservoir occurs more strongly.

The results of hydrobiological observations allowed to characterize the spatial distribution and identify trends in the long-term dynamics of the pollution level of water bodies and their ecological state to assess the results of environmental protection measures.

Hydrobiological observations included studying the development of phytoplankton, zooplankton, macrophytes, periphyton, zoobenthos, and other aquatic population groups. Surface water quality was assessed using a set of hydrobiological indicators (Pantle and Buccu probability index, Goodnight-Whitley index, biotic index), taking into account the ecological characteristics of both water bodies as a whole and their components.

Since the areas of water entering the Shortan reservoir are not very large (K=5.99), these areas are not used, and the amount of precipitation is not high (225 mm), the risk of biogenic elements entering with rainwater is not significant for the overall balance of the Shortan reservoir (<5 %). In such conditions, the simplest way to assess the risk of eutrophication of the reservoir is to determine the level of the available amount of biogenic elements compared to the permissible amount.

Noteworthy, the results of the calculations showed that the average annual amount of phosphates in the reservoir water was 0.0012 mg/l, and this indicator is much lower than the permissible amounts. Therefore, the condition of the Shortan reservoir can be assessed as ecologically reliable.

4 Conclusions

According to the results of the conducted research and fund data analysis, the hydrochemical and hydrobiological parameters of the water were within the limits of the standards set for the open basins where drinking water was stored. During the reservoir operation, the results of observing the changes in the cover of the reservoir bowl with algae over the years show that the areas covered with grass in the reservoir bowl were increasing year by year. For example, according to the data of 2007, 0.386 km^2 of the reservoir basin was covered with algae, and by 2021, this indicator was 0.677 km^2. The intensity of the eutrophication processes in the water basin may cause the number of biogenic elements to exceed and change the basin's water quality in the near future. To prevent the observed situation, it is required to reduce the number of algae in the reservoir and to implement measures to increase water exchange.

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