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Efficient use of reservoirs in Uzbekistan

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Abstract. The article offers an in-depth examination of water resources and reservoirs in Uzbekistan, emphasizing their importance for sustainable water management in the region. It presents comprehensive data on the current state of these reservoirs, categorizing them by type and highlighting the primary challenges they face regarding water resource utilization. Key issues such as siltation, overgrowing, and reduced useful volumes are discussed in detail, alongside the implications of these problems for the efficiency of water use. The article further explores the methodologies employed to assess sediment distribution within the reservoirs and the techniques used to quantify sedimentation volumes. By understanding these dynamics, stakeholders can better address the pressing issues affecting water availability and reservoir functionality. In conclusion, the article suggests practical strategies and innovative solutions to mitigate these challenges, aiming to promote more rational use of water resources and enhance the long-term viability of Uzbekistan's reservoirs in the face of environmental change.

1 Introduction

Reservoirs are a vital part of the infrastructure of many countries, including Uzbekistan. This article examines the state of reservoirs in Uzbekistan and discusses prospects and possible solutions for effective water management [1]. As is known, many reservoirs have been built for the purpose of rational use and regulation of water resources. In recent years, as a result of global climate change and periodic water shortages, certain problems have arisen in economic sectors.

The Republic of Uzbekistan is located in the Aral Sea basin, its main sources of water are the Amu Darya, Syr Darya and Zarafshan rivers, as well as inland rivers, sais and groundwater. The average long-term annual water flow of all sources of the Aral Sea basin is 116.2 billion cubic meters, of which more than 67.4 percent is formed in the Amu Darya basin, less than 32.6 percent - in the Syr Darya basin. The total reserve of groundwater is

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31.2 billion cubic meters, 47.2 percent of which falls in the Amu Darya basin, 52.8 percent - in the Syr Darya basin [2].

According to the schemes for the integrated use and protection of water resources in the Amu Darya and Syr Darya basins, the average long-term water intake limit for the Republic of Uzbekistan is 51 billion cubic meters, of which 10.2 billion (20%) is formed on the territory of the republic, 40.8 billion (80%) is formed on the territory of neighboring countries. [2]. The distribution of water resource use is as follows: agriculture – 90%, industry and energy – 5%, public utilities – 4%, fish farming – 1% [2]. The area of irrigated land in the republic is 4.3 million hectares, on average 90-91 percent of all water resources are used in agriculture.

Natural water resources are distributed unevenly throughout the year in our republic, and the rational use of water resources, the fight against floods and mudflows, and the development of industry and agriculture are of great importance. [3, 4].

Currently, reservoirs with a total volume of 19.93 billion m3 are used, including the total volume of reservoirs in the Syr Darya basin is 5.93 billion m^3, and the total volume of reservoirs in the Amu Darya basin is 14.0 billion m^3. [2, 4].

There are mainly two types of reservoirs: flood reservoirs and channel reservoirs [5].

Since the territory of our republic is geographically diverse, the reservoirs are also geographically different [6, 7]: reservoirs in mountainous areas, reservoirs in foothill areas, reservoirs on plains and in lowlands (Figure 1).

Fig. 1. Main reservoirs of the Republic of Uzbekistan.

The total depth of reservoirs belonging to the group of reservoirs located in mountainous areas is up to 200 m, and the greatest depth of reservoir emptying during the reservoir operation is up to 100 m. Even when such reservoirs are emptied less, the water level changes sharply, but the surface area of the water does not change significantly. Reservoirs belonging to the third group have a normal backwater level (NBL) above 1200 m. The accumulation of sediment in reservoirs located in mountainous areas is the main reason for the increase in the volume of river runoff during floods, which are usually caused by precipitation, as well as erosion. Examples of a group of reservoirs located in mountainous areas are Akhangaran, Charvak, Tupalang and Hisarak. [8, 9]. Rational use of the reservoir is associated with many factors [10, 11]. The main problems are: Lack of water resources. Uzbekistan faces an acute problem of water shortage, which seriously limits the possibilities of agriculture and daily water consumption by the population. Water shortage has a negative impact on the economy and social well-being of the country [12]; Uneven distribution of water. Many rivers flowing through the territory of Uzbekistan are of an international nature, which leads to difficulties in sharing water with neighboring countries. This problem requires careful international cooperation to find sustainable solutions; Water losses due to evaporation. After the construction of a reservoir, an additional area covered by water is formed, therefore, additional water losses due to evaporation occur, since evaporation from the water surface is significantly higher than from the land surface. The larger the surface area of the reservoir, the higher the water losses due to evaporation. Due to the overgrowing of reservoirs, additional evaporation occurs; Siltation of the reservoir. Most of the existing large reservoirs in the territory of the Republic of Uzbekistan were built and commissioned in the 20th century. Over the years, under the influence of certain changes, natural and anthropogenic factors, reservoirs become silted up, which leads to changes in morphometric indicators and changes in the hydrobiological regime [13, 14].

The consequence of which is a decrease in the useful volume, an increase in water losses due to evaporation, filtration, etc., as well as a deterioration in the ecological state of the region.

The main reasons for the filling of the useful volume of reservoirs with sediments are as follows: the formation of reservoir banks under the influence of water, sediments brought by the flow of rivers, canals, sediments brought by the flow of mudflows.

In the mountainous and hilly regions of our republic, the category of turbulent flows includes mudflows and floods caused by atmospheric precipitation. Therefore, with each observed mudflow, a large amount of sediment flows down and causes siltation of the useful volume of reservoirs. A sharp decrease in the useful volume negatively affects the normal and reliable operation of reservoirs [15].

Siltation of a reservoir is a loss of water volume caused by an increase in the absolute mark of the bottom. The influx of suspended sediments into the catchment area, wind transfer of sand from land, sediments of chemical compounds, biomass of aquatic vegetation, wave coastal erosion and other factors lead to siltation of reservoirs. boundary - these are the reasons. Siltation of a reservoir is a complex process [13].

The main method recommended for combating siltation is flushing sediments with water discharged from the reservoir. However, the current situation with water resources does not allow these measures to be taken, since, due to a decrease in the water content of rivers, reservoirs are often not completely filled. It is common practice to leave the reservoir without water for the winter if there is no need for it. This is not done during the growing season and in the presence of higher aquatic vegetation (reeds, cane, etc.), growing over the area of the water area with a water depth of less than 1.5 m [16].

For each specific reservoir, methods for combating siltation are selected based on local conditions and on the basis of a technical and economic justification. The referenced literature outlines the process of siltation caused by sediments in water bodies across various terrains worldwide, highlighting the primary contributing factors. It includes calculations of the relationship between the speed of sediment layer transport (particularly bottom sediments) and water flow. Einstein formulated the relationship between the inflow of turbid sediment particles from the channel bottom and sediment consumption as follows. The most effective works for removal of deposited sediments are reservoir flushing: shallow, deep, with regulation of turbidity of flushing flow. The choice of flushing method is determined by technical and economic analysis, capabilities of the power system, requirements of water users and other local factors. However, they become insufficient and new approaches are required [17]. On the other hand, as studies of recent years show, almost all reservoirs have lost their useful capacity due to siltation.

2 Materials and methods

As is known, the equation of water balance of a reservoir is written in general form:

$$\sum K - \sum Ч \pm A \pm D = 0, \quad (1)$$

where: $\sum K$ - the amount of water entering the reservoir, $\sum Ч$ - amount of water leaving a reservoir, A - accumulation; Д – sediment.

At different stages of construction and operation of the reservoir, the interaction of individual elements of water exchange may differ. During the period of filling the reservoir with water, the elements of water exchange change more intensively due to the increase in its volume and surface area. During the operation of the reservoir, a fairly strong correlation is formed between the elements of the hydrological cycle, which is characteristic of different reservoirs [4]. It should be noted that during this period, the elements of the water balance change significantly.

One of the factors affecting the useful volume of a reservoir is siltation. When the reservoir volume is filled with sediment, the technical characteristics of the reservoir deteriorate, large sedimentary silts enter irrigation canals and culverts, and the efficiency of reservoir management decreases. The above and other difficulties necessitate sedimentation forecasting, which negatively affects the technical condition and economic indicators of reservoirs [10, 18].

The results of scientific studies conducted in the field show that existing methods for assessing reservoir siltation do not always reflect the volume of siltation.

Rational regulation of the amount of sediment in reservoirs is of great practical and theoretical importance. On the one hand, this will serve to improve the determination of the volume of siltation of reservoirs, and on the other hand, the use of river sediments as a useful resource, as finely dispersed sediment particles rich in minerals as a fertilizer [14].

Based on the works [13, 14], we will consider the calculation of sedimentation of sediment particles in a reservoir. We write the equation for the change in the kinetic energy of turbidity in the reservoir as.

$$\frac{dE}{dl} = F_i - R_x \ , \quad (2)$$

then: F_i- gravity and Archimedes:

$$F_i = -g(\rho_т - \rho)V_т n \ sin\alpha \ , \quad (3)$$

$R_x -$ resistance force:

$$R_x = -\frac{1}{2}\rho V_т n \frac{d\vartheta^2}{dl} \ , \quad (4)$$

Then, let's put it (3) and (4) to (2):

$$\frac{dE}{dl} = -g(\rho_т - \rho)V_т n \cdot sin\alpha + \frac{1}{2}\rho V_т n \frac{d\vartheta^2}{dl} \ , \quad (5)$$

here: n is the number of solid particles per unit volume; sin α is the flow angle; $\rho_т$; ρ – Density of solid particulars and liquid respectively; $V_т$ - size of solid particles; g - acceleration of gravity; ϑ – average flow rate.

Kinetic energy of turbid flow:

$$E = \frac{2\rho_т V_т \vartheta^2 \cdot n}{3} \quad , \tag{6}$$

Substituting expression (6) into expression (5), we have:

$$\frac{dE}{dl} = -g(\rho_т - \rho)V_т \frac{3}{2}\frac{E}{\rho_т V_т \vartheta^2} \cdot sin\alpha + \frac{3}{4}\rho V_т \frac{E}{\rho_т V_т \vartheta^2}\frac{d\vartheta^2}{dl} \quad , \tag{7}$$

Integrating the last expression and moving from the number of turbidity particles to the turbidity concentration, expression (7) is written as follows:

$$\frac{s_i}{s_o} = \left(\frac{\omega_i}{\omega_o}\right)^{n_1} \cdot exp\left\{-\frac{3g(\rho_i - \rho)}{\rho_т\, Q^2}\int_0^l sin\alpha\omega^2 dl\right\} \tag{8}$$

Bearing in mind that the turbidity consumption:

$$P_i = s_i\, Q \;\; ; \tag{9}$$

Volume of turbidity:

$$V_i = s_i\, Q \cdot t \;\; ; \tag{10}$$

Considering the surface area of the flow in the section under consideration as a function of depth;

$$\omega_i = f(H_i)\, , \tag{11}$$

substituting (11) and (10) into (8), we obtain the following expression:

$$\frac{V_i}{V_{НПУ}} = к\left(\frac{H_i}{H_{НПУ}}\right)^{n_1}, \tag{12}$$

where: $H_{НПУ}$ – depth corresponding to normal water level,
$V_{НПУ}$ – reservoir volume corresponding to normal backwater level,
κ and n_1 - coefficients are determined on the basis of in situ field studies.

The derived formula (11) expresses the relative volume of turbidity in the reservoir as a function of the relative depth of water in the reservoir.

3 Results

Effective use of the above formula (12) requires quantitative determination of n1 and k. Analytical determination of the sum of these coefficients is complicated by the variability of the reservoir volume. Therefore, the values of n1 and k are determined based on data obtained in field studies, for which data collected from several reservoirs are used [19, 20].

Analysis of field study data shows that the volume of sediment in many reservoirs is 1.5-3 times higher than the design values.

Comparison of the calculated values of reservoir volume reduction and data obtained as a result of observations carried out during the operation of reservoirs shows that the proposed method gives good results.

4 Conclusion

Reservoirs of Uzbekistan have a significant impact on ensuring sustainable water supply of the country. The solution of the above problems requires the introduction of new technologies and active use of international experience in the operation of reservoirs. As noted above, the main problems in the rational use of reservoirs remain siltation, overgrowing and shortage of water resources in the context of climate change and reduced precipitation.

References

1. S. Rakhmatullaev, F. Huneau, H. Celle-Jeanton, et al., Environmental Earth Sciences **68**, 985-998 (2013)
2. Decree of the President of the Republic of Uzbekistan “On approval of the concept of development of water management of the Republic of Uzbekistan for 2020-2030”, Tashkent (2020)
3. A. M. Arifzhanov, I. A. Akhmedkhodjaeva, Vodnyye resursy (Water resources) (Tashkent, 2011)
4. L. Samiev, U. Vokhidova, E. Tursunova, et al., E3S Web of Conferences **508**, 07006(2024) DOI: https://doi.org/10.1051/e3sconf/202450807006
5. I. A. Akhmedkhodjaeva, T. U. Appakhodjaeva, Z. I. Ibragimova, Prognoz poteri yomkosti ruslovykh vodokhranilishch sezonnogo regulirovaniya (Forecast of loss of capacity of channel reservoirs of seasonal regulation). Monograph (Tashkent 2019)
6. F. Gapparov, A. Khaidarov, Sh. Yakhshiev, et al., Problematika issledovaniya i potentsial issledovaniy v Uzbekistane v kontekste zarastaniya vodokhranilishch i ikh svyaz' s morfometriyey (Research issues and research potential in Uzbekistan in the context of reservoir overgrowth and their relationship with morphometry). International Journal of Agrobiotechnology and Veterinarymedicine **2(1)** (2023) https://sciencebox.uz/index.php/tibbiyot/article/view/8344
7. Regional information base of the water sector of Central Asia. «CAREWIB» Experience of combating siltation of reservoirs (The Scientific and Information Center of the ICWC Republic of Uzbekistan, Tashkent, 2011) http://cawater-info.net/library/rus/carewib/reservoir_sedimentation_review.pdf
8. L. Samiev, S. Shaymardanov, S. Xoshimov, and O. Mamadiyorov, E3S Web of Conferences **452**, 02019 (2023) DOI: https://doi.org/10.1051/e3sconf/202345202019
9. A. Khaydarov, Central Asian Journal of Water Research **6(2)**, 89–105 (2020) DOI: 10.29258/CAJWR/2020-R1.v6-2/89-105.eng
10. D. Abduraimova, R. Rakhmonov, I. Akhmedov, et al., AIP Conference Proceedings **2432**, 040001 (2022) DOI:10.1063/5.0089645
11. H. Biemans, I. Haddeland, P. Kabat, et al., Impact of reservoirs on river discharge and irrigation water supply during the 20th century. Water Resources Research **47(3)** (2011)
12. G. L. Stephens, J. M. Slingo, E. Rignot, Proceedings of the Royal Society A **476(2236)**, 20190458 (2020)
13. A. Arifjanov, L. Samiev, Sh. Akmalov, Dependence of Fractional Structure of River Sediments on Chemical Composition. International Journal of Innovative Technology and Exploring Engineering **9(1)** (2019)

14. A. Arifjanov, F. Gapparov, T. Apakxujaeva, S. Xoshimov, IOP Conference Series: Earth and Environmental Science **614(1)**, 012079 (2020) DOI:10.1088/1755-1315/614/1/012079
15. L'. Jurík, M. Zeleňáková, T. Kaletová, A. Arifjanov, The Handbook of Environmental Chemistry **69**, 115-131 (2019)
16. E. Kellner, Wiley Interdisciplinary Reviews: Water **8(3)**, e1514 (2021)
17. S. Rakhmatullaev, F. Huneau, P. Le Coustumer, et al., Water **2(2)**, 307-320 (2010)
18. P. J. Gierszewski, M. Habel, J. Szmańda, M. Luc, Science of the Total Environment Journal **710**, 136202 (2020)
19. E. Kellner, Wiley Interdisciplinary Reviews: Water **8(3)**, e1514 (2021)
20. V. Vidović, G. Krajačić, N. Matak, et al., Renewable and Sustainable Energy Reviews **178**, 113237 (2023)