Determination of the trajectory of sedition of fluid particles in the forebay of pumping stations

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Abstract. In the article, the determination of the sedimentation territory of turbid particles in the forebay of the irrigation pumping station is aimed at preserving the useful volume of the forebay, in which the forebay of the irrigation pumping station PK-1512+01 GFC (The great Fergana canal) and SEC (Sokh Eastern Canal) located in the large Fergana canal is taken as an object. The review of the literature showed that the deposition of particles is directly related to the following factors, which are affected by the speed of the flow, the diameter of the particle, the difference between the densities of water and the particle, the shape of the particle and the order of movement of the flow, the viscosity of water and other factors. In these studies, we primarily aim to increase the performance of the forebay by defining the particle settling zone to preserve the useful vane size. Calculations of the method of calculating the sedimentation rate of cloudy particles using theoretical and empirical formulas were carried out and conclusions were drawn by comparing the results.

1 Introduction

Currently, in developed countries, there is 20-60% sedimentation of water intake structures in irrigation pumping stations, during the irrigation season of agricultural crops, and a change in pump operation mode. This indicates that increasing the efficiency of irrigation systems and reclamation facilities, ensuring their reliable use, and reducing operating costs are among the most urgent problems in the development of agriculture and water management in our republic.

In particular, it is an important issue to develop the rules for the technical use of pumping stations and to provide and approve the norms of electricity consumption of pumping station aggregates in accordance with the volume of water. In particular, the President of the Republic of Uzbekistan Decree No. PD-4486 of October 9, 2019, Decree No. PD-6024 of 10.07.2020, Decision No. PD-5005 of 24.02.2021, Decision No. PQ-145 of 03.01.2022 testify to the relevance. The above-mentioned normative documents contain scientifically based recommendations on the rational and efficient use of water resources, ensuring the reliable and safe operation of water management facilities, reservoirs, pumping stations and

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irrigation and drainage systems, as well as the creation and improvement of water accounting tools focused on development [1-3].

It is known that irrigation and land reclamation, agriculture and irrigation pumping stations are being researched on a large scale around the world. Until now, scientific works have been considered on researching optimal hydraulic parameters of water flow in irrigation pumping stations, increasing control and operational efficiency, calculating the distribution of turbid particles along the length of the stream, preventing turbidity in forebays, and effective methods of cleaning turbid deposits [4-6].

In addition to the different diameters of turbid particles in the stream at the irrigation pumping stations, there are unsolved problems if we take into account the direct dependence of the speed of the flow on the shape of the particle and the sedimentation of the particle.

2 Statement of the research problem

Effective operation of irrigation pumping stations in the field of modern practices of agriculture and water management is important in providing reliable water to cultivated areas. However, one of the serious problems affecting the operation of these pumping stations is the deposition of turbid particles in the forebay. The accumulation of these particles not only reduces the efficiency of the pumping station, but also reduces the useful volume of the forebay.

Although various aspects of hydraulic parameters, pump efficiency, and turbidity control have been investigated in previous studies, the issue of accurately determining the sedimentation region of turbidity remains relatively understudied. This gap in understanding is a serious obstacle to optimizing pump station performance and maintaining the functionality of the forebay. Therefore, this study seeks to fill this gap by developing a comprehensive understanding of the factors affecting the settling zone of turbid particles and proposing a methodology to accurately calculate their settling trajectory[7-9].

By addressing the research problem of sedimentation in the context of an irrigation pumping station, this study aims to contribute practical insights into improving the operational efficiency of pumping stations and ensuring the reliability of agricultural land water supply. Through a combined approach of theoretical analysis, empirical calculations, and field research, this study seeks to provide a solid framework for solving turbidity deposition problems and optimizing water resource use. To carry out the research work, it was carried out in the forebay of GFC and SEC pumping station located in Rishton district of Fergana region.

Today, the pumping station provides water to the lands of Altariq and Rishtan districts. The pumping station has 3 D3200-75 pumps with an electric power of N-1000 kW. The diameter of the transmission pipe of the pump is Ø-1200, the length is L-6050 meters and the water consumption is Q- 1.8 m^3/s.

It is known that the water coming from the Norin, Karadarya and Sokh rivers is considered the source of the Big Fergana canal. Since the pumping station receives water from the Big Fergana canal, it directly depends on the mode of operation. Especially in the months of March, April, May, June, weather, floods and rains, the content of sand and turbidity in the water flowing from the rivers changes seasonally. This causes a decrease in the forebay operation mode and the efficiency of the pump. For example, in these months, the amount of turbidity in the water in forebay is observed in the range of 4-10 g/l. As a result, it has a direct effect on the reduction of the useful volume of the pump station's forebayand the reduction of the pump's performance. Design parameters of BFC and SEC pumping station forebayand flow.

3 Materials and methods

When determining the territory of sedimentation of turbid particles in the pumping station forebays, the shape and hydraulic parameters of the forebayare mentioned in the norms of RSE 2.06.01-97 and ISE 2.06.03-12. In a case where the flow is moving along a certain slope and its cross-sectional surface is continuously expanding, it is of great importance to determine the main sedimentation zone of the particles[10-12].

The values of the pulsation speed (longitudinal and transverse) that occur at the bottom of the structure during the deposition of particles are equal to zero or less than the value of the hydraulic size. Due to this reason, turbidity particles begin to sink to the bottom of the structure, and the variation of turbidity particle size along the length of the forebayis also shown in Figure 1, according to which the smallest particles sink to the end of the forebay.

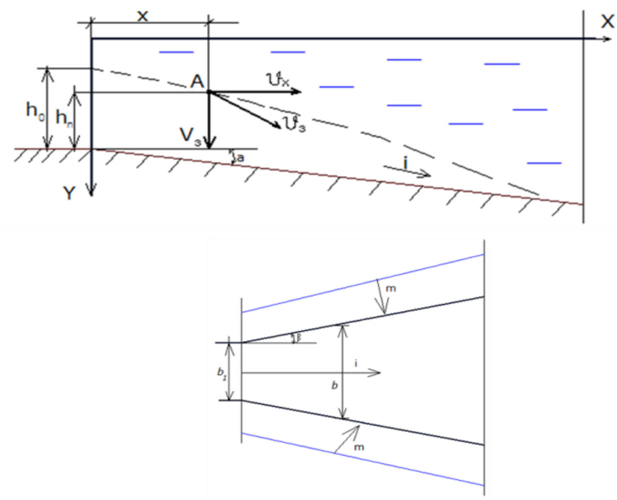

Fig. 1. Schematic diagram of the sedimentation trajectory of the cloud particle in the forebay

It is stated that the sedimentation trajectory of the fuzzy particles is that the particles with the same size and density sink to the bottom of the structure based on Gauss's standard law, and the length of the particles to sink to the center is determined by the following expression. [13-15]

$$L_{av} = \frac{v_{av} \cdot h}{w} \qquad (1)$$

Here, h is the depth of the particle; v_{av} - average speed of water flow; w is the hydraulic size of the particle. If we solve the deposition of turbid particles in the forebay using this equation (1), this research will cause errors because the expression is intended for a rectangular non-sloping structure; The effect of the concentration of turbid particles was not taken into account, the sedimentation rate was considered equal to its hydraulic size. When determining the sedimentation trajectory of turbid particles in the forebay, it can be concluded in the analysis that the above equation (4) is valid only for water intake facilities with a rectangular bottom without a slope. It has been considered by some researchers that the front camera is filled with cloudy particles theoretically, we can get the formula (2).

$$\frac{\partial p}{\partial l} + \gamma b \frac{\partial z}{\partial t} = 0 \qquad (2)$$

Here: p-pressure, l-length, z-depth, g-relative weight, t-time, b-width. formula (3)was expressed by some scientists as follows:

$$(p_1 - p_2)\Delta t = (z_1 - z_2)\Delta l\gamma b, \qquad \frac{p_1}{\gamma} = H_1 \tag{3}$$

$$W_3 = (z_1 - z_2)\Delta lb$$

$$\textit{considering that} \quad dW_3 = (H_1 - H_2)dt \tag{4}$$

These equations and others have been used by researchers in their research. These methods used $s = f(q, h, v)$ and $s = (q, h, u)$ formulas of different forms in calculating fuzzy particles[16-17].

It should be noted that forecasting methods based on equations (3) and (4) accept the elements of water intake facilities in unchanged areas during the calculation interval period, which reduces the accuracy level of calculations.

4 Results and discussion

The proposed formulas (5) and (7) allow to determine the sedimentation territory of spherical fuzzy particles only. Before we determine the sedimentation trajectory of spherical solid particles in the forebay flow, we must take into account the unit speed distribution, which can be determined by the following formula in works.

$$V_3^{III} = \frac{1}{2}\left(\sqrt{(\frac{36 \cdot \nu_c}{d})^2 + 7{,}25(\frac{\rho_3}{\rho_c} - 1)d \cdot g} - \frac{36 \cdot \nu_c}{d}\right) \tag{5}$$

Here V_{III}^3 – is the sedimentation speed of spherical (spherical) particles,

Here acceleration of gravity (g = 9,80665 m/s^2); ρ_3 — particle density; ρ_c — liquid density. ν_c - the coefficient of kinematic viscosity of the flow, d- spherical particle diameter. The above formula (4) is among the similar formulas and is considered a universal formula after being verified by field and laboratory research here we can find the ω-cross-sectional surface[18-20].

$$\omega = bh + mh^2 \tag{6}$$

$$y = \frac{V_3^{III}}{Q}\left(A\frac{x^3}{3} + B\frac{x^2}{2}\omega x\right) \tag{7}$$

Here, the coefficients A, B are determined by various authors on the basis of experiments, for example, A=24, B=0.44 and A=32, B=0.83, are the values, Q- Pump water consumption m^3 /s Above (6) it is possible to determine the sedimentation trajectory of turbid particles with different diameters and densities. Let's check the proposed equation (6) for determining the trajectory of sedimentation of cloudy particles on the example of GFC (The great Fergana canal) and SEC (Sokh Eastern Canal) pumping station forebay. Sedimentation velocities in a slow-moving stream of turbid particles of known diameter in a forebay were obtained for single, spherical particles. If the particles in the flow are not spherical and their concentration is high, the sedimentation rate values change.

Fig. 2. Scheme of field experiments of BFC and SEC pumping station vanguard

When the capacity of the water intake facility is $Q - 2.2\ m/s$ the depth of the forebay is $h_2 - 2.2\ m$, the length of the forebay is $l - 13\ m$, the width of the forebay at the entrance is $b - 2\ m$, the slope is $i - 0{,}2$, the slope coefficient is $m - 1$, the expansion angle is $\beta - 17.5^0$, The density of the cloudy particle $\rho = 2600\ kg/m$, The coefficient of kinematic viscosity of the water flow $\nu_c = 1{,}006 \cdot 10{-}6\ m^2/s$, The diameter of the cloudy particle $d = 0{,}3 \cdot 10^{-3}\ m$, was obtained.

Table 1. Co-ordinates of sedimentation of fuzzy particles.

x, m	2	4	6	8	10	12
y, m	0.134	0.28	0.625	1.18	1.64	2.12

The image of determining the trajectory of sedimentation of cloudy particles in x and u coordinates in the front camera is shown in Fig. 1. Based on the results of the calculations, it was determined that a spherical particle with a size $d = 0{,}3 \cdot 10^{-3}\ m$, density $\rho = 2600\ kg/m^3$, will sink to the bottom of the forebay at a distance of 12 meters.

Fig. 3. Scheme of the experimental facility

Table 2. The composition of the fractions of cloudy particles in the advance camera in the cross-section of months

№	Sampling times	Fractionsap (мм), в %							
		1.0-0.5 mm	0.5-0.25 mm	0.25-0.10 mm	0.1-0.05 mm	0.05-0.01 mm	0.01-0.005 mm	≤0.005-mm	Physical mud
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	March	-	0.9	17.3	26.4	43.1	1.8	2.3	8.2
2	April	0.7	1.4	25.1	30	33.2	1.3	1.5	6.8
3	May	1.9	3.5	34.8	25.9	24.3	2.7	1.6	5.2
4	June	2.5	5.2	35.2	43.8	9,7	0.4	0.8	2.4

In Table 2 above, the monthly cross-section of cloudy particles in the advance chamber flow was obtained by means of field studies. It can be seen that if we take the month of June as an example, the fractional share is as follows: particles in the range of 1.0-0.5 mm are 2.5% of 0.5-0.25 mm. particles 5.2%, 0.25-0.10 mm 35.2%, 0.05-0.01 mm 43.8%, 0.01-0.005 mm particles 9.7%, particles larger than ≤ 0.005mm 0.8%, and physical clay is 2.4%.

5 Conclusion

Considering the modern problems in agriculture and water resources management, this study investigated the important problem of sedimentation of turbid particles in the front part of PK-1512+01 GFC (The great Fergana canal) and SEC (Sokh Eastern Canal) irrigation pumping station. By analyzing the complex interplay of factors such as flow rate, particle size, density variation, particle geometry, and flow dynamics, we attempted to improve the efficiency and productivity of the forebay.

Through careful examination of theoretical and empirical formulas, we have developed a methodology for calculating sedimentation rates of turbid particles. By applying this methodology, we effectively determined the deposition trajectory of particles of different sizes along the sediment length. This not only helps to optimize the performance of the pump, but also preserves the useful volume of the forebay, resulting in increased stability of the pump.

Our field studies and calculations were confirmed by analysis of particle fractions in different months. The data from this comprehensive approach allowed us to accurately determine the depositional trajectory of the turbid particles. Although our research is mainly focused on the specific connection of PK-1512+01 GFC (The great Fergana canal) and SEC (Sokh Eastern Canal) pumping station, when analyzing the fractional composition of the samples taken from the pump station forebay, particles with sizes of 0.25...0.3 mm are from the forebay head. It is found in the field at a distance of 9...13 meters (1 - picture). Particles larger than 0.3 mm settle at a distance of 4...8 meters from the head of the vane camera. Other sizes of turbid particles are noticeable in calculations and sample readings of an average of 10 ... 15 %. the principles and methodologies established here have broader implications for improving irrigation system efficiency and water management practices.

In conclusion, this study provides valuable insights into maintaining the functionality of irrigation pumping stations by bridging the gap between theoretical analysis and practical results. Based on these results, we can contribute to the sustainable use of water resources and agricultural development by providing a reliable methodology for determining the important factors affecting particle deposition and trajectory determination.

References

1. F. Papa, J.F. Crétaux, M. Grippa, E. Robert, M. Trigg, R.M. Tshimanga, ... & S. Calmant, Surveys in Geophysics **44(1)**, 43-93 (2023)
2. A.M. Arifjanov, A.X. Sattorov, D. Atakulov, & I.X. Iminov, IOP Conference Series: Earth and Environmental Science **1231(1)**, 012060 (2023) IOP Publishing.
3. I. Eker, & T. Kara, ISA transactions **42(3)**, 461-473 (2003)
4. A. Arifjanov, S. Jurayev, T. Qosimov, S. Xoshimov, & Z. Abdulkhaev, E3S Web of Conferences **401**, 03074 (2023)
5. M. Mamajonov, & B.M. Shakirov, Scientific-technical journal **22(2)**, 39-43 (2018)
6. Aybek Arifjanov, Samiyev Luqmon, Zaytuna Ibragimova and Q. Ch. Ulashov, E3S Web of Conferences **401**, 01016 (2023) https://doi.org/10.1051/e3sconf/202340101016
7. A. Sattorov, Science and innovation **1(A7)**, 750-755 (2022)
8. A. Arifjanov, L. Samiyev, S. Xoshimov, S. Shaymardanov, S. Tadjiboyev, E3S Web of Conferences **401**, 01020 (2023) https://doi.org/10.1051/e3sconf/202340101020
9. E. Madaliev, M. Madaliev, I. Mullaev, A. Sattorov, & A. Ibrokhimov, AIP Conference Proceedings **2612(1)**, 030002 (2023) AIP Publishing LLC.
10. A. Arifjanov, D. Atakulov, I. Akhmedov, A. Hoshimov, International Conference on Environmental Technologies and Engineering for Sustainable Development (2022) https://doi.org/10.1088/1755-1315/1112/1/012137
11. S. Xoshimov, D. Atakulov, O. Yalgashev, S. Komilov, J. Boykulov, *Evaluation of sedimentation of water reservoirs with modern technologies*. IV International Scientific Conference “Construction Mechanics, Hydraulics and Water Resources Engineering” (CONMECHYDRO - 2022) https://doi.org/10.1051/e3sconf/202336503033
12. A. Arifjanov, L.N. Samiev, Z. Abdulkhaev, D. Abduraimova, S. Yusupov, T. Kaletová, Acta Hydrologica Slovaca **23(2)**, 172-179 (2022) www.uh.sav.sk/ah/ https://doi.org/10.31577/ahs-2022-0023.02.0019
13. A. Khaydarov, T. Apakxujayeva, D. Atakulov, *Influence of geographical location on reservoir vegetation formation*. V International Scientific Conference “Construction Mechanics, Hydraulics and Water Resources Engineering” (CONMECHYDRO - 2023) https://doi.org/10.1051/e3sconf/202340101013
14. A. Fatxulloyev, Q. Rakhimov, D. Allayorov, L. Samiev, & M. Otakhonov, Journal of Water and Land Development (2023)
15. K. Rakhimov, S. Melikuziyev, & R. Sultanov, E3S Web of Conferences **401**, 01042 (2023)
16. A. Arifjanov, F. Babajanov, I. Akhmedov, O. Fozilov, & I. Umarov, E3S Web of Conferences **365**, 03017 (2023)
17. D. Abduraimova, M. Otakhonov, & F. Babajanov, E3S Web of Conferences **264**, 03008 (2021)
18. Z. Abdulkhaev, M. Madraximov, A. Arifjanov, & N. Tashpulotov, AIP Conference Proceedings **2612(1)**, (2023)
19. Z. Abdulkhaev, M. Madraximov, A. Akramov, & A. Arifjanov, AIP Conference Proceedings **2789(1)**, (2023)

20. M.A. Shoyev, A.R. Ibroximov, M.E. Madaliev, J.J. Dusiyorov, O.Q. Rayimqulov, & M.N. Ismatov, E3S Web of Conferences **401**, 01036 (2023)