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Fundamentals of hydraulic calculation of settling tanks and the choice of their optimal parameters (in the drip irrigation system)

Asror Yangiev[1*], *Shokhrukh* Azizov[1], *Dilmurod* Adjimuratov[1], *Sherzod* Panjiev[1], *Shaydobek* Kurbonov[1], and *Galiya* Omarova[2]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan
[2]Taraz Regional University named after M.Kh.Dulaty, Taraz, Kazakhstan

Abstract. The study of sedimentation processes in the clarifiers in the drip irrigation system was carried out in the fields of farms in the Bukhara, Kogon, Peshku, and Romiton districts of the Bukhara region, which are supplied with water from the Amudarya river. During the research, methods of field observation, generally accepted methods in hydraulics, and methods of comparing experimental results with hydraulic calculations were used. Hydraulic calculation of turbid sedimentation process in sediments was performed by A.G.Khachatryan method. As a result, a graph of the relationship between the settling length and the settling rate of the mud in was developed for different water consumption. As the length of the settling tank increases, the settling rate of the mud increases, i.e., the settling rate of the 41 m long settling tank is 30-40%, while that of the 800 m length is 70-80%. If 20 ha of land is irrigated in 6 plots, then 3.33 ha of land is irrigated in each plot. The water norm required for 1 irrigation of cotton on 3.33 ha of land is 900-950 m3, while the average is 250-300 m3 / ha. If 2 chambers with a length of 10 x 40 m (depth 2-2.5 m) are taken in each chamber, then in the first chamber, 35-40% of the distilled water passes into the second chamber, and in 8 hours, it becomes another 35-45 %, and clear water can be sent to the irrigation system through pumping units. In such cases, water should be constantly supplied to the first chamber from the ditch until the end of 1 irrigation of 20 ha.

1 Introduction

Resolution of the President of the Republic of Uzbekistan dated October 25, 2019, No PP-4499 "On measures to expand mechanisms to encourage the implementation of water-saving technologies in agriculture," states the need for special research in the field of more efficient use of drip irrigation technology [1-4]. The recommended dimensions for the construction of a water treatment plant on the area of 20 hectares of cotton fields of farms receiving water from the Amudarya are as follows [7]: the average turbidity of water in the irrigation network receiving water from the Amu-Bukhara canal is 2-3 kg/m^3, and the

*Corresponding author: yangiev_asror_63@mail.ru

average fraction of turbid particles in it is 0.25-1.1 mm, if the pump unit has a capacity of 315 m^3/h punctuation distance is at least 25 m. The settling basin should consist of at least two chambers. According to calculations, the total length of the settling basin will be 41 m, width 13 m, of which the length of the first chamber will be 25 m, depth 2.0 m, and the length of the second chamber will be 16 m, depth 1.7 m. According to the above recommendations, the volume of water in one-time filled sumps (cooling pools) reaches 3-5 hectares, and the irrigation norm for irrigating 20 hectares of land is 6 times. Therefore, it is important to develop recommendations to substantiate the optimal parameters of drip irrigation systems in farms receiving water from the Amudarya basin [5, 6, 11-15].

2 Method

During the research, methods of field observation, generally accepted methods in hydraulics, and methods of comparing experimental results with hydraulic calculations were used.

3 Results

Due to the turbidity of the Amudarya water flow, the size of the sediments in the drip irrigation system has not been improved, and the deposition of mud along their length is not fully ensured. Assuming a constant flow of water from the canals to the settling basin then, the mud in the built settling basin will not have time to fully sink, resulting in the release of turbid water from the system filters and pipe drips during field irrigation. Therefore, research is necessary to improve drip irrigation systems' size in farms receiving water from the Amudarya basin is necessary. Field research was conducted in drip systems installed in cotton fields in several districts of the Bukhara region, which are supplied with water from the Amudarya River. A drip irrigation system has been installed at the Islam farm in the Kagan district to irrigate 20 hectares of cotton fields (Figure 1). Through culverts, water is supplied to the drip irrigation system from the plot canal. The system is built with a single chamber covered with a membrane, the dimensions of which are as follows:

$$b=11\ m; \qquad L=18\ m; \qquad h=2.5\ m.$$

The sump (cooling pool) dimensions were designed according to initial recommendations [7]. It is known that the water in the canal of this farm is from the Amudarya basin system, and the level of turbidity is high. Therefore, the flow turbidity is deposited in the designed settler, and the distilled water is pumped to the drip irrigation system.

Fig. 1. Drip irrigation system on the farm "Islam".

Using experimental field methods, turbidity samples were taken to determine the turbidity level of the flow according to the scheme below.

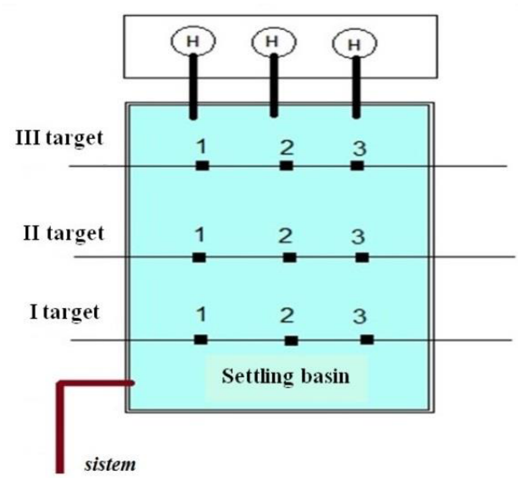

Fig. 2. Drip irrigation system of "Islam" farm. The scheme of sampling of mud in the Settling basin.

Turbidity samples were taken from 3 wells along the length of the sediment, the beginning, middle, and end of the sediment, using a bathometer. At the same time, samples were taken at a depth of 0.2h and 0.8h from 2 vertical storks along the length of each stork. The samples were analyzed in the soil laboratory of ("TIIAME" NRU) Bukhara Institute of Natural Resources Management (Uzbekistan).
The results are shown in Table 1 and Figure 2.

Table 1. Analysis of the settling basin on the farm "Islam"
(The size of the settling basin is 18x11 meters)

№	Names	Quantity, (g/l)		Quantity, (g/l)		Quantity,(g/l)	
1.	I target	0.2h	0.626	0.2h	0.661	0.2h	0.584
		0.8h	0.647	0.8h	0.678	0.8h	0.623
2.	II target	0.2h	0.382	0.2h	0.396	0.2h	0.361
		0.8h	0.421	0.8h	0.453	0.8h	0.417
3.	III target	0.2h	0.249	0.2h	0.251	0.2h	0.228
		0.8h	0.264	0.8h	0.282	0.8h	0.234

Analysis of laboratory samples shows that the turbidity of the flow from the beginning of the settling tank (1st stage – 0.66 g/l) to the end (3rd stage – 0.26 g/l) decreased by 39%. Similar surveys were conducted on farms "Adizobod Erkin Mahmud" of Bukhara district, "Sharifbobo" of Romitan district, and "Fattoev" of Peshku district. The size of water intakes on these farms is the same as on the farm "Islam" in the Kagan district and is designed to irrigate 20 hectares of cotton fields. Experimental analysis shows that the sedimentation rate of turbid sediments from the beginning to the end of the sediments in the conducted experimental sites is from 20% to 40%. If it is assumed that the water from the site canals constantly flows into the sediments, then the mud along the length of the sediments built has not yet completely subsided. As a result, during the field irrigation, turbid water was also released from the system filters and pipe drips, i.e., turbidity in the drips ranged from 0,0041 g/l to 0,0141 g/l. Therefore, to reduce the risk of mudslides on the drip irrigation system in the farms supplied with water from the Amudarya River, their hydraulic calculations were carried out to further improve the optimal parameters of sediments for different conditions.

The calculation of the process of turbid sedimentation in the sediments was carried out by the method of A.G.Khachatryan. The calculation procedure for this method is as follows [8, 9, 13, 14, 15].

The sedimentation curve of the mud in the sediment is determined by the following formula:

$$S_{wo}^{T} = S_{wo}^{o} - \Delta S_{wo}^{T} \tag{1}$$

here: S_{wo} is the ordinate of the sinking curve for a situation where there is no effect of turbulent flow; ΔS_{wo} is correction for turbulence.

The sinking curve in still water is determined by the following formula:

$$S_{wo}^{o} = 1 - \frac{1}{w_o}\int_o^{w_o} \underline{P}_{(w)} \cdot dw \tag{2}$$

here: w_o is the hydraulic magnitude of the sediment coverage; $\underline{P}_w$ is turbidity dispersion function.

The coverage of the precipitator is determined by the following formula:

$$w_o = \frac{\vartheta \cdot H_{av}}{L} \tag{3}$$

Here: v, H_{av} is the average speed and depth in the damper, respectively; L is the length of the settling basin on the selected plot.

The average depth in the settling basin:

$$H_{av} = \frac{\omega}{B} \tag{4}$$

Here: ω is the live cutting surface of the settling basin; B is the width of the settling basin across the water level.

The distribution of turbidity fractions by size corresponds to Khachatryan law:

$$J = \frac{C}{w} \qquad (5)$$

Here: $J < w$ comparative turbidity in hydraulic magnitude; C is constant distribution of fractions by size.

For the account $P_{2.27}$ and $P_{0.09}$ the ordinate of the fuzzy curve on the fractional content was used, that is 0.05 and 0.01 mm hydraulic size for diameter fractional composition 2.27 and 0,09 mm/s case. In that case,

$$C = \frac{\underline{P}_{2.27} - \underline{P}_{0.09}}{\ln\frac{2.27}{0.09}} = 0.31 \cdot (\underline{P}_{2.27} - \underline{P}_{0.09}) \qquad (6)$$

By defining a constant C The total ordinate curve of the fuzzy fraction composition is determined by the following formula:

$$\underline{P}_w = \underline{P}_{0.09} + C \cdot \ln\frac{w}{0.09} = \underline{P}_{2.27} - C \cdot \ln\frac{2.27}{w} \qquad (7)$$

In that case, the ordinates of the sinking curve are determined by the following formula:

$$S^o_{w_o} = 1 - \underline{P}_w + C = 1 - \underline{P}_{2.27} + C \cdot \ln(\frac{2.27}{w} + 1) = 1 - \underline{P}_{0.09} - C \cdot \ln(\frac{w_o}{0.09} - 1) = \\ = S^0_{2.27} + C \cdot \ln\frac{2{,}27}{w_o} = S^o_{0.09} - C \cdot \ln\frac{w_o}{0.09} = 1 - \underline{P}_{w_o} \qquad (8)$$

The ordinates of the turbidity change curve are as follows:

$$\underline{P}^o_w = \underline{P}_w - C = \underline{P}_{2.27} - C \cdot (\ln\frac{2.27}{w} + 1) = 1 - \underline{P}_{0.09} - C \cdot (\ln\frac{w}{0.09} - 1) = \\ = S^o_{2.27} + C \cdot \ln\frac{2{,}27}{w} = S^o_{0.09} - C \cdot \ln\frac{w}{0.09} \qquad (9)$$

The turbulence correction is as follows:

$$\Delta S^{\mathrm{T}}_w = \underline{P}_{Cr} \cdot S^o_w \qquad (10)$$

Here: $\underline{P}_{Cr}$ is comparative critical turbidity.

$$\underline{P}_{Cr} = \frac{\rho_{Cr}}{\rho_o} \qquad (11)$$

Here: ρ_{Cr} is critical turbidity.

Critical turbidity Determined by the A.G Khachatryans formula [8, 7]:

$$\rho_{Cr} = \frac{0.2 \cdot u_{в}}{C} \cdot \underline{P}_{u.в} \qquad (12)$$

Here: $\underline{P}_{u.в}$ is the relative composition of the fraction in given turbidity in units.

$$\underline{P}_{u.в} = \underline{P}_{0.09} + C \cdot \ln \frac{u_в}{0.09} \quad (13)$$

The suspended component of the turbulent pulsation is as follows:

$$u_в = 0.065 \cdot \frac{n^{0.5} \cdot \vartheta^{0.5} \cdot (\vartheta - 0.05)}{H_{aver}^{0,33}} \quad (14)$$

Here: n is the roughness of the sedimentary core; ϑ is average speed in the sump.

(1) and (5) in the cooler w_0, we have a calculation formula for determining the sedimentation curve of turbines in a turbulent flow.

$$S_{w_o}^{T} = (1 - \underline{P}_{Cr}) \cdot S_{w_o}^{o} = (1 - \frac{\rho_{Cr}}{\rho_o}) \cdot S_{w_o}^{o} \quad (15)$$

The length of the settling tank is calculated according to the degree of settling of the mud in it (3):

$$L = \frac{\vartheta_{aver} \cdot H_{aver}}{w_o} \quad (16)$$

Here: w_0 is the coverage of the settling basin providing a given sinking level.

The coverage of the required settling is determined by the following formula:

$$w_o = e^{\left(\frac{1 - \underline{P}_{0,09} - 1,41 \cdot C}{C} - \frac{S_{wo}^{T}}{C \cdot (1 - \rho_{Cr})}\right)} \quad (17)$$

The above method is an effective method for sand and clay sludge. Speed in the settling tank 0.2-0.4 m/s when this method gives satisfactory results.

The following is found for the coagulation state of the sedimentation of sludge in the precipitator:

$$S_{w}^{TK} = S_{w>0.09}^{o} + \alpha \cdot S_{w<0.09}^{oк} \quad (18)$$

Here: $S_{w>0.09}^{o}$ is punctuation rate when the turbidity fraction in the sediment is greater than 0.01 mm; $S_{w<0.09}^{oк}$ is when the mud fraction is less than 0.01 mm ($w = 0.09 s/mm$) degree of silence; α is a coefficient that considers the occurrence of coagulation in the flow. Here speed in the sump $\vartheta_{aver} \leq 0.1 m/s$ when $\alpha = 0.85$ equal.

$S_w > 0.09$ the value (2) is determined by the condition as follows:

$$S^{ок}_{w>0.09} = \underline{P}_{w>0.09} - \frac{1}{w}\int_{0.09}^{w} \underline{P}_w \cdot dw = 1 - \underline{P}_{0.09} - \frac{1}{w}\int_{0.09}^{w} C \cdot \ln\frac{w}{0.09} \cdot dw = \\ = 1 - \underline{P}_{0.09} - C \cdot (\ln\frac{w}{0.09} - 1) - \frac{C \cdot 0.09}{w} \quad (19)$$

The first threshold of coagulation is determined as follows:

$$\Pi_1 = \frac{t_1}{H_{aver}} = \frac{500}{H_{aver}}, s/mm \quad (20)$$

Here: H_{aver} is average speed in the silencer, mm; t_1 is onset time of sinking intensity, s.

The second threshold of coagulation is determined as follows:

$$\Pi_2 = \Pi_1 + \frac{8}{(\rho_{0,09} \cdot H_{aver})^{0,78}}, s/mm \quad (21)$$

Here: $\rho_{0.09}$ is turbidity that creates muds $w < 0.09\ mm/s, kg/m^3$

$$\rho_{0.09} = \rho_o \cdot \underline{P}_{0.09} \quad (22)$$

Here: ρ_o is initial turbidity at the head of the condenser, kg/m^3.

The subsidence curve in the interval up to the Π_2 coagulated mass is determined as follows:

$$S^{ok}_{w<0.09} = \underline{P}_{0.09} \cdot \left[1 - e^{-k(\frac{1}{w} - \Pi_1)}\right] \quad (23)$$

Here: K is empirical coefficient

$$K = 0.15 \cdot (\rho_{0.09} \cdot H_{aver})^{1.3} \quad (24)$$

The total ordinate of the sedimentation curve of muds up to the second threshold of coagulation ($w \geq \frac{1}{\Pi_2}$), (19, 20, 24) is determined by the following formula:

$$S^{TK}_{W} = 1 - \underline{P}_{0.09} - C \cdot (\ln\frac{w}{0.09} - 1 + \frac{0,09}{w}) + \alpha \cdot \underline{P}_{0.09}[1 - e] \\ = 1 - 0.15 \cdot \underline{P}_{0.09} - C \cdot (\ln\frac{w}{0.09} - 1 + \frac{0.09}{W}) - \frac{0.85 \cdot \underline{P}_{0.09}}{e^{k(\frac{1}{w} - \Pi_1)}} \quad (25)$$

The effective length of the damper is determined by the following formula:

$$L_p = L_{ef} = 1000 \cdot \vartheta_{aver} \cdot H_{aver} \cdot \Pi_2 \quad (26)$$

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4 Discussion

Using the above formulas below, the water consumption from the ditch to the settler $Q = 0.3\ m3/s$, turbidity of the water in the ditch: $\rho = 1.5 - 2.0\ g/l$ [15, 16], sedative resolution: $b = 13\ m$; $H = 2.5\ m$; $L = 30 - 300\ m$ is a graph of the relationship between the length of the silencer and the degree of blurred punctuation (Fig.3). In the same way, it is possible to perform calculations in a special Excel program for any water consumption.

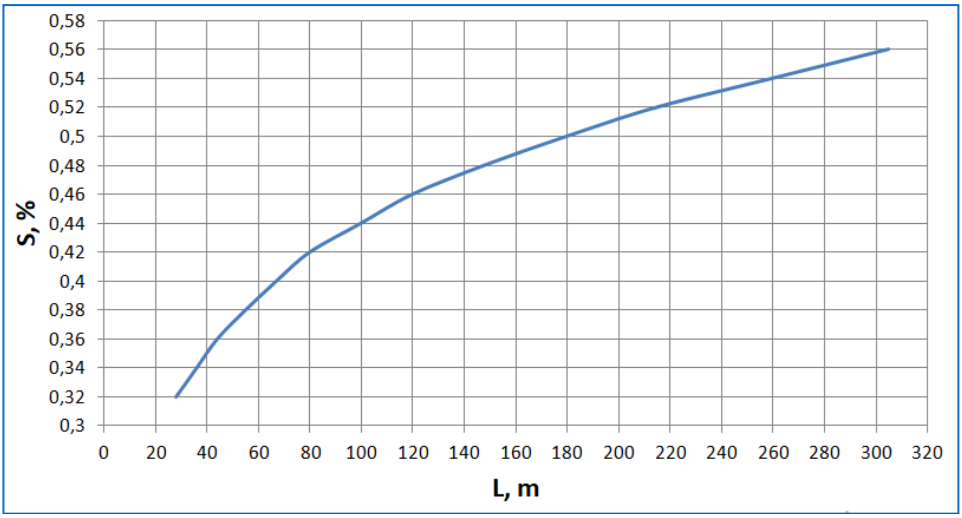

Fig. 3. *$S_{wOП2}$ = f(L) connection graph.*

5 Conclusion

1. Experimental analysis shows that the sedimentation rate of turbid sediments from the beginning to the end of the sediments in the conducted experimental sites is from 20% to 40%. If it is assumed that the water from the site canals is constantly flowing into the sediments, then the mud along the length of the built sediments has not yet completely subsided. As a result, during the field irrigation, turbid water was also released from the system filters and pipe drips, i.e., turbidity in the drips ranged from 0.0041 g/l to 0.0141 g/l.
2. Hydraulic calculation of turbid sedimentation process in sediments was performed by A.G.Khachatryan method. As a result, a graph of the relationship between the settling length and the settling rate of the mud in was developed for different water consumption. As the length of the settling tank increases, the settling rate of the mud increases, i.e., the settling rate of the 41 m long settling tank is 30-40%, while that of the 800 m length is 70-80%.
3. If 20 ha of land is irrigated in 6 plots, then 3.33 ha of land is irrigated in each plot. The water norm required for 1 irrigation of cotton on 3.33 ha of land is 900-950 m^3, while the average is 250-300 m3 / ha. If 2 chambers with a length of 10 x 40 m (depth 2-2.5 m) are taken in each chamber, then in the first chamber, 35-40% of the distilled water passes into the second chamber, and in 8 hours, it becomes another 35-45 %, and clear water can be sent to the irrigation system through pumping units. In such cases, water should be constantly supplied to the first chamber from the ditch until the end of 1 irrigation of 20 ha. Subsequent 2, 3 ... n - irrigation is also carried out in the order of the first irrigation.

4. Suppose in some areas, there is an excess of land that does not reduce the coefficient of land use, or it is not possible to bring water to the canals on a regular basis during the growing season. In that case, it is advisable to adopt the size of irrigators based on the amount of water per 20 hectares of land. In this case, the dimensions of the settler for 6000 m^3 of water can be as follows:

b = 15 m, h = 2,5 m, L = 160 m; b = 10 m, h = 2,5 m, L = 240 m. Calculations show that 70-85% of the mud along its length manages to sink in such pits.

5. It is advisable to use the above recommendations based on the geographical location of farmland, land use coefficients, and periods of the water supply of canals during the growing season.

6. These studies are the results of preliminary research conducted on farms in the Bukhara region. In the future, it is necessary to conduct further research for other river basins and to further improve the optimal parameters of irrigators for different conditions.

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