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Experimental investigation of the effect of baffles on the efficiency improvement of irrigation sedimentation tank structures

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Abstract. Sedimentation tanks are essential structures to filter the suspended sediments in the inlet flow which are constructed at the inlet of the basins forked from rivers and irrigation canals. The larger the constructed tank, the better the sedimentation process is conducted. However, the construction and dredging costs increase. In this regard, improving the performance and sedimentation efficiency seem necessary by alternative methods. One of these effective methods is using baffle plates. Most of the studies carried out in this field are on the use of these baffles in the primary and secondary sedimentation tanks. Hence, this study is carrier out with the objective of increasing the retention efficiency in the irrigation sedimentation tanks using baffles. To reach this goal, the experiments were carried out in a flume with length 8 meters, width 0.3 meters, and height 0.5 meters, considering a sedimentation tanks with a length of 3 meters, in three different inlet concentration, three flow rates and three Froude numbers. The baffles were mounted at the bottom of the tank and the effects of the angle, height and position in the tanks were investigated. The results showed that on average, employing the baffles increased the sedimentation efficiency 5 to 6% and the highest value was obtained for angle 60 with respect to the flow direction. According to the results of this study, the most favorable height and position of these baffles were obtained to be in 40% of the depth of the flow and 50% of the length of the sedimentation tank, respectively. Also, by increasing the number of baffles, the sedimentation efficiency decreased. Regarding the sedimentation regions in this case, more than 80% of the settled sediments were observed in the middle of the tank measured from the inlet.

Keywords: sedimentation tank, retention, baffles, suspended sediments

1. Introduction

One of the common methods for sedimentation and filtering the suspended sediments in the water is to use gravity force. The sedimentation tanks are used to filter and remove the sediments from the flow in projects such as urban water supply, wastewater treatment and irrigation networks forked from rivers and are usually constructed either in rectangular or circular shapes. This structure is used in two types of primary and secondary in wastewater treatment plans and most of the studies are concentrated in this field. In primary sedimentation tanks, the initial concentration of the inlet is low and the sedimentation depends on the hydrodynamics of the tank. However, in secondary sedimentation tanks which are located after biologic filters, the concentration at the inlet is higher and the concentration distribution also affects the sedimentation. In general, the differences in the appearance of the irrigation and wastewater treatment sedimentation tanks are in their inlets and the way the inlet energy is dispersed from the upstream to the tank (Henderson *et al.* 2018, Sanada, 2018, Stelson 2018).

Sedimentation tanks in the wastewater plan are essential parts of the wastewater treatment facilities such that they include one-quarter to one-third of the total construction costs (Swamee and Tyagi 1996). In irrigation sedimentation tanks, which are the main topic of this study, the issues regarding sedimentation in the irrigation networks consist of reduction of the capacity of canals, the reduction of the annual acreage for agriculture, providing the proper condition for the growth of weeds, cutting off the water flow for dredging the canals, erosion and damages of the walls of the canals and increased facilities maintenance costs show the importance and necessity of using this type of structure. Also, in hydroelectric power plants, in order to prevent corrosions and damages to the turbines, the sequestration of the suspended particles and proper design of the sedimentation tanks seem necessary. However, the high costs of constructing this structure by traditional design have led to the elimination of this structure in a number of irrigation networks and new operational issues.

Its design principles are based on increasing the cross-section of the canals and consequently the reduction of the flow velocity to provide the sufficient time for the sediments to settle and increase the sedimentation efficiency. The amount of the settled sediments divided by the inlet sediments in the sedimentation tank is known as retention efficiency. Clearly, the dredging of the sedimentation tank focused at a point is much cheaper than dredging tens and hundreds of kilometer of the canal (Shetab-Boushehri *et al.* 2010). The sedimentation efficiency in the tanks depends on three parameters of the

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inlet concentration of the particles, dimensions of the tank, and the characteristics of the flow in the tank including Reynolds number, Froude number and buoyancy force. The effort is always to change the geometry of the flow and consequently change the flow patter to increase the efficiency of the tank. To decrease the vortices and rotational flows and making sure regarding the proper performance of the tanks, and considering the direct relationship between the flow velocity and the length of the tank, the tanks are usually designed to be long and deep which causes the costs to increase. Also, proper sedimentation requires a slow flow in the tank. Therefore, carrying out research on the optimization of the performance of the tank and increasing the sedimentation efficiency without increasing the dimensions is a normal and necessary task. Various empirical and semi-empirical methods are performed to reach these goals in the past and numerous solutions have been suggested. One of these effective solutions is to use baffles.

The baffles act as barriers, effectively suppressing the horizontal velocities of the flow and forcing the particles to the bottom of the basin (Shahrokhi *et al*. 2011a). It must be noted that using baffles without enough caution can worsen performance compared with the tank without a baffle. Various studies are carried out numerically and experimentally regarding using plate at the bottom of the primary and secondary sedimentation tanks with the inlet flow with different cross-sections which show the effectiveness of this structure on the performance of the tank including the flow characteristics and sedimentation efficiency. (Bretscher *et al*. 1992, Ahmad *et al*. 1996, Huggins *et al*. 2005, Goula *et al*. 2005, Razmi *et al*. 2009, 2013, Tamayol *et al*. 2010, Jamshidnia and Firoozabadi. 2010, Shahrokhi *et al*. 2011, Shahrokhi *et al*. 2012, Lee *et al*. 2002). Efficiency of TLDs with bottom-mounted baffles in suppression of structural responses when subjected to harmonic excitations was presented by Shad *et al*. (2016). An efficient model was formulated by Kolaei *et al*. (2017) for analysis of a coupled fluid slosh-vehicle dynamic system to study the effects of different baffle designs on directional dynamic performance of a partially-filled tank vehicle.

The abovementioned researches showed the impact of the baffles on preventing the intense variations of the flow in the width of the tanks and diffusion of the inlet sediments in the width and this structure at the bottom of the tank led to considerable changes in the flow pattern and uniformity of the velocity profile compared to the case without these structures (Ahmad *et al*. 1996). Also, near the bottom of the tank, the flow velocity and the kinetic energy of the flow decreases and a slower velocity profile is formed compared to the case without the baffles and this will be a suitable condition for a better sedimentation and increased efficiency (Tamayol and Firoozabadi 2006, Tamayol *et al* 2008, Jamshidnia and Firoozabadi 2010).

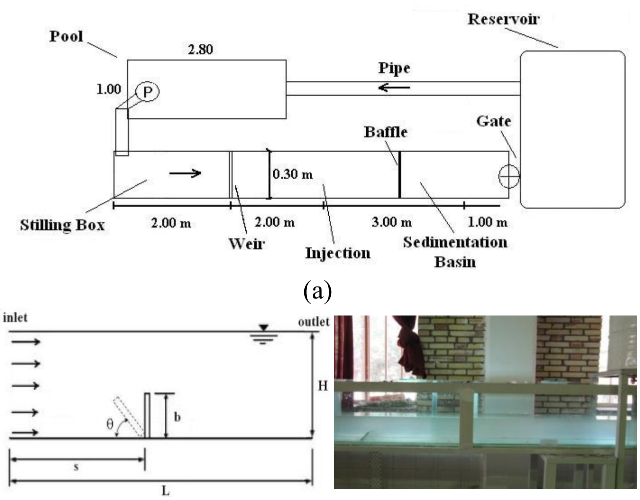
One could point out that in the primary sedimentation tank, considering the low inlet concentration the baffles have more impact on the efficiency of the tank at the surface. However, in the secondary sedimentation tanks, embedded plate at the bottom of the tank improves the sedimentation process.

Few studies have been performed on the irrigation sedimentation tanks including the research carried out by Khademi *et al*. (2008). They studied increasing the efficiency of the sedimentation tanks by adding two-sided vertical guide vanes in the inlet, in two forms of experimental and numerical studies and found out that the time the jet enters the upstream canal, intense velocity variations happen in the width of the canal. Installing these vanes in the depth of 15% leads to 15% increase in the efficiency. Razmi *et al*. (2008) found that best location of the vertical baffle is obtained when the volume of the circulation zone is minimized or the dead zone is divided into smaller parts, and they showed that this baffle can reduce the size of the dead zones and turbulent kinetic energy in comparison with the no-baffle condition. Radi *et al*. (2009) studied the possibility of improving the performance of rectangular sedimentation tank by using transverse guide vanes and found that if the initial parts of the tank are designed to have a sudden change, trapping the sediments by the tank decreases due to the formation of rotational flows. Also, they showed that installing vertical transverse guide vanes at the bottom with a depth of 20% and 6% length from the beginning of the tank could lead to increasing the efficiency of the sedimentation tank up to 12% for fine-grained sediments.

Shahrohki *et al*. (2011b, 2011c) was performed numerical simulation to investigate the effects of vertical baffle location on the flow field in rectangular primary sedimentation tanks. Based on the smallest volume of the circulation zone and kinetic energy, the maximum concentration of the suspended sediments in the settling zone and the highest value of removal efficiency, they proved that the baffle (using a baffle height-to-depth ratio of b/H=0.18) should be placed between 0.125 and 0.20 (inlet-to-tank length ratio).

Shahrokhi *et al*. (2012) carried out numerical simulations on the effect of the baffle angle on the performance of the primary sedimentation tanks. The results showed that by assuming an inlet flow from the bottom, the proper angle for the baffle with a high performance and the least dead zones was obtained to be 90 degrees. Also, they carried out a similar numerical simulation on the effect of the location and position of the baffle on the performance of the primary sedimentation tanks. The results showed that by assuming inlet from the bottom and fixed height of the baffle equal to 0.176 of the flow depth, the proper location of the baffle at the bottom of the tank with a high performance, decreased kinetic energy and the lease dead zone was obtained to be at 12.5% of the length of the tank (Shahrokhi *et al*. 2013). Razmi *et al*. (2013) investigated the effect of the baffle position on the performance of a primary settling tank experimentally and numerically. Their results showed that the best position of the bottom baffle (θ=90°) is relatively close to the entrance jet (10-20% tank length), while the best baffle height is around 25-30% of the water depth.

The experimental results by He *et al*. (2015) showed that the parallel-connected baffles outperformed the series-connected baffles because it could disperse flow faster and



(a)

(b) (c)

Fig. 1 (a) A view of applied experimental flume; Schematic diagram of the basin; (b) Schematic diagram of the basin; (c) a photo of baffle with θ=60° in the basin

in less space by splitting the large inflow into many small branches instead of solely depending on flow internal friction over a longer flow path, as was the case under the series-connected baffles. Wang *et al*. (2016) analyzed of transient lateral sloshing in a partially-filled cylindrical tank with multi baffles including floating circular baffle, wall-mounted ring baffle, floating ring baffle and their combination form, and those baffles with inclination using a coupled multimodal method and scaled boundary finite element method (SBFEM).

By studying the literature in the field of using baffles at the bottom of the tank in the whole width of the irrigation sedimentation tanks as baffle walls which are the main topic of this study, very few studies are carried out and the presented studies are mostly on the flow guiding baffles and their effects on the sedimentation efficiency. Therefore, this study tries to study the effect of the transverse baffles at the bottom of the tank on the retention efficiency of the irrigation sedimentation tanks in a broader range. Thus, the effect of the plate angles compared to the flow direction, height and the position of the installed plates in the tanks and the simultaneous effect of these parameters on the retention efficiency are studied. Also, the effect of hydraulic parameters of the flow e.g. Froude number (flow rate) and the depth of the flow as well as the inlet concentration of the sediment to the tank on the efficiency of the tanks, with and without the plates at the bottom are studied.

2. Materials and methods

Experiments were carried out at the Fluid Mechanic Laboratory of Kashan Islamic Azad University. The experiments were conducted in a tilting flume having a length of 8 m, a width of 0.30 m, and a depth of 0.50 m with and without baffles. A rectangular sedimentation basin 3.0 m in length (L) and 0.3 m in width was provided at the end of the channel. Fig. 1 shows a view of the experimental flume utilized in this study. A sluice gate was provided at the end of the flume for control of the depth of flow (H) within the flume. The plate models are built with glass and have the same width as the flume with different heights and are installed at certain locations using glue. The inlet flow is supplied by the pumping system available at the flume upstream and total flow rate was measured by a calibrated 60° *V* notched weir at the beginning of the channel. The stage-discharge relationship for the triangular weir after the calibration is as follows

$$Q = 0.822 \times H_W^{2.50} \tag{1}$$

In this equation, H_W is the depth of the flow on the weir (meters) and Q is the flow rate (m^3/s).

Table 1 The range of the experimental data

Range	Q (lit/s)	H (cm)	U (m/s)	C (gr/lit)	Fr	L (m)
Min	2.0	15	0.037	1.0	0.026	3
Max	10	25	0.216	11.0	0.217	3

The experiments are carried out in three flow rates with variations in the depth and velocity of the flow in the sedimentation tank as well as variations in the sediments concentration in the inlet. Table 1 shows the range of the values of the experiments data. The sediments used in the experiment are of running sand type with an average diameter of 130 microns. Using a funnel-shaped tank with three 1-inch valves installed at its end, the dry sediments are injected to the entire width during the experiment. By keeping the height of the sediments fixed inside the tank by adding the sediments during the experiment, possible variations of the settling velocities of the sediments or the amount of injected sediments are prevented. The amount of the injection is controlled with the openness of the valves and is a function of the openness of the valves which are calibrated before using the apparatus. To determine the duration of each experiment, the stability condition of the outlet concentration of the tank was investigated such that by fixing the variations of the concentration of the outlet sediments from the tank to a specific value, the time of the experiment is finished. Therefore, the initial experiments without baffles lasted for 80 minutes to reach the equilibrium state. Based on the results obtained from the experiments, the equilibrium is reached after 30 minutes. Therefore, other experiments were performed for 30 minutes.

Fig. 2 shows a sample of the outlet density variations versus time for flow rate 2.22 lit/s and inlet concentration 5 g/lit. As observed in Fig. 2, the velocity of the outlet concentration is very high at the beginning of the experiment such that after 15 minutes since the beginning of the experiment (50% of the stability time), 84% of the total outlet concentration was achieved. But, these variations decreased as the time passed and finally reached a constant value. The depth of the water (H) in the experiments was considered to be 20 cm. To accurately calculate the retention efficiency of the sedimentation tank, weighting method was used such that a specific weight of the sediments was injected to the canal at a specific time

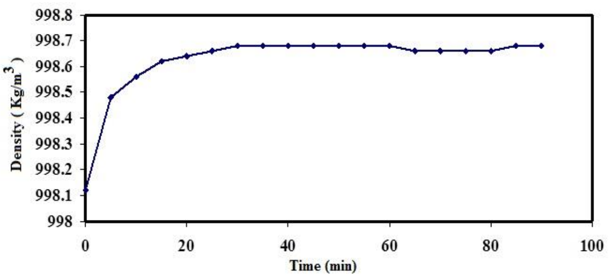


Fig. 2 The variations of the density of the outlet flow versus time at the time of injecting the sediments

and the total settled sediments in the sedimentation tank were collected after the experiment is finished and are dried in the furnace. By dividing the weight of the dried settled sediments by the total weight of the injected sediments, the retention efficiency is obtained.

Also, the retention efficiency is calculated by the difference of the suspended load of the inlet and outlet of the tank such that the density of the outlet flow is measured at the beginning and at the end of the experiment and their difference is found to be the outlet suspended load. Finally, considering the inlet concentration to the tank, the retention efficiency is calculated using the equation below

$$RE = 1 - \frac{C_o}{C_i} \tag{2}$$

In which, RE is the retention efficiency and C_i and C_o are the mean concentration of the inlet and outlet sediments per unit time in the sedimentation tank, respectively.

3. Results and discussion

3.1 Effect of the baffle angle

To investigate the impact of the baffles and their angels, a series of experiments were carried out with 6 baffle angles (θ) 30, 45, 60, 90, 120 and 150 degrees and without baffles, with three flow rates 2.0, 5.0 and 10.0 lit/s and three different concentrations 1, 3, and 5 g/lit and a total of 63 experiments were carried out. In these experiments, in order to study the effect of the plate angles, the effect of height and position of the baffles were neglected and a fixed height (W) equal to 8 cm (W/H=0.40) was considered for the baffles and the position 1.5 m from the inlet of the tank (s/L=0.50) was considered for their location.

According to the results presented in table 2, in all of the experiments, increased retention efficiency was observed for the sedimentation tanks using vertical baffles at the bottom of the tank (θ=90°) compared to the cases without baffles and the increased values are in the range of 0.3 to 3.9%. The highest increased values of 3.9% were for the case with the maximum flow rate and mean concentration 3 g/lit. Based on the points made in the introduction regarding the sedimentation efficiency and the effects of the flow characteristics and inlet concentration on it, one could deduce that considering the same inlet concentrations, using the baffles at the bottom of the tank affects the flow characteristics, specifically the flow velocity inside the tank and it causes the velocity to decrease and leads to increased efficiency. Also, by investigating the effect of the plate angles with respect to the flow direction, in all of the experiment, increased efficiency is observed compared to the cases without baffles and even with vertical baffles.

Table 2 The removal efficiency (%) of the basin for various cases

Number	Fr	*C*	No Baffle	Angles of Baffle (Degree)					
		gr/lit		30	45	60	90	120	150
1	0.026	1	70.2	70.4	70.9	71.1	70.5	70.1	69.6
2	0.026	3	75.8	76.5	77.3	78.2	77.1	76.5	74.9
3	0.026	5	82.6	82.9	83.5	85.3	84.2	82.8	79.3
4	0.063	1	67.4	66.8	67.5	69.1	68.1	67.2	61.8
5	0.063	3	72.2	72.3	74.3	76.8	75.8	73.9	68.5
6	0.063	5	78.5	78.6	79.8	83.7	81.4	79.3	73.8
7	0.116	1	63.3	63.1	63.4	65.6	64.4	62.1	59.2
8	0.116	3	68.7	69.1	70.8	74.0	72.6	69.7	62.8
9	0.116	5	73.8	74.8	75.5	79.8	77.3	74.8	67.0

The highest increase in the efficiency was achieved for the tank with baffles with angle 60 degrees which was 6.2% compared to the case without baffles with the maximum flow rate and concentration. Also, in the case with the maximum flow rate and concentration, by changing the plate angles from 90 to 60 degree, the retention efficiency increases from 77.3% to 79.8% which shows a 2.5% increase. In general, the efficiency increase range in these two angles is between 0.60 and 2.5%. The results also show that the difference between the value of efficiency (%) of a sedimentation basin with baffle angle θ=60º increases from 2.5% to 9.0% compared to the basin without any baffle.

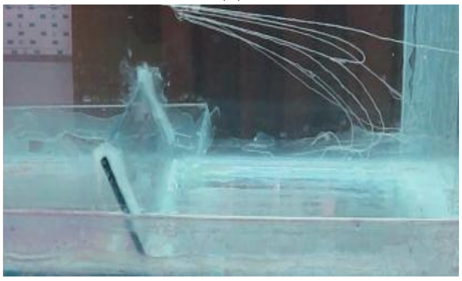
In Figs. 3 (a)-(d), the particles path-lines and flow vortices regions are displayed. According to the obtained results in Table 2 and Fig. 3, one could point out the following remarks:

1- In the upstream and downstream of the baffles, the vortex and rotational regions are formed due to pressure gradient which definitely directly depends on the dimensions and height of this structure and the smaller these regions, which lead to settlement of the sediments, the more favorable the condition for sedimentation.

2- It is correct that for baffle with fixed heights, increasing the angle (θ=90º) act as an obstacle against the flow and the efficiency increases compared to the case without baffles. However, increasing this angle leads to increased velocity in the upper edge of the baffles due to decreased effective depth of the flow and increased turbulence of the flow which causes the settling of the sediments not occur in these regions. Even at high flow rates, reverse flow and movement of the sediment toward the upstream of the tank is observed.

3- One could address the construction costs of the tank as an effective factor according to the explanations provided in the introduction. Considering the similar dimensions of these baffles, the efficiency could be increased only by changing the angle.

(a)



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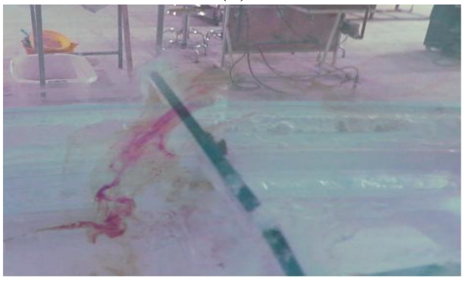

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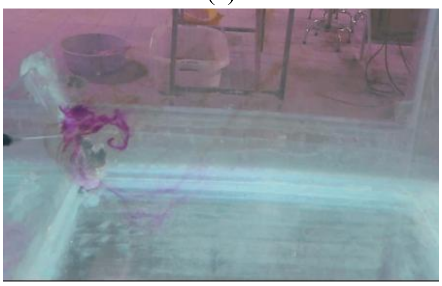

(d)

Fig. 3 (a) Longitudinal flow pattern, (b) cross-flow pattern, (c) streamlines and baffle upstream vortex, (d) streamlines and baffle downstream vortex

Also based on the results, one could deduce that in most of the experiments, increasing and decreasing of the retention efficiency of the tanks is observed for the baffles with angles less than 90 degrees and more than 90 degrees, respectively, compared to the case without baffles.

3.2 Determining the proper height of the baffles

To study the effect of the height of the baffles on the sequestration efficiency and determining the proper height, a series of experiments are carried out with plate angle 60 degrees (θ) and different heights (W) equal to 4, 5, 6, 8, and 10 cm with flow depths (H) 20, 25, 30, 40, and 50%, respectively with similar hydraulic conditions as the previous experiment and another 24 experiments were

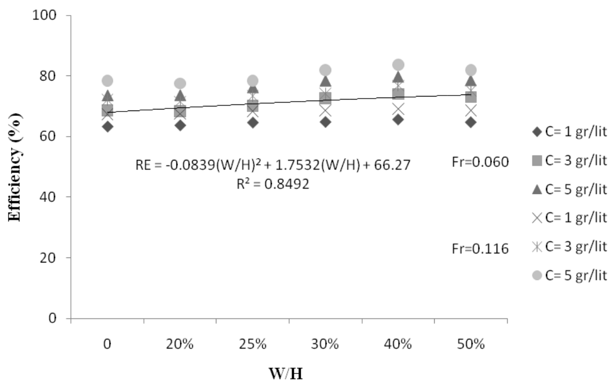

Fig. 4 Variations of removal efficiency considering different heights of baffles

performed. In these experiments, the effects of the location of the baffles parameter were neglected and in all of the experiments, the baffles were installed in the middle of the tank. According to the results of the previous experiment and the fact that the effect of the baffles on Froude number and low concentrations was negligible compared to the case without plate, this value was neglected.

The results presented in Fig. 4 shows that increasing the height of the baffles from 20% of the depth increases the sedimentation efficiency compared to the case without baffles. The maximum efficiency is achieved for 40% height in all the experiments and as expected, the maximum increase in efficiency compared to the case without baffles was for the maximum flow rate and concentration with a value of 6.2%. Based on the all the obtained results, a second order relationship was obtained for two parameters submergence depth of the baffles (W/H) and the retention efficiency (RE), which is illustrated in Fig. 4.

It was observed that the variations of efficiency increase at submergence depths 30% and 40% for both Froude numbers increase linearly with increasing the inlet concentration. For instance, Fig. 5 shows the variations of efficiency increase for Froude number 0.116 for depths 30% and 40% for which increasing the height of the baffles by 10% in high and low concentrations lead to efficiency increases of 26.50% and 53%, respectively. This could be justified by noting that by keeping fixed the condition of the flow and the inlet concentration as two effective parameters on the sequestration efficiency, the main factor of this efficiency increase is the presence of the baffles and the impact of their heights. In plate with submergence depths 30% and 50% compared to the case without baffles, the same efficiency increase was achieved. One could argue that in baffles with depth 30%, the main factor of this increase is the reduction of the vortex regions around; however in baffles with depth 50%, the height of the baffles is known to be the main factor of this increase. Also, during the experiments of the baffles with height 50% of the flow depth, it was observed that this height affects the flow depth and water surface and lowered levels of the water was observed as well. The efficiency decrease in this case compared to submergence depth 40% is due to the decreased effective depth of the flow and increased velocity on the baffles.

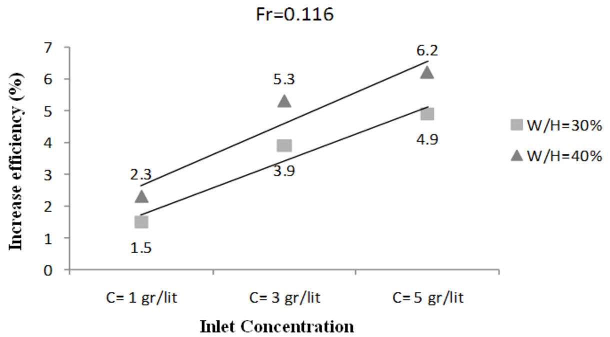

Fig. 5 Increasing of efficiency considering the variations of submergence depths of the baffles and the inlet concentration

3.3 Investigating the proper location for the baffles

In this series of experiments, in order to investigate the proper location for the baffles, the height of the baffles (*W*) is considered to be 8 cm equal to 40% of the water depth, baffle angle (θ) is considered to be 60 degrees and is located in various baffle distances from the inlet to tank length ratios, *S/L*=0.167, 0.33, 0.50 and 0.67 for a baffle height *W/H*=0.40.

Comparing the results presented in Table 3, one could conclude that the retention efficiency increase is higher for the sedimentation tanks with baffles in the middle of the tank. Also, the results show that in high flow rates and concentrations, the impact of the optimized location of the plate in the middle of the tank is higher and the efficiency increase is also higher in this case.

In this research, an efficiency increase of 6.2% was achieved at Froude number 0.116 and concentration 5 g/lit compared to the case without baffles. Considering the fine-grained sediments in these experiments, the assumptions that scouring and re-suspension of these particles are higher and they are usually at the end of the sedimentation tank were not out of sight; however, the obtained results reject this assumption. Also, considering the particles being fine-grained and due to their low settling velocity compared to the flow velocity, the impact of the baffles in close distances to the inlet has less effect on the sedimentation efficiency of the tanks. By comparing the values of the efficiency in the value ranges of (*s/L*) being 0.33 to 0.50 in most of the experiments, a small increase of about 1.1% was observed in the efficiency. Considering these values, this range could be considered to be the proper range for installing the baffles. Regarding the sedimentation regions in this case, more than 80% of the settled sediments were observed to be in the middle of the tank. Considering the condition of the flow and the same inlet concentration, the location of the baffles are a factor to increase the retention efficiency.

Studying the obtained results, a second order equation was derived relating the two non-dimensional parameters (*s/L*) and retention efficiency (*RE*) in all the experiments with mean squared (R^2=0.978) as follows

$$RE = -0.62(\mathrm{s/L})^2 + 4.559(\mathrm{s/L}) + 68.12 \qquad (3)$$

Table 3 Retention efficiency values (%) versus the variations of the location of baffles

Numbers	*Fr*	*C* gr/lit	No Baffle	S/L 0.167	0.33	0.5	0.67
1	0.063	1	67.4	67.6	68.0	69.1	67.5
2	0.063	3	72.2	74.5	76.1	76.8	75.2
3	0.063	5	78.5	79.8	82.6	83.7	81.1
4	0.116	1	63.3	63.8	64.6	65.6	63.9
5	0.116	3	68.7	70.8	73.1	74.0	72.0
6	0.116	5	73.6	75.60	79.1	79.8	76.5

Table 4 The impact of the inlet concentration on the values of retention efficiency (%)

Numbers	*Q* lit/s	*C* gr/lit	No Baffle	With Baffle	Different
1	2.22	3	75.8	78.2	2.40
2	2.22	5	82.6	85.3	2.70
3	5.00	3	72.2	76.8	4.60
4	5.00	5	78.5	83.7	5.20
5	6.00	3	71.1	75.6	4.50
6	6.00	5	76.6	81.8	5.20
7	10.0	3	68.7	74.0	5.30
8	10.0	5	73.6	79.8	6.20

The abovementioned results show that in all of the experiments, the highest retention efficiency and efficiency increase were met at high flow rates and concentrations which indicate the effectiveness of the baffles which could be installed and used in sedimentation tanks for rivers with suspended sediments and high flow rates.

3.4 Investigating the effect of inlet concentration

Since, in the constructed apparatus for injecting dry sediments, changing the inlet concentration was possible by changing the openness of the valve, the effect of the inlet concentration was studied as an effective factor on the efficiency for 4 flow rates and 3 concentrations and hydraulic conditions similar to the previous experiments. The baffles were considered with characteristics *W/H*=0.40, *s/L*=0.50 and θ=60°. Considering the obtained results in Table 4, as it has become clear, efficiency increase is achieved at the same hydraulic condition (flow rate, velocity and water depth), particle size and sedimentation tank dimensions by increasing the inlet concentration. According to Fig. 6, one could point out that considering the slope of the efficiency increases, the efficiency increase in the tank with baffles at high concentrations is higher. In this study, for concentration 3.0 g/lit, except for the low flow rate 2.22 lit/s, for other flow rates 5.0, 6.0 and 10.0 lit/s, the efficiency increase was obtained to be 5.6, 4.4 and 5.3%, respectively.

3.5 The effect of froude number

Also, to study the flow rates and its impact on the efficiency, conclusions were made from the results of the

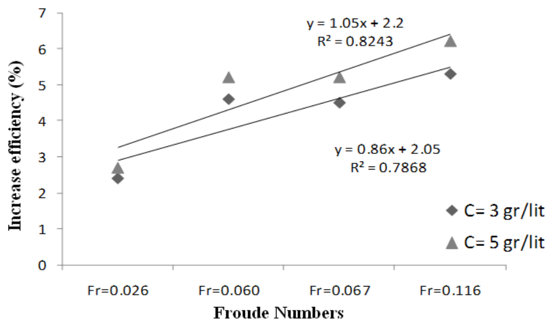

Fig. 6 Sedimentation tank efficiency increase versus the inlet concentration with baffles

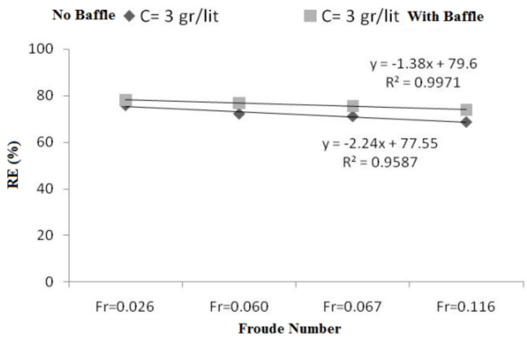

Fig. 7 The variations of sedimentation tank efficiency versus the Froude number with and without baffles

previous experiments and Table 4. In irrigation sedimentation tanks, increasing the flow rate with the same characteristics, the retention efficiency decreases with and without baffles (Fig. 7). However, according to Fig. 6 and the slope of the lines, the efficiency reduction is lower for the tanks with baffles by increasing the flow rate.

In this study with concentration 5 g/lit and similar conditions, increasing the flow rate from 5.0 to 10.0 lit/s, causes the sequestration efficiency to decrease from 83.7% to 79.8%. One could deduce that increasing the flow rate (Froude number) increases the flow velocity and consequently increases the vortex and eddy regions in the flow. These vortices lead to the movement of the sediments, even the settled sediments, and decrease the settling of the sediments and finally decrease the sedimentation efficiency. Another point is that even though the sedimentation efficiency decreases in two cases of with and without baffles by increasing the flow rate, the efficiency difference between the tank with and without baffles shows an increase (Table 4) which in turn shows the effect of the baffles. Also, it is observed that decreasing the flow rate and Froude number (Fig. 6) reduces the effect of the baffles on the sedimentation efficiency of the tank and the values of efficiency are close to one another. This result is also evident in Tamayol *et al*.'s work (2010).

3.6 The effects of flow depth

To study the effects of the flow depth on the retention efficiency based on the height of the laboratory flume and weir, depths 20, 24, and 25 cm were selected as the new options. Then the experiments were carried out for the

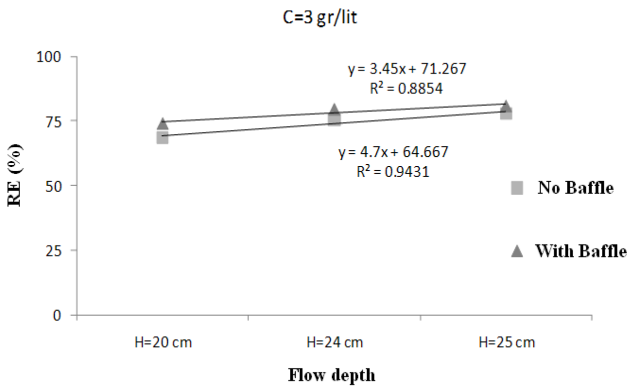

Fig. 8 The variations of sedimentation tank efficiency versus the flow depth with and without baffles

sedimentation tank with and without baffles with flow rate 10.0 lit/s and moderate concentration class 3 g/lit. The characteristics of the baffles were considered to be the same as the previous experiment. It was observed that decreasing the depth of the water in sedimentation tanks with and without baffles, the efficiency decreases (Fig. 8). It could be noted that decreasing the depth, decreases the effective level of the flow and consequently leads to increasing the velocity and creating vortices and eddies in the tank.

In this study, for flow rate 10.0 lit/s and concentration 3 g/lit, 5.3% and 4.2% efficiency increase was achieved for 20 to 24 cm, respectively. Here, unlike the results for flow rates, it was determined that considering the sedimentation efficiency increase in two cases of with and without baffles, increasing the depth, leads to decrease in the difference of the efficiencies between the tanks with and without baffles which shows the effect of the height parameter. The efficiency decreases, when height of baffle is not optimal condition.

According to Fig. 8, by increasing the depth of the flow, the slope of the variations of efficiency is higher in the sedimentation tanks without baffles. It is worth noting that due to increasing the depth of the water to 24 cm, the 8 cm height of the baffles are decreased from the 40% water depth optimal point and the same situation happens for the experiments of the first series with depth 20 and plate height 5 cm (efficiency increase is about 4%).

4. Conclusions

Sedimentation basins are used in irrigation networks for the removal of suspended sediments. Installation of baffles can improve the efficiency of the basin in terms of settling. By the experimental studies on the effect of the baffles on the irrigation sedimentation tanks efficiency, it is found that:

- Using one vertical plate on the bottom of the tank, considering the flow rates used in this research, causes the efficiency to increase by 3.9%. By decreasing the angle of the baffles from the vertical position with respect to the flow direction, an increase is observed in the efficiency. The best angle with the highest efficiency increase (6.2%) among different angles is obtained to be 60 degrees.

- By increasing the flow impact angle on the baffles, their performance of the sequestration of sediments is decreased.
- The best performance was observed for the experiments with baffles with height 40% of the flow depth with 60 degree angle with respect to the flow direction and the efficiency difference variations was observed to be 26% to 53% by increasing the height of the plate by 10%. In the same flow condition, in order to increase the retention efficiency of the tanks, using the baffles in the middle of the tanks seems appropriate.
- In the range of one-third to the middle of the tanks in all conditions, the variations of efficiency increases are about 0.7% to 1.1% which could be introduced as the proper range for installing the baffles.
- The highest sequestration efficiency of the tanks with plates were observed for high flow rates and concentrations which shows that the plates could be installed and used in sedimentation tanks for rivers with high inlet suspended sediments with high flow rates.
- By increasing the inlet concentration, the retention efficiency increases in both cases with and without baffles and the efficiency increase in higher for tanks with baffles compared to the tanks without baffles.
- Considering the obtained efficiency values, increasing the flow rate, cause the percentage of the particles in the outlet to increase. This increase is about 20% to 30%.
- Increasing the flow depth by 25% in sedimentation tanks with the same plate characteristics, the efficiency different compared to the case without baffles decrease from 5.3% to 2.8%, showing a 50% decrease.
- Furthermore, the measured data indicates that by increasing the Froude number and decreasing the depth of flow, the removal efficiencies of the basin with and without baffle are decreased.
- The results showed that increasing the submergence depth from the optimal point has an inverse impact on the efficiency.

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