Using lower and upper baffle arrangements to enhance sedimentation tank performance

E A AL-Mafraji and H A Al-Mussawy

1 M.Sc. student Dept. Of Environment Engineering, College of Engineering, Mustansiriyah University, Baghdad 10047, Iraq
2 Asst. Prof. Dr Dept. Of Water Resources Engineering, College of Engineering, Mustansiriyah University, Baghdad 10047, Iraq.

Abstract. Traditional sedimentation tanks are massive structures that need require extensive detention times to allow the separation of particles from suspension by gravity. Many researchers have proposed methods of enhancing sedimentation efficiency, including changing the geometry of tanks by installing barriers at the bottom of the basin, in order to reduce demand for chemical processes, which require trained operators to determine the appropriate doses of coagulants. The aim of the current research was make the flow route longer and to distribute suspension over various sedimentation tank compartments in order to increase residence time and thus enhance sedimentation, with effects judges based on calculating the turbidity, density, and viscosity, Froude number (Fr), Reynolds number (Re), settling velocity (vs), detention time (D.T.), height of sludge (hs), and sediment removal. The theoretical aspects were supported by the collection of practical results through laboratory testing that showed that the best Fr, Re, and hs occurred in zone 3, where the opening height of the central baffle created a short-circuit that scoured the deposited particle, while the best turbidity removal occurred with the smallest discharge. The evidence overall suggested that adding both lower and upper baffles improves the performance of sedimentation tanks because this arrangement achieves two essential goals: lengthening the track and damping or calming the flow within the settling zone; however, this only occurs if the vertical upper baffle is situated in a suitable location.

Keywords: sedimentation tank baffles, short-circuiting, stability flow, residence time, sedimentation efficiency

1. Introduction
Suspended solids are the main cause of pollution in surface waters, especially with regard to heavy metals. These solids can quickly clog sand filters [1], and thus different types of sedimentation basins, whether natural or constructed, are required to manage surface water and to control the infiltration of suspended particles.

Despite the continued successful design and reliable operation of current water treatment plants, these issues remain a source of concern for all water workers and constant adjustments and technology development are ongoing to improve performance in this regard. Making adjustments to poorly performing conventional sedimentation basins is an ongoing task, and various techniques to improve the performance of even adequate systems are constantly under development. One of the factors most in need of enhancement in sedimentation tanks the hydrodynamics of proper flow.

Stability of a channel is often a challenge when water is withdrawn from the basin by the water intake, thereby reducing the velocity of the flow going to an estuary, as this changes the
sedimentary transport rate in the estuary near the outlet, causing the level of protection in the area surrounding the entrance to increase, causing obstruction, which disturbs the balance between the flow and sediment transport and the natural channel stability[3]. Poor overall performance is often a result of space limitations and hydraulic inefficiency [24], which may thus result in long-term detriment to society [25].

Lamella [2], trap or baffle boxes [4], or vane system methods can be used to enhance sedimentation management. Lamella may create problems due to the requirement for large numbers and the small distances between each one, however, as this shortens the path of the particles and makes them deposit more rapidly, causing corrosion and blockages. These thus require frequent replacement, however, increasing the economic cost.

Barriers are one of the most inexpensive methods and often the most effective way to improve hydraulic properties; they can also be used to improve the settling properties of suspensions or lamella [2]. Over time, their efficiency is reduced, however, even if they are cleaned internally. Several studies have been conducted on single baffles with different positions, heights, and angles both in the laboratory and in large basins, while other researchers have investigated using several baffles, analysing the relevant data in many different ways, such as simulation using C.F.D. or mathematical modelling using experimentally defined parameters [5-23].

Combination baffles can be used to direct the flow and redress harmful hydraulic properties. The configuration of the S-form connected baffle was achieved over several studies [26-32] to lengthen the flow path and increase detention time to enhance the settling process. However, it is expensive to implement inside a large basin and may also generate strong and undesirable disturbances at the turns, generating hydrodynamic scour, especially at high flow rates, by forcing the flow through a cramped path and altering the direction unnecessarily.

Researchers in [33] suggested incorporating wide puddles with holes of various sizes to restrict flow in a sedimentation basin's core to improve the effectiveness of sediment trapping. Although the barriers distributed the flow energy in a balanced manner through the sedimentation basin, offering increased detention time and enhancing the removal of particles, particle accumulation and cleaning barriers were a concern for the workers involved. Likewise, [34] placed perforated walls inside a swamp between the entrance and exit area to distribute the strong flow between barriers holes that allowed only a small portion of the flow to pass, causing a decrease in the volume of deposits washed out by the rapid flow.

The impact of using barriers positioned at the entrance on damping and distributing rapid flows to improve the sedimentation process has been investigated in several studies [35-37]; those using numerical and physical modelling methods have thus generated several positive results. However, [38-39] suggested that the inlet structure should be located at the basin bottom in order to make the density stream more stable when density flows differed; this impacts the sedimentation technique because it prevents the particles from settling in layers.
Tests were conducted in [40] for two different configurations of barriers (parallel connected barriers and series-connected barriers) for a number of flow rates in order to investigate sedimentation basin performance in terms of total suspended solids removal and increased detention time. The parallel connected barriers were identified as the preferred option for high flow rates, as they distribute robust and rapid flow faster and into smaller regions by dividing flow into smaller branches instead of relying only on the intrafraction of flow above long flow course as seen in series-connected barriers.

In this paper, a combination of a vertical lower baffle and a vertical upper baffle in the lower area was used to create a baffle system. This system divided the tank into several compartments and caused the water to move over and under the baffles, lengthening the flow and distributing the suspension in each compartment or zone, thereby increasing residence time and enhancing the performance of the sedimentation tank.

2. Material and Method

2.1. Hydrometer test
The sieves used were arranged from top to bottom as 300, 200, and pan; 500 g of kaolin were then added at the top, and the sieves were shaken by mechanical vibrators until the kaolin stopped passing through them. A 50 g sample of the kaolin that passed through the 200 sieve was then taken and added to a pan with 125 ml of 4% NaPO₃ solution for a period of 14 hours. This was then transferred to the mixer cup and distilled water was added such that two-thirds of the mixture was covered for a minute; the entire mixture was then transferred to a graduated cup and covered. The graduated cup was flipped up and down once a second for a minute (60 times), then placed on a flat surface for two minutes. A hydrometer was inserted very slowly into the graduated cup, and a first reading of the hydrometer and the temperature of the solution was recorded. These readings were repeated after 4 and 5 minutes, then at 8, 16, and 30 minutes and 2, 4, 8, 16, 32, 64, and 96 hours. The data was recorded until identical readings indicated the end of particle precipitation, after which the smallest deposition diameter for the kaolin substance was determined; after 25 days, this was 0.0002 mm as seen in equation (1).

2.2. Preparation suspension and tracer dye
Different proportions of kaolin (Gt = 2.65 by pycnometer, as in equation (3), d = 0.0002mm by hydrometer test as in equation (1)) were added to the tank until the turbidity required was obtained. This was achieved in this experiment at 21.9 g of kaolin inside a 119L feed tank (tank supply sedimentation basin) filled with tap water (10 NTU, turbidity measured using a turbidity meter), as shown in fig. (1). The water density was not changed by the dye added as a tracer in this experiment to allow the pattern of water flow through the tank to be observed visually. A 3g packet of Blue Dye was opened and poured into a litre of deionized or distilled water and shaken well. A 1-litre bottle was used for storage of the prepared Blue Dye.

2.3. Experimental design and procedure
2.3.1. Empirical configuration

The settling process was observed in a laboratory model of a sediment formation tank obtained from Armfield Engineering (UK). The tank was 100 cm long, 40 cm wide, and 25 cm deep, with a depth of water of 20 cm. The slope of the tank bed was zero. Three baffles were placed in the basin at distances from the inlet of 20 cm, 50 cm, and 80 cm, respectively. The height of the two baffles from the bottom (gate opening or orifice) were 0 cm, 3 cm, and 6 cm, as shown in figure 1. The feed tank, which had a maximum capacity of 120 l, was used to prepare the suspension, and the flow rate of the sedimentation tank was fixed at 1 litre per/min by means of the gate valve and flow meter. The freshwater was mixed with kaolin continuously within the feed tank inlet flow before the flow was fed into the sedimentation tank using a circulation pump. The sedimentation tank was placed ahead of the tank to ensure a stable flow of suspension was maintained, and fluctuation was ensured on it entering the basin to prevent particle concentration in the internal flow. A stopwatch was started when the supply valve was opened and the tracer dye added to the sedimentation basin. After that, samples were taken from the entrance, exit, and inside the sedimentation tank, as shown in table 1, and measurements of turbidity, density, and viscosity were conducted to allow hydraulic parameters and turbidity removal to be calculated.

2.3.2. Sample collection

All samples were collected using plastic tubes (10 ml). Samples were taken of raw water, the water settled in each zone inside the basin, and treated water, and the physical and chemical properties of the samples were determined by means of testing conducted using equipment available in the water treatment lab of the Environmental Department in the College of Engineering at Al-Mustansiriya University/Iraq.

2.3.3. Turbidity, mass density, and viscosity measurements

Turbidity was measured using a turbidity meter supplied by the Hatch Company. Mass density was measured using a pycnometer of standard volume, with and without suspension; the reading was then entered as in equation (5). Viscosity was measured using a Canon-Fenske Routine viscometer, with 10 ml of suspension added to the pipette pump. Once the liquid reached an appropriate level in the viscometer, the sucking was stopped, and the pipette pump removed. The time required in seconds for the sample to travel the required distance (A to B) on the viscometer was then recorded. The experiment was repeated by replacing the suspension with distilled water, and the time taken by the distilled water to pass through the capillary tubes was also calculated and it is entered in the data as in equation (4).
Figure 1. Schematic diagram of the laboratory sedimentation tank set-up with baffles.

2.4. Applicable Equations

\[ d_p = K \left( \frac{L}{T} \right)^{0.5} \quad (1) \]

\[ \rho_s = \frac{M_{\text{Sample}} - M_{\text{air}}}{\text{vol}_{\text{psc}}} \quad (2) \]

\[ G_t = \frac{\rho_s}{\rho_w} \quad (3) \]

\[ \mu_s = \frac{\mu_s \rho_s t_s}{\rho_w t_w} \quad (4) \]

\[ SOR = \frac{q}{l_z w} \quad (5) \]
\[ V_h = \frac{q}{hW} \quad (6) \]

\[ Re_{in} = \frac{\rho_w V_{in} d}{\mu_w} \quad (7) \]

\[ Fr_{in} = \frac{V_{in}}{\left(\frac{\rho_s - \rho_w}{\rho_w} g d\right)^{0.5}} \quad (8) \]

\[ R = \frac{W h}{2h + W} \quad (9) \]

\[ Re = \frac{\rho_w V_{in} R}{\mu_w} \quad (10) \]

\[ Fr = \frac{V_h}{\left(\frac{\rho_s - \rho_w}{\rho_w} g R\right)^{0.5}} \quad (11) \]

\[ V_s = \frac{g (\rho_s - \rho_w) d^2_i}{18 \mu_g} \quad (12) \]

\[ V_{cr} = \frac{D}{D.T} \quad (13) \]

\[ V_{Sc} = \left(\frac{40 (\rho_s - \rho_w) g D}{3 \rho_w}\right)^{0.5} \quad (14) \]

\[ pr = \frac{V_S}{SOR} \times 100 \quad (15) \]

\[ D.T = \frac{vol}{Q} \quad (16) \]

\[ C_m = C_i \times pr \quad (17) \]
\[ M_{ds} = C_m \cdot Q \quad (18) \]

\[ M_{ws} = \frac{M_{ds}}{ps} \quad (19) \]

\[ h_s = \frac{M_{ws}}{\rho_w w L_z} \quad (20) \]

3. Results and discussion

3.1. Effect of upper and lower baffle arrangements on velocity, short cycle incidence, and turbulence flow.

The distribution of the suspended solution inside the basin dramatically affected sedimentation efficiency due to the irregular distribution caused by the currents and high flow velocities near the bottom of the basin, which led to scour of the stable sludge layer. In addition, the irregular flow created dead spaces inside the sedimentation basin, where the baffles tended to reverse the incoming flow to create a more even flow in the reservoir. Figure 2 shows how the baffle arrangement straightened the flow paths and minimised the turbulence.

![Figure 2. The flow path through the upper and lower baffle arrangement.](image)

The tank was divided into four compartments by the upper and lower baffle arrangements, with the influent point in the lower tray, and the turnaround on the top tray creating both "diagonal flow" and "plug flow" inside the sedimentation tank. This decreased the "short-circuit" and allowed for adequate detention time.
Figure 3 show that the baffles effectively stopped rotational motion and induced turbulence where the baffle was spaced 6 cm from the bottom (covering a third of the water depth), while in the case of the 3 cm baffle, a short-circuit was created before and after the upper baffle.

![Image of Figure 3 showing short-circuit upstream and downstream of the upper baffle where spacing from the bottom was 3 cm.](image)

**Figure 3.** Short-circuit upstream and downstream of the upper baffle where spacing from the bottom was 3 cm.

When the flow moved under the baffle at the height of 3 cm, the other baffles did not achieve counter-current flow in the ensuing transfer compartment, as friction resistance along the walls of the basin and on its bottom hindered the movement of water. Consequently, the speed of motion of the liquid near the walls and the bottom was less than its mean value, while in the centre of the basin, it was greater than its mean value, causing turbulence and the formation of vortices. This suggests that any baffle must be deep enough to prevent the flow pulling under the baffle.

The flow system's stability is indicated by the Fr coefficient, which should be more than $10^{-5}$ for regular flow. Figure 4 shows that the baffles arrangement created a stable hydraulic flow, particularly in the case of the upper baffle at high discharges, based on the Froud number parameters, which are within the specified range of uniform flow.
Figure 4. Variations in Froude number with discharge along the basin.

The upper barrier progressively increases the damping ratio, especially when the barrier is close to the surface of the water; placing the top edge of the barrier under the surface of the water causes the drift to pass over it, preventing floating matter from escaping into the effluent. The effect of the barrier is reduced when it reaches the free surface, however, as the tank becomes separated. In the upper mounted barrier, the damping ratio increased when it was close to the liquid surface and increased barrier depth caused the liquid to flow downward, calming the flow field and reducing energy accumulation due to small differences in the relative speed. The ideal sedimentation tank values are $Fr > 10^{-5}$, as small Froude numbers indicate flow not controlled by horizontal flow that may incur back mixing; however, as the Froude number increases significantly, disturbance may increase or there may be a transfer of the anchorage of the bottom. Increasing the Froude number increases discharge, as it reflects an increase in the speed of entry, reducing the efficiency of removal whether a barrier is used or not; however, introducing a barrier reduces the rate of increase, especially at high speeds, consistent with previous research [18]. An increase in Froude number also means an increase in Reynolds number, and thus the movement seen in figure 4 and the shape seen in figure 5 are compatible in terms of increase and decrease.

A cross-velocity vehicle is present in turbulent flow, which causes the isolated particles to scatter and reduces efficiency. Ensuring laminar flow is difficult, and flow is often carried out in horizontal rectangular sediments under conditions with less efficiency than those calculated for ideal conditions. When developing these basins, it is important to acknowledge that the use of barriers can greatly affect such flow.
Figure 5 shows the reduced turbulence of the inflow caused by the baffles at 0.4 litres/min, which is greater than at 1 litre/min; however, in both cases, the flow remains stratified.

![Graph showing variation in Reynolds number with discharge along the basin.](image)

**Figure 5.** Variation in Reynolds number with discharge along the basin.

The $Re_{in}$ at 0.4 L/min and at 1 L/min (Reynolds number in pipe controlled by influent discharge, as in equation (7)) is smaller than 2,000; the flow of water entering is thus laminar. The $Re$ at both 0.4 L/min and 1 L/min (Reynolds number inside the sedimentation tank as in equation (10)) is smaller than 20,000, indicating that this was also laminar flow, and although the $Re$ at 0.4 L/min was the best, the effect of the baffle is clearer at 1 L/min, especially in terms of how the upper baffle dampens the flow. As Reynolds Law is the product of a solution of the Navier stock equations used to study the real flow of fluid, the speed of entry of water affects the value of the Reynolds number; whenever the entry velocity of the suspended solution is low and whenever there is turbulence, the role of the barrier is more apparent in terms of the estimation of the entry velocity.

### 3.2. Effect of upper and lower baffle arrangements on scouring and removal

The rate of gain of momentum under the gravitational field and the rate of loss of momentum to resist buoyancy remain the same, while the rate of loss of momentum due to fluid friction increases with the increase in settling velocity. This causes a situation whereby the particle gains momentum under the gravitational field at the same rate as it loses momentum to the surrounding fluid mass. Under this dynamic equilibrium, the particle falls with constant momentum,
generating the constant settling velocity, vs. This velocity may be the characteristic settling velocity or only the particle's settling velocity (vs). In settling, a particle is identified by its settling velocity (vs) and no other parameter.

Figure 6 shows that the settling velocity, as in equation (12), is constant in 1 L/min circumstances, while changing with the location and position of the baffles at 0.4 L/min.

As seen in equation (13), Vcr is the critical particle settling velocity between the top of the basin and the bottom, based on a specific detention time, which significantly affects the proportion of the settled particles removed. When both the surface and the bottom of the settling zone are identical and parallel, the particles are in a discrete state in which the critical settling velocity equals the overflow velocity or surface loading; at that point, removal is independent of the depth of the tank.

Figure 7 shows that all particles had vs. < vcr moving through the length of the settling zone, and thus did not re-enter suspension.
Relationship between $v_s$ and $v_{cr}$ along the basin at different discharges.

Removal of particles and non-removal of combined particle pathways within the settling zone are dependent on the relationship of $v_{cr}$ with $v_s$. When $v_s < v_{cr}$, the particles do not all attach to the sludge zone, and thus are removed partially in the ratio ($v_s/v_{cr}$).

Figure 8 shows that the flow with entry speed at 1 L/min slowed down by a greater amount inside the basin, as observed by determining the horizontal velocity of the suspension per equation (6) inside the basin.

![Figure 8](image_url)
The role of the baffles is clearer in the high discharge despite turbidity removal being greater with low discharge; this is due to the role of the slow speed of entry to the sedimentation tank, as horizontal velocity plays an essential role in turbulence, scour, and the formation of short-circuits.

Negative flow distribution may create surges of flow at the bottom of the tank and cause particle transportation along the basin's length to the exit, preventing the removal of solids from water by sedimentation. Figure 9 shows that the horizontal velocity in this case was just sufficient to cause $V_{sc}$ to be greater than flow velocity so that no bottom scour occurred.

![Figure 9. Relationship between $V_h$ and $V_{sc}$ along the basin for different discharges.](image)

Scour velocity is based on the principle of the force of particle transport and the movement of particles deposited at the bottom; when $V_h < V_{sc}$, no scour occurs at the bottom of the tank. The carrying and scouring powers of flowing water, which are a function of its velocity, are reduced, allowing suspended particles to settle by gravity to the bottom of holding tanks or basins and to not be resuspended by scour.

Figure 10 show that water velocity toward S.O.R. as in equation (5) is greater than water velocity down (vs), causing the water to exit from the tank before all particles have sunk to the bottom of the tank, causing partial removal. A larger percentage of removal was seen in the zones located before and after the upper baffle because its cross-sectional area was larger than that of the others.
Figure 10. Effect of baffle arrangements at different discharges on the direction of water velocity affecting ss removal.

If the horizontal velocity is greater than the vertical speed, this can damage sedimentation tanks because it can cause drift in precipitating particles. The force of the water is greater than the gravitational force, causing sedimentation resulting from the vertical movement time to be dependent on the horizontal movement, as particles may exit before sedimentation is deposited where inlet turbid water is equal to outlet turbid water.

Figure 11 shows that the horizontal velocity was higher than the vertical speed, and that the comparison ratio increased as the discharge increased; when comparing the horizontal velocity of flow with the horizontal velocity known to cause scour particles, however, it was shown to be lower.

Figure 11. Relationship between velocity (vs. and vh) with different discharges along the tank.
The lower vertical velocity (settling velocity) caused by the particles' small diameter was directly proportional to the settling speed and perhaps also the lack of internal turbidity affecting the sludge density deposited in each zone. This is consistent with Newton, who explained that if force acted in a suspension, there would be no acceleration other than a steady falling velocity known as granule drop. This is another reason for the increase in settling time over detention time as seen in figure 12.

![Figure 12](image_url)

**Figure 12.** Relationship between time (tH and tV) with different discharges along the tank.

Figure 13 shows the percentage of turbidity removal and the absence of the particles that cause turbidity of outlet suspension to be identical to the turbidity of inlet suspension or the occurrence of scouring; this is evident from the increase of the turbidity of outlet compared with the turbidity of the inlet.
The turbidity removal is higher at a discharge of 0.4 L/min because the entry speed is slower. The greatest sludge height occurred in z1 (the entry zone); however, in terms of examining the effect of the barriers, it is clear from the chart that the speed of entry into the basin decreased more at the higher discharge.

**Figure 13.** Variation of turbidity with different discharges along the tank.
Table 1 shows that the best height of sludge was achieved when X/L was equal to 0.9, in zone 3, as shown in Figure 3, where the depth of water was equal to 10 cm. The best sedimentation process was seen in z3 because it had the best flow conditions (\(Re_3=2.688\), \(Fr_3=0.00015716\), \(hs=0.12614m\)) [18]. It was thus concluded that the depth of the water affects the percentage of removal and that the relationship between these is also directly related to the presence or absence of barriers, as the height of the water increases the area of water and reduces the speed; however, its effect on the various discharges or the locations of the barriers in this research was not examined. The efficiency of sedimentation varies with differences in water height, barrier height, and inlet drainage, though it is not necessarily true that when the water rises, the sedimentation increases.

In general, the sedimentation process is enhanced by using a lower and upper baffle arrangement, as this forces the water to flow over, under, or around the baffles, which lengthens residence: where detention time without a baffle was 1.33 hr, with the baffle arrangement, the overall detention time was 4 hr, and turbidity removal was increased by 25% with 0.0002 mm of kaolin without coagulant, which is naturally disinclined to settle because it moves directly with the effluent without particle amplification.

Table 1. Variation of \(hs\) at different discharges with X/L and H(m).

| Zone | X/L | Water height (m) | \(hs\) at 0.4 (L/min) | \(hs\) at 1 (L/min) |
|------|-----|-----------------|---------------------|-------------------|
| z1   | 0.15| 0.55            | 2.63844E-06         | 0.124622189       |
| z2   | 0.9 | 0.05            | 1.4135E-06          | 0.124245177       |
| z3   | 0.55| 0.05            | 9.14458E-07         | 0.121872426       |
| z4   | 1   | 0.05            | 2.7583E-06          | 0.124341352       |
| z1   | 0.15| 0.1             | 2.8143E-06          | 0.125431266       |
| z2   | 0.55| 0.1             | 9.02E-07            | 0.124442371       |
| z3   | 0.9 | 0.1             | 8.6683E-07          | 0.126136687       |
| z4   | 1   | 0.1             | 2.68964E-06         | 0.122888311       |
| z1   | 0.15| 0.15            | 2.71916E-06         | 0.116920809       |
| z2   | 0.55| 0.15            | 9.26589E-07         | 0.120168352       |
| z3   | 0.9 | 0.15            | 8.84333E-07         | 0.120540816       |
| z4   | 1   | 0.15            | 2.77812E-06         | 0.116903811       |
| z1   | 0.15| 0.2             | 2.73149E-06         | 0.120760566       |
| z2   | 0.55| 0.2             | 8.93748E-07         | 0.114552942       |
| z3   | 0.9 | 0.2             | 9.31289E-07         | 0.117086886       |
| z4   | 1   | 0.2             | 2.792E-06           | 0.117086886       |

\(^a\) Large \(hs\).
\(^b\) Moderate \(hs\).
\(^c\) Small \(hs\).
\(^d\) Very small \(hs\).
Most readings were highest on the edge of the baffle (upper baffle or lower baffle) nearest to the surface of the water, and the effect of the upper barrier (separated from the bottom by a distance 0.06 m) on z3 increased at a water depth of 0.01 m, where z3>z2. After this depth of water, the difference begins to decrease until it returned to similar conditions as before contact, where z3<z2. The upper baffle, which can slide up and down, has a clearer effect in terms of reserving the particles in the discharge at 1 L/min, and the maximum height of the sludge was found in z3.

4. Terminology

\( M_{\text{sample}} \): sample weight inside pycnometer, \( g \)

\( M_{\text{air}} \): air weight inside pycnometer (weight of empty pycnometer), \( g \)

\( \text{vol}_{\text{psc}} \): standard size for pycnometer used, 50 ml, \( \rho_s \), \( \rho_w \): density of particle, density of water, \( \frac{kg}{m^3} \)

\( G_t \): specific gravity at soil solid the same temperature, dimensionless

\( d_p \): particle diameter(2 * 10^{-7} m), m

\( K, L \): constants of the diameter calculation Tables

\( T \): length sedimentation time, \( min \)

\( t_s, t_w \): mean time of flow of particle from A to B; mean time of flow of water from A to B, \( sec \)

\( \mu_s, \mu_w \): viscosity of particle; thickness of water, \( pa.s \)

\( Q \): discharge of influent, \( m^3/sec \)

\( L_z \): length of each zone of sedimentation tank, m

\( w \): width of sedimentation(0.4), m

\( SOR \): surface overflow rate, \( m/s \)

\( h \): depth of water(0.2), m

\( V_h \): horizontal velocity, \( m/s \)

\( V_{\text{in}} \): inlet velocity \( \frac{Q}{\pi(d/2)^2} \), \( m/s \)

\( d \): diameter of pipeline entering the fluid(0.025), m

\( Re_{\text{in}} \): inlet Reynold number, \( \text{dimensionless} \)

\( g \): ground acceleration 9.81 \( m/s^2 \)

\( Fr_{\text{in}} \): inlet Froude number, \( \text{dimensionless} \)

\( R \): hydraulic radius, m

\( Re \): Reynold number inside sedimentation tank, \( \text{dimensionless} \)

\( Fr \): Froude number inside sedimentation tank, \( \text{dimensionless} \)

\( V_s \): settling velocity, \( m/s \)

\( D \): depth of fluid, m

\( V_{sc} \): scour velocity, \( m/s \)

\( vol \): volume of sedimentation tank(0.08), \( m^3 \)

\( D, T \) or \( th \): detention time or horizontal time (th), \( \text{hours} \)

\( pr \): present removal, %

\( C_m \): sludge concentration collected in bottom
$M_{ds}$: the mass of dry sludge, \( \frac{kg}{T} \)

$M_{ws}$: mass of wet sludge, \( \frac{kg}{s} \)

$h_s$: height of sludge, \( (m) \)

Turbidity removal = \( \frac{\text{inlet turbid} - \text{outlet turbid}}{\text{inlet turbid}} \) * 100

$X/L$: a distance of baffle from an inlet/length of tank

t$V$: The time of the fall or the vertical time, hour

5. Conclusions

1-Solid baffles may be constructed in a basin or similar device to dissipate water energy on the fluid entering or leaving the basin.

2- Inter-basin baffles that are distributed relatively uniformly across the length and width of the basin can increase the length: width ratio of the flow path and achieve a uniform flow pattern across the entire basin.

3- The functions of a basin’s barriers change with their location, height, number of obstacles, and arrangement inside sedimentation basin areas.

4-Baffles close to the entrance reduce a suspended solution’s speed entering the basin, while baffles placed at a midway point improve the flow suspension’s path, and baffles in the outlet increase detention time.

5- Anchored barriers can be used to increase stability in a pond without increasing turbulence or the risk of re-suspension.

6-The arrangement of the barriers may also affect the whole area: a lower vertical barrier near the entrance can further block heavy solid particles, while upper vertical barriers that do not touch the bottom reserve soft particles. Low barriers close to the exit also help to draw water towards the exit.

7-The edge of any barrier nearest the water's surface differs from the parts of barriers near the reservoir's centre in terms of debris removal percentage. This percentage increases the closer the barrier is to the water surface, as well as increasing with the number of barriers and the barriers' height

8- Lower and upper baffles arrangements may be particularly useful for very long sedimentation basins that may experience extra sloshing forces.
9- The desired Reynolds number and Froude number may be achieved by modifying the tank using a baffle arrangement instead of by manipulating the tank's height or width.

6. References

1- Kerry J. Howe, David W. Hand, John C. Crittenden, R. Rhodes Trussell, George Tchobanoglous (2012). "Principles of Water Treatment" John Wiley & Sons; Inc. Hoboken " New Jersey.

2- Rasha Salah AL-Kizwini. (, 2015)." Improvement of sedimentation process using inclined plates," Mesopotamia Environmental Journal. Vol.2, No 1:100-114.

3-Chih Ted Yang, Lawrence K. Wang. (, 2015). "Advances in Water Resources Engineering." Springer International Publishing, Switzerland.

4-Gordon England P.E., John Royal. (, 2002)." SEDIMENTATION CONTROL USING TWO BAFFLE BOXES IN SERIES. "

5-Ali Hadi Ghawi, Yaser Ibrahim Jasem. (, 2018)." Optimization of the Horizontal Sedimentation Tank to Predict Turbidity Removal Efficiency in Water Treatment Plant in Iraq." Diyala Journal of Engineering Sciences, Vol. 11, No. 1, March 2018, pages 33 – 37.

6-Mahmoud Lutfy, Kamal El-Nahhas, Mohamed Safwat. (, 2015)." PERFORMANCE OPTIMIZATION OF RECTANGULAR SETTLING TANKS IN SMALL WATER TREATMENT PLANTS BY NUMERICAL APPROACH." International Water Technology Journal, I.W.T.J. Vol. 5 – No.3 September 2015.

7-Fatemeh Rostami, Mahdi Shahrokhi, Md Azlin Md Said, Rozi Abdullah, Syafalni St. ( 2011)." Numerical modeling on inlet aperture effects on flow pattern in primary settling tanks." Applied Mathematical Modelling, June 2011, Pages 3012-3020.

8-Fatemeh Rostami, Mahdi Shahrokhi, Md Azlin Md Said, Rozi Abdullah, Syafalni St. ( 2011) "The Computational Modeling of Baffle Configuration in the Primary Sedimentation Tanks" 2011 2nd International Conference on Environmental Science and Technology. IPCBEE vol.6 (2011) © (2011) IACSIT Press, Singapore.

9-Hamidreza Jamshidnia, Bahar Firoozabadi, and Yasushi Takeda. (, 2010)." An experimental study of the flow structure in a rectangular sedimentation open channel in the presence of a baffle." Journal of Applied Mechanics Vol.13.
10-Mohammad Mehdi Heydari, Mahmood Shafai Bajestan, Heidar Kashkuli, H. Sedghi. (2013). "The effect angle of the baffle on the performance of settling basin." World Applied Sciences Journal, 21(6):829-837.

11-Amir Mehdi Ramzi, B. Firoozabadi, Roham Bakhtyar, David Andrew Barry. (2013). "Experiments and numerical modeling of baffle configuration affect the performance of sedimentation tanks." Canadian Journal of Civil Engineering 40(2).

12-Mahdi Shahrokhi, Fatemeh Rostami, Saeed-Reza Sabbagh-Yazdi, Md Azlin Md Said. (2012). "The effect of the baffle angle on primary sedimentation tank efficiency." Canadian Journal of Civil Engineering 39(3):293-303.

13-Mostafa Hassanian, Emad S. Elmolla, Usama F. Mahmoud. (2018). "Modeling the effect of inlet baffle longitudinal and vertical positions on the settling tank performance with computational fluid dynamics." Al-Azhar University Civil Engineering Research Magazine (C.E.R.M.) Vol. (40) No. (2).

14-Mohammad Mehdi Heydari, Mahmood Shafai Bajestan, Heidar Kashkuli, H. Sedghi. (2013). "The effective angle of the baffle on the performance of settling basin" World Applied Sciences Journal 21(6):829-837.

15-Saeed Al-Saadi, Salima Al-Yaqoubi, Nabila Al-Moharbi, Sheikha Al-Rusheid. (2016). "Study on Flow Behaviour in Rectangular Sedimentation Tank." International Journal of Scientific and Engineering Research 7(9):301.

16-Saber deldar, A. Jafarian, Hamidreza Kharinezhad arani. (2018). "Investigating the effect of flow entrance and existence of baffle on sedimentation efficiency using Discrete Phase Model (D.P.M.)." Tan's phenom, Nano Micro Scales, 629-36.

17-Hafez Asgharzadeh, B. Firoozabadi, Hossein Afshin. (2011). "Experimental investigation of effects of baffle configurations on the performance of a secondary sedimentation tank." Scientia Iranica 18(4):938–949.

18-Mohammad Mehdi Heydari, Mahmood Shafai Bajestan, Heidar Kashkuli, H. Sedghi. (2013). "Experimental study of baffle angle effect on the removal efficiency of the sedimentation basin." Middle East Journal of Scientific Research 20(1):65-73.

19-N. S. Park, S. S. Kim, Y. J. Lee, C. K. Wang. (2014). "Effects of longitudinal baffles on particles settling in a sedimentation basin." In: Water Science & Technology.

20- Athanasia M. Goula, Margaritis Kostoglou, Thodoris D. Karapantsios, Anastasios I. Zouboulis. (2008). "A CFD methodology for the design of sedimentation tanks in potable water-treatment, Case study: The influence of a feed flow control baffle." Chemical Engineering Journal 140 110–121.
21- Arash Farjood, Bruce W. Melville, Asaad Y. Shamseldin. (2015) "Optimisation of baffles for sediment retention ponds." Asia Pacific Stormwater Conference, Auckland, New Zealand, 20 May 2015 – 22

22- Tae Hoon Yoon, Seung Oh Lee. (, 2012). "Numerical modeling of sedimentation basins with a baffle." K.S.C.E. Journal of Civil Engineering 4(4):227-232.

23- Mahdi Shahrokhi, Fatemeh Rostami, Md Azlin Md Said, Syafalni St. (2013) "Numerical modeling of baffle location effects on the flow pattern of primary sedimentation tanks." Applied Mathematical Modelling 37(6):4486–4496.

24- Reed, S.C., Crites, R.W., Middlebrooks, E.J., 1995. Natural Systems for Waste Management and Treatment, seconded. McGraw-Hill, New York.

25- Su, D., Fang, X., Fang, Z., 2010. Effectiveness and downstream impacts of stormwater retention ponds required for land development. In: World Environmental and Water Resources Congress 2010, pp. 3071-3081.

26- Marsalek, J., Watt, W.E., Henry, D., 1992. Retrofitting stormwater ponds for water quality control. Water Pollut. Res. J. Can. 27, 403-422.

27- Pedahzur, R., Nasser, A.M., Dor, I., Fattal, B., Shuval, H.I., 1993. The effect of baffle installation on the performance of a single-cell stabilization pond. Water Sci. Technol. 27 (7-8), 45-52.

28- Shaw, J.K.E., Watt, W.E., Marsalek, J., Anderson, B.C., Crowder, A.A., 1997. Flow pattern characterization in an urban stormwater detention pond and implications for water quality. Water Qual. Res. J. Can. 32 (1), 53-71.

29- Walt, J.J.V.D., Water, M., 2000. To baffle or not to baffle e some baffled solution. In :The WISA 2000 Biennial Conference, Sun City, South Africa, 28 May 1 June.

30- Khan, L.A., Wicklein, E.A., Teixeira, E.C., 2006. Validation of a three-dimensional computational fluid dynamics model of a contact tank. J. Hydraul. Eng. 132 (γ), 741-746.

31- Zhang, J., Lee, H., Khoo, B., Teo, C., Haja, N., Peng, K., 2011. Modeling and simulations of flow pattern, chlorite concentration, and mean age distributions in potable water service reservoir of Singapore. J. Hydraul. Eng. 137 (7), 575-584.

32- Kim, D., Stoesser, T., Kim, J., 2013. Modeling aspects of flow and solute transport simulations in water disinfection tanks. Appl. Math. Model. 37 (16-17) 8039-8050.

33- Thaxton, C.S., Calantoni, J., McLaughlin, R.A., 2004. Hydrodynamic assessment of various types of baffles in a sediment retention pond. Trans. ASAE 47(γ) 741-749.
34- Thaxton, C.S., McLaughlin, R.A., 2005. Sediment captures the effectiveness of various baffle types in a sediment retention pond. Trans. ASAE 48 (5), 1795-1802.

35- Howard, A., Mohseni, O., Gulliver, J., Stefan, H., 2011. S.A.F.L. baffle retrofit for suspended sediment removal in storm sewer sumps. Water Res. 45 settlers (5), 5895-5904.

36- Tamayol, A., Firoozabadi, B., Ashjari, M.A., 2010. Hydrodynamics of secondary settling tanks and increasing their performance using baffles. J. Environ. Eng. 136 settlers (2), 1-39.

37- Ramzi, A.M., Bakhtyar, R., Firoozabadi, B., Barry, D.A., 2013. Experiments and numerical modeling of baffle configuration effects on the performance of sedimentation tanks. Can. J. Civ. Eng. 40 (2), 140-150.

38- Krebs, P., Vischer, D., Gujer, W., 1995. Inlet-structure design for final clarifiers. J. Environ. Eng. 121 (8), 558-564.

39- Ueberl, J., Hager, W., 1997. Improved design of final settling tanks. J. Environ. Eng. 123 settlers (2), 269-268.

40- Cheng He, Eric Scott, Quintin Rochfort, (, 2015). "Enhancing sedimentation by improving flow conditions using parallel retrofit baffles"Journal of Environmental Management 160 (2015) 1-6.