EFFECT OF BAFFLES ON THE FLOW AND HYDRODYNAMICS OF SETTLING BASINS: A REVIEW

Mohammad Mehdi Heydari* and Hamid Reza Mehrzadegan**

ABSTRACT

Settling basins are one of the most important and popular methods to remove suspended sediments from irrigation and drainage networks, power canals and wastewater treatment plants. In these structures, due to different velocity gradients, short-circuiting enlargement of dead zones and high flow mixing problems are caused by circulation regions (dead zones), which can reduce the optimal sedimentation of particles. A common approach to tackle these problems is to use baffles. This paper reviewed the research work on position and size of the baffles in settling tanks and their effects on the hydrodynamics and flow field. This review is a preliminary attempt to consolidate the information for future workers on settling basins.

KEYWORDS: Settling basins; sedimentation baffles; haudralic structure; position; hydrodynamics; velocity; turbulent; Iran.

INTRODUCTION

One of the problems in irrigation structures is sedimentation control in the irrigation networks (1). Sedimentation by gravity is the most common and extensively applied treatment process for the removal of solids from water and wastewater. Settling basins are essential hydraulic structures which have to be designed and constructed at all river water intakes to remove most of suspended sediments, which enter the intake with flowing water. There are two commonly used settling tank configurations, namely, circular and rectangular. The settling tank is the most important object of wastewater treatment plant. Two main types of sedimentation tanks are primary and secondary settling tanks. A primary settling tank has low influent concentration. Its flow field is minimally influenced by the concentration field and its buoyancy effects are negligible. Secondary settling tanks, however, have higher influent concentration (33). In many cases, buoyancy is simply

---

***Department of Water Engineering, Sciences and Research Branch, Islamic Azad University, Khouzestan, **Department of Mechanic Engineering, Kashan Branch, Islamic Azad University, Kashan, Iran.**

omitted from the k-ε turbulence models (42, 43). However, many other researchers opted to take buoyancy into consideration (11, 4). According to the investigations of Camp (8) and Swamee and Tyagi (54), the investment costs of settling facilities contribute to a large portion (typically one-fourth to one-third) of the total cost of treatment plant construction. A uniform flow field is essential to increase the efficiency of settling tank. This enables particles to settle at a constant velocity in less time (46). Due to sedimentation in these structures, problems arise like high costs of structures and maintenance, reduced capacity of water transport, annual acreage reduction, corrosion and damage of turbine. In addition, the existences of circulation regions (dead zones) reduce the sedimentation of particles and have major influence on the hydraulic condition of flow field inside the settling basins.

Circulation zones are named as dead zones in tanks because in these regions water is trapped and fluid have less volume for flow and sedimentation occured. According to this, the existence of large circulation regions lower tank performance (58). Baud and Hager (6) observed tornado vortices in the corners of rectangular settling tanks. To reduce the deteriorating effect of the density current on the effluent quality, influences of both size of aperture and vertical location of the inlet structure have been investigated (14, 29). Different methods are proposed for reducing the effects of these problems and increasing the tank efficiency (57).

A common approach for decreasing settling problems is to use baffles which can reduce effects of the unfavorable phenomena such as short circuiting between inlet and outlet and density currents in primary and secondary settling tanks, respectively (63). Use of baffles without a comprehensive flow study may result in tanks with lower performance and adding baffles will increase the cost. Therefore, it is essential to investigate the optimal position and size of the baffles in settling tanks. The baffles usually install at the bottom or surface of the rectangular settling tanks. Various studies have been conducted on the effect position and size of baffles on the flow and hydraulics of settling tanks (such as effect on velocity gradient near the bed, decreased the probability of short-circuiting, provide better conditions for sedimentation) and the major findings of these studies are presented here. In primary settling tanks for increasing their sedimentation performance, baffles are usually placed in the front of inlet opening, while for secondary settling tanks, baffles are built at the bottom of the tank to increase their sedimentation performance (63).

In this paper, the numerical and experimental research work on position and size of the baffles in settling tanks and their effects on the hydrodynamics and flow field was reviewed. Finally, suitable baffle position and size for rectangular settling basins is summarized. This review was a preliminary attempt to consolidate information for future workers on settling basins.

Equations and turbulent models

In this section, the usual governing equations for 2D fluid flow and sediments and the turbulence models in the settling basin are introduced.

The governing equations are conservation of mass and momentum. The flow is in a turbulent regime and Reynolds averaged Navier-Stokes equations govern the flow field. The three-dimensional effects are limited to a small region close to a wall, which can be neglected. Hence, the flow field is assumed to be steady and two dimensional, incompressible and particles are treated as a continuum field (63). The mass conservation equation for water (fluid) is given below:

$$\nabla.\vec{\boldsymbol{V}} = 0$$

Where $\vec{\boldsymbol{V}}$ is velocity vector.

The momentum equations are given below: (58, 63, 64)

$$\boldsymbol{u}\frac{\partial \mathrm{u}}{\partial x}+\boldsymbol{v}$$

u

$$\boldsymbol{u}\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{x}}+v\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{y}}=-\frac{1}{\rho}\frac{\partial \boldsymbol{p}}{\partial \boldsymbol{x}}+\frac{\partial}{\partial \boldsymbol{x}}\left(v\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{y}}\right)+\frac{\partial}{\partial \boldsymbol{y}}\left(v\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{y}}\right)+\frac{\partial}{\partial \boldsymbol{x}}\left(v_{\boldsymbol{t}}\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{x}}\right)+\frac{\partial}{\partial \boldsymbol{y}}\left(v_{\boldsymbol{t}}\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{y}}\right)\text{-- (2)}$$

$$\boldsymbol{u}\frac{\partial v}{\partial \boldsymbol{x}}+v\frac{\partial v}{\partial \boldsymbol{y}}=-\frac{1}{\rho}\frac{\partial \boldsymbol{p}}{\partial \boldsymbol{y}}+\frac{\partial}{\partial \boldsymbol{x}}\left(v\frac{\partial v}{\partial \boldsymbol{y}}\right)+\frac{\partial}{\partial \boldsymbol{y}}\left(v\frac{\partial v}{\partial \boldsymbol{y}}\right)+\frac{\partial}{\partial \boldsymbol{x}}\left(v_{\boldsymbol{t}}\frac{\partial v}{\partial \boldsymbol{x}}\right)+\frac{\partial}{\partial \boldsymbol{y}}\left(v_{\boldsymbol{t}}\frac{\partial v}{\partial \boldsymbol{y}}\right)-(3)$$

where u and v are stream wise and normal velocity in x and y directions. ρ is the fluid density.

In order to close the set of governing equations, turbulence models for calculation of Reynolds stresses are also required. Flow in the settling tanks is generally in a low Reynolds number turbulent flow regime. The Reynolds number based on the depth of tank is in the range of 10,000–80,000 (57). The existence of recirculation zones and the importance of prediction of size of these regions have made it necessary to use turbulence models carefully

(58). Thus, a proper turbulence model will improve the accuracy of predicted results (63). Many researchers have worked on the effects of different types of turbulence models on the flow field and concentration field. Although early researchers like Dobbins (12) and Camp (8) were aware of the importance of turbulent mixing and recirculation zones. They were not able to provide adequate solutions, due to the lack of suitable hydrodynamics and turbulence models. More advanced numerical models have been proposed recently by Larsen (29), Schamber and Larock (42), Imam and McCorquodale (19), Abdel-Gawad and McCorquodale (1), Celik ***et al.*** (9), Stamou ***et al.*** (51), Lyn and Zhang (31), Rodi (38), Adams ***et al.*** (2), Ashjari and Firoozabadi (5) , Jayanthi and Narayanan (22) and Fan ***et al.*** (13) which have been applied with at least partial success in prediction of the flow field in settling tanks. Many researchers used different types of k-ε models (standard, RNG) to simulate and predict flow field in settling tanks. Finally, RNG model is more responsive to the effects of rapid strain and streamlines curvature than the standard k-ε model, which explains the superior performance of RNG model for certain classes of flow (31). Particle dispersion, occulation or resuspension are considered another important aspect. Turbulence parameters, such as viscosity, intensity etc. are also important (58). Tamayol and Firoozabadi (58), Tamayol ***et al.*** (64) and Shamloo and Bayat (49) recommended the use of RNG model.

The effects of baffles

Various studies have been conducted on effects of position and size of baffles on the flow and hydrodynamics of settling tanks (sedimentation basins). Hamlan and Wahab (16) found that using a transverse baffle can reduce the effects of these factors, and enhance sedimentation performance. Imam ***et al.*** (19) solved the flow equations with a constant turbulent eddy diffusivity assumption. They have shown that the main hydraulic of recirculating flows could be reproduced with a constant eddy viscosity if a partial slip boundary condition is used on the solid boundaries. Imam (20) a complete simulation of a tank that has a depth/length ratio 1:7 used to formulate the flow equations. Imam ***et al.*** optimized the height of baffle about 25% of depth (baffle height-to-depth ratio of $H_b/H=0.25$). More than that leads to the formation of a bottom jet at the bed of tank which occurs as a result of circulation in the sedimentation layer and non-uniformity of velocity field. Lower than that would results in short-circuiting enlargement of the dead zone (19). Crosby (10) observed that a mid-radius baffle extending from the floor up to mid-depth decreased the effluent SS concentration of the clarifier by 37.5%. Krebs (25) and Krebs ***et al.*** (24, 26) investigated the effect of inlet and intermediate baffles on the flow field in final clarifiers. Their research was based on experiments, numerical modeling and analytical relations. In rectangular tanks, influent enters the basin at inlet. Energy dissipation is the main objective in designing a primary clarifier inlet. Energy of influent must be dissipate at the inlet zone by selecting the best position and configuration of inlet or using the baffles in inlet zone (26). Zhou and McCorquodale (68, 69) also investigated the effects of density stratification on the hydrodynamics and flow field in secondary settling tanks with and without reaction baffles. In these simulations, the sludge withdrawal took place homogeneously over the bottom boundary while the upper end of sludge blanket was regarded as the lower boundary of computational domain. The model indicated that the presence of a baffle can reduce this entrainment. Zhon ***et al.*** (70) applied numerical modeling to study the performance of circular clarifiers with reaction baffles under various ranges of suspended solid concentrations and hydraulic loadings. The importance of a baffle in dissipating the kinetic energy of incoming flow and reducing short circuiting indicates that the location of baffle has a pronounced effect on the nature of flow (70). Bretscher ***et al.*** (7) recommended the use of velocity and concentration fields for a rectangular clarifier equipped with an intermediate baffle. The aforementioned studies showed that the installation of intermediate baffle is effective. But experimental investigations of Taeby-Harandy and Schroeder (56) on the primary clarifiers showed that the placement of an intermediate baffle, installed close to middle of the clarifier and extended from the floor upward to one-third depth had no significant effect on efficiency. They believe that the discrepancy between results of their studies and other workers is likely due to the difference in flow patterns meaning that, if the dominant current is a surface current, a baffle extending from the top upward may improve the solid removal efficiency (56).

Ahmed ***et al.*** (3) studied the effects of position and height of baffle in a secondary sedimentation tank by placing the baffle at three different positions and various heights, qualitatively. The best result for the case in which an inlet baffle of the height of 67% of the total depth was placed in the first 5% of the channel. It should be noted that the suitable position for a baffle is directly related to flow field and buoyancy force (3). The construction of baffled channels in water treatment plants with no mechanical parts is considered to be more reliable, requires less maintenance and hence reduces cost (53).

Yoon and Lee (67), a mathematical model for predicting velocity field and concentration distribution of suspended materials in a settling tank is established by stream-function and vorticity transport equations with a constant eddy viscosity. The eddy viscosity is determined by using measured data. The model was tested with measured data for velocities and concentrations. The model was applied to investigate the effect of submergence and location of a baffle on removal of solid. It is found that the model can be used to simulate velocity fields and concentration profiles for two open channels effluent system. Also, they indicates that more efficient settling of suspended materials can be taken place in the range of submergence of H_b/H (baffle height-to-depth ratio) =0.4-0.5. The experiments were conducted with a two effluent systems consisted of midsection effluent and end effluent, at both effluents the removal efficiencies are maximum at about $H_b/H=0.4$.

Tamayol ***et al.*** (65) investigated the effect of inlet and height of inlet baffle on the flow field and performance of primary settling tanks. They found that for primary settling tanks, the interior baffle is not suitable and it does not affect the flow field.

Huggins ***et al.*** (18) tested a number of potential raceway design modifications, noticed that by adding a baffle, the overall percentage of solid removal efficiency increased from 81.8 to 91.1%.

Tamayol ***et al.*** (62) simulated the effect of a simple baffle at various positions. Their results showed that when the baffle is located in recirculation region, the dead zone (recirculation regions) would be reduced in size and the best position for baffle is somewhere in the circulation zone to spoil this circulation region. Moreover, if the baffle is located in an improper position or if it has an improper height, the particle removal performance in primary sedimentation tank would be decreased drastically (62, 60). Tamayol ***et al.*** (61) found that best position for the inlet is near the bottom and existence of a reflection entrance baffle near free surface of settling tanks can increase the performance of primary settling tanks.

Fan ***et al.*** (13) observed that solid concentration profile in the flow region near the baffle is similar to that obtained without a baffle. By contrast, solid concentration increases sharply in outer region of the baffle, which suggests that solid phase congregates rapidly at the end of baffle.

Goula ***et al.*** (15) used numerical modeling to study particle settling in a sedimentation tank equipped with a vertical baffle installed at the inlet. The authors showed that the baffle increased particle settling efficiency from 90.4% for a standard tank without a baffle to 98.6% for a tank with an installed baffle.

Khademi ***et al.*** (23) indicated that, when the linear transition transmits the flow with high momentum from the upstream canal into the basin with no extra turbulence and a parallel 2D flow was established in the basin. The baffle had no positive effect on the trap efficiency and sedimentation length. However, in 3D conditions in which incoming jet travels a considerable distance and caused large variations of transverse velocity in the basin, installing the baffle in a relative submergence (15%) can increase the trap efficiency of settling basin up to 8.5%. This may be attributed to the role of baffle in decaying kinetic energy of impinging jet and spreading the sediment particles in width of settling basin.

Sajjadi ***et al.*** (40) studied the effect of height and position of baffle to increase removal efficiency in irrigation settling basin with fluent software. The results showed that baffle increased removal efficiency and best position is first third until half of settling basin length. In addition, best height is equal to 0.4 of water deep in settling basin. Installing baffles improved the performance of a tank in terms of settling. The baffles act as barriers, effectively suppressing the horizontal velocities of flow and forcing the particles to bottom of basin (41).

Razmi ***et al.*** (37) investigated the presence of a baffle and its effect on hydrodynamics of flow field in a primary settling tank by experimental and numerical approaches. The best location of the baffle is obtained when the volume of circulation zone is minimized or the dead zone is divided into smaller parts. Results showed that this baffle can reduce size of dead zones and turbulent kinetic energy in comparison with no-baffle condition.

Radi ***et al.*** (35) investigated the effect of a submerged flat baffle normal to flow direction, on the trap efficiency of a settling basin. The results indicated that in 3D conditions in which incoming jet travels a considerable distance from inlet and causes large variations of transverse velocity in the basin. Installing the baffle in a relative submergence of 20% and a relative distance of 6% can increase the trap efficiency of settling basin up to 12%. This may be attributed to the role of baffle in decaying the kinetic energy of impinging jet and spreading the sediment particles in width of the settling basin.

Tamayol ***et al.*** (63) also reported that in high Reynolds numbers, the flow field and baffle position are not affected by the inlet Froude number. Three baffle positions were also tested for determination of suitable position. Results showed that the suitable position is related to importance of buoyancy forces. When the buoyancy forces are not important, a reflection baffle may improve the tank performance, while for the cases with strong buoyancy forces and density currents baffle must be placed at the bottom of tank. In this case, locating the baffle in range of 0.15-0.40. The tank length improves the overall efficiency. Also, it is proposed that in designing process, the volumetric flow rate and velocities should be designed in a way that variation of inlet concentration does not affect the flow field and suitable position of the baffles (63).

The velocity measurements were performed by a three-dimensional Acoustic Doppler Velocimeter (ADV) to investigate baffle effects on the velocity distribution in a primary rectangular sedimentation tank, quantitatively (64). The height of baffles was fixed to almost one fourth of the total water depth. Experimental results indicated that baffle can alter the hydrodynamics of a flow field in different ways. It was also found quantitatively that the baffle can change distribution of velocity at its downstream by increasing flow velocity and kinetic energy. Baffle also influences the velocity gradient near the bed of channel. Baffle provision may have possibility of providing better conditions for sedimentation by influencing velocity profiles. Positioning of a baffle in the middle of channel may improve the flow field at its downstream by modifying the velocity gradient near the channel bed. Positioning of an inlet region baffle might be beneficial at low Reynolds numbers, but further investigations are necessary (21).

Shahrohki ***et al.*** (46, 44) performed numerical simulation to investigate the effects of baffle location on the flow field. The results of this computational model prove that the baffle (using a baffle height-to-depth ratio of $H_b/H=0.18$) should be placed between 0.125 and 0.20 (inlet-to-tank length ratio) based on the smallest volume of circulation zone and kinetic energy, the maximum concentration of suspended sediments in the settling zone and the highest value of removal efficiency (44).

The extended baffle increases the kinetic energy and dissipation rate in the inlet baffle in region and consequently, weakens the currents in this region. Having two or three slots serving as inlets are better compared to one aperture only because uniform flow was generated in shorter distances and the turbulence kinetic energy and volume of circulation zone was considerably low in these cases (39).

Numerical approaches were carried out by Shahrohki ***et al.*** (44) to investigate the effects of different number of baffles in different locations on the flow field. Results illustrate that using two baffles in suitable position reduced the size of circulation zone. The comparison of size of dead zone in the sedimentation tanks showed that the best position for a single baffle is located at 12.5 % of the tank length, from the inlet slot. Using the second baffle in sedimentation tank can decrease the size of circulation zone. The best place for second baffle is 38.8% of tank length from the inlet opening.

Shahrohki ***et al.*** (46, 43, 44) performed numerical simulation to investigate the effects of vertical baffle location on the flow field in rectangular primary sedimentation tanks. The results of this computational model prove 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) based on the smallest volume of circulation zone and kinetic energy. The maximum concentration of suspended sediments in the settling zone and the highest value of removal efficiency (44). Heydari ***et al.*** (17) investigated the effect of angle baffle in settling basins using a 3D model (Ansys Fluent 46). Their results showed that the installation of a baffle in middle of settling basin with angle of attack 60 degree with flow improved tank efficiency (7-14%) in terms of sedimentation compared to without baffle. Razmi ***et al.*** (36) investigated the effects of baffle position on the performance of a primary settling tank experimentally and numerically. Their results showed that the best position of bottom baffle ($\theta=90^\circ$) 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 effect of baffle angles and position were examined using a 2D model (Flow-3D, 2003) applied to a small-scale, 2-m long laboratory setup (39, 48). Right-angled (to the tank base) baffles were most favorable for sedimentation. In addition, it was concluded that, to get high settling performance, the baffle should be somewhere close to the inlet. However the effects of baffle height and optimal baffle configuration were not considered.

CONCLUSION AND RECOMMENDATIONS

In this paper, the presence of baffle and its effect on the hydrodynamics of the flow field has been reviewed in settling tank by experimental and numerical approaches. The conclusion and recommendations drawn from this paper are summarized below:

1. The RNG model is highly suitable for prediction of size of re-circulation regions and prediction of different flow patterns. So, the use of RNG model is recommended.
2. For settling tanks (the inlet opening at top of tank), the interior baffle is not suitable, but in tanks with very large circulation zones, especially in the final settling tanks, it seems to increase tank performance.

3. The best location for the surface baffle is in range of 0.20-0.40 of the tank length. The suitable height of the surface baffle in sedimentation tank is 0.25-0.50 of the flow depth.
4. In settling tanks (the inlet opening at top or bottom of tank) locating the bottom baffle in range of 0.20-0.50 tank length. The best position appears to be in the middle of circulation region, because at this position, the baffle cuts the circulating streamlines and split the dead zones. Bottom baffle destroy the high speed jet and reduce the flow velocity near the bottom of tank. The positioning of an inlet region baffle might be beneficial at low Reynolds numbers, but further investigations are necessary.
5. The suitable height of the bottom baffle in sedimentation tank is 0.20-0.40 of the flow depth. It can increase the trap efficiency of settling basin and can reduce the size of dead zones and turbulent kinetic energy.
6. Number of baffles in different locations affect the flow field and can decrease the size of circulation zones.
7. Finding an exact criterion for the Reynolds number needs a comprehensive experimental and numerical study.
8. The effects of both bottom and surface baffles together on the flow field and hydrodynamics of settling tanks should also be investigated.

REFERENCES

1. Abdel-Gawad, S. M. and J. A. McCorquodale. 1985. Numerical simulation of rectangular settling tanks. J. Hydraulic Res. 23(2):85-100.
2. Adams, E.W. and W. Rodi. 1990. Modeling ow and mixing in sedimentation tanks, J. Hydraulic Engg.116(7):895-913.
3. Ahmed, F. H., A. Kamel and A. Jawad, S. 1996. Experimental determination of the optimal location and contraction of sedimentation tank baffles. Water, Air and Soil Pollution, 92, 251–271.
4. Armbruster, M., P. Krebs and W. Rodi. 2001. Numerical modelling of dynamic sludge blanket behaviour in secondary clarifiers. Wat. Sci. Tech., 42(11):173-80.
5. Ashjari, M. A., and B. Firoozabadi. 2003. Use of nonlinear k-ε in calculation of performance of settling tanks. Proc., ISME, 11th Int. Mech. Engg. Conf. (CD-ROM), Mashhad, Iran, 34–43.
6. Baud O. and W.H. Hager. 2000. Tornado vortices in settling tanks. J. Environ. Engg., 126(2):189-91.
7. Bretscher, U., P. Krebs and W.H. Hager. 1992. Improvement of flow in final settling tanks, J. Environ. Engg. 118(3):307-21.
8. Camp, T.R. 1946. Sedimentation and the design of settling tanks, Trans. ASCE, 111(6):895-952.

9. Celik, I., W. Rodi and A.I. Stamou. 1985. Prediction of hydrodynamic characteristics of rectangular settling tanks, Int. Symposium of Rened Flow Modeling and Turbulence Measurements, Iowa, USA.
10. Crosby, R. M. 1984. Evaluation of the hydraulic characteristics of activated sludge secondary clarifiers, Report EPA-600/2. Environmental Protection Agency, Office of Research and Development, Washington, D.C. U.S.
11. Devantier, B.A. and B.E. Larock. 1986. Modelling a recirculating density-driven turbulent flow. Int. J. Num. Meth. Fluids, 6, 241-53.
12. Dobbins, W.E. 1944. Effects of turbulence on sedimentation, Transactions of ASCE, 109(2218):629-56.
13. Fan, L., N. Xu, X. Ke and H. Shi. 2007. Numerical simulation of secondary sedimentation tank for urban wastewater, J. Chinese Instt. Chemical Engineers, 38:425-33.
14. Fischerström C.N.H., Isgård E. and I. Larsen. 1967. Settling of activated sludge in horizontal tanks. J. Sanitary Eng. Div., 93(SA3), 73-83.
15. Goula, A.M., ***et al.,*** 2007. A CFD methodology for the design of sedimentation tanks in potable water treatment case study, the influence of a feed flow control baffle. Chem. Eng. J., 140:110-21.
16. Hamlan, M. J. and A. H. A. Wahab. 1970. Settling characteristics of sewage in density currents. Water Research. 4:251-71.
17. Heydari, M.M. S Bajestan, M. Kashkuli, H.A, Sedghi, H. 2013. The effect angle of baffle on the performance of settling basin, World Applied Sciences Journal. 21(6):829-37.
18. Huggins, D. L., R.H. Piedrahita and T. Rumsey. 2005. Analysis of sediment transport modeling using computational fluid dynamics (CFD) for aquaculture raceways, Aquacult. Eng., 31, 277-93.
19. Imam, E., J.A. McCorquodale and J.K. Bewtra. 1983. Numerical modeling of sedimentation tanks, J. Hydraulic Engg. 109(12):1740-54.
20. Imam, E.H. 1981. Numerical Modeling of Rectangular Clarrifiers, PhD. Thesis, University of Windsor, Ontario, Canada.
21. Jamshidnia, H., and Firoozabadi, B. 2010. Experimental investigation of baffle effect on the flow in a rectangular primary sedimentation tank, Transaction B: Mechanical Engg. 17(4):241-52.
22. Jayanti, S. and S. Narayanan. 2004. Computational study of particle-eddy interaction in sedimentation tanks, Journal Environ Engg. 130:37-49.

23. Khademi, M.,Omid, M.H., Hourfar. 2007. An experimental and numerical investigation of the effect of submerged baffle on the trap efficiency, J. Hydraulics, 11-24 (In Persian).
24. Krebs P., D. Vischer, W. Gujer. 1992. Improvement of secondary clarifiers efficiency by porous walls, Wat. Sci. and Technology, 26(5-6).
25. Krebs, P. 1991. The hydraulics of final settling tanks, Wat. Sci. Tech., 23:1037-1046.
26. Krebs, P. 1995. Success and shortcomings of clarifier modeling. J. Water Sci. Tech. 31(2):181-91.
27. Krebs, P., D. Vischer and W. Gujer. 1995. Inlet-structure design for final clarifiers. J. Environ Engg. ASCE, 121(8):558-64.
28. Lakehal, D., P. Krebs, J. Krijgsman and W. Rodi. 1999. Computing shear flow and sludge blanket in secondary clarifiers. J. Hydr. Engg. 125(3), 253-62.
29. Larsen, P. 1977. On the hydraulics of rectangular settling basins. Report No. 1001, Dept. of Wat. Res. Engg., Lund Institute of Technology, Lund, Sweden.
30. Larsen, P. 1977. On the hydraulics of settling basins, Rep.No. 1001, Dept. of Water Resour. Engg. Lund Instt. Technol. Lund, Sweden.
31. Lyn, D. A., and Z. Zhang. 1989. Boundary-fitted numerical modelling of sedimentation tanks. Proc. 23rd, IAHR and AIRH, Ottawa, Canada.
32. Mehdizadeh, A., and B. Firoozabadi. 2009. Simulation of a density current turbulent flow employing different RANS models, A Comparison study, Transaction B: Mechanical Engg. 16(1):53-63.
33. Metcalf and Eddy. 2003. Wastewater Engineering Treatment and Reuse. NewYork, McGraw-Hill.
34. Narayanan, B., J. Demir, R. Chan, G. Sheehan, R. Gray and S. Jones. 2001. Hydrodynamic modeling helps improve secondary clarifier performance. Proc. 74th Annual WEF Conference and Exposition on Water Quality and Wastewater Treatment, 13-17 October, Atlanta, USA.
35. Radi, H., M.H. Omid, J. Farhoudi. 2009. Experimental study of effect of transverse baffle on the trap efficiency of rectangular settling basin with a sudden expansion inlet, Iranian Journal of Irrigation and Drainage, 3(1):127-34, (In Persian).
36. Razmi AM, R. Bakhtyar, B. Firoozabadi, DA. Barry. 2013. Experiments and numerical modeling of baffle configuration effects on the performance of sedimentation tanks. Canadian J. Civil Eng. 40(2):140-50.

37. Razmi, A.M., B. Firoozabadi and G. Ahmadi. 2008. Experimental and numerical approach to enlargement of performance of primary settling tanks. J. Applied Fluid Mechanics, 2(1), 1-13.
38. Rodi, W. 1993. Turbulence Models and their application in hydraulics, IAHR, Delft, the Netherlands.
39. Rostami F, M. Shahrokhi, Md. Said MA. Abdullah R, S. Syafalni. 2011. Numerical modeling on inlet aperture effects on flow pattern in primary settling tanks. Applied Mathematical Modelling, 35(6):3012-20. doi:10.1016/j.apm.12.007.
40. Sajjadi, S.M., Shafai Bejestan, M., and M. Bina. 2005. Effect of baffle in irrigation settling basin with CFD. 3rd National Water Resources of Iran, Tabriz, (In Persian).
41. Sammarraee, M.A. and A. Chan. 2009. Large-eddy simulations of particle sedimentation in a longitudinal sedimentation basin of a water treatment plant. Part 2, The effects of baffles. Chemical Eng. J. 152: 315-21.
42. Schamber, D.R. and B.E. Larock. 1981. Numerical analysis of flow in sedimentation basins. J. Hydr. Div., 107(5):575-91.
43. Shahrokhi M, F. Rostami, Md Said MA, S. Sabbagh-Yazdi, S. Syafalni. 2011a. The effect of number of baffles on the improvement efficiency of primary sedimentation tanks. Applied Mathematical Modelling 36(8):3725-35. doi:10.1016/j.apm.2011.11.001.
44. Shahrokhi M, F. Rostami, Md Said MA, S. Syafalni. 2011c. Numerical simulation of influence of inlet configuration on flow pattern in primary rectangular sedimentation tanks, World Applied Sciences Journal. 15(7):1024-31.
45. Shahrokhi, M., F. Rostami, Md Said MA, S. Syafalni. 2011. The Computational Modeling of Baffle Configuration in the Primary Sedimentation Tanks. 2th ICEST, 392-96.
46. Shahrokhi, M., F. Rostami, Md Said, M.A. and S. Syafalni. 2011. Numerical modeling of the effect of the baffle location on the flow field, sediment concentration and efficiency of the rectangular primary sedimentation tanks, World Applied Sciences Journal 15 (9), 1296-1309.
47. Shahrokhi, M., Rostami, F., Md Said, M.A. and Syafalni, S. 2011. Numerical Simulation of Influence of Inlet Configuration on Flow Pattern in Primary Rectangular Sedimentation Tanks, World Applied Sciences Journal 15 (7), 1024-31.
48. Shahrokhi, M., F. Rostami, Md Said, M.A., S. Sabbagh-Yazdi, s. Syafalni and R. Abdullah. 2012. The effect of baffle angle on primary

sedimentation tank efficiency. Canadian J. Civil Engg, 39(3):293-03. doi: 10.1139/L2012-002.

49. Shamloo, H., and A.R. Bayat. 2008. Evaluation different turbulant models in hydraulic design of primary sedimentation tank, 4th National Congress of Civil Engineering, Tehran (In persian).
50. Shetab-Boushehri, S.N., S.F. Mousavi and S.B. Shetab-Boushehri. 2010. Design of settling basins in irrigation network using simulation and mathematical programming. J. Irrig. Drain. Engg. 136(2):99-106.
51. Stamou, A. L., E.W. Adams and W. Rodi. 1989. Numerical modeling of flow and settling in primary rectangular clarifiers. J. Hydraul.Res., 27, 665-82.
52. Stamou, A.I., M. Latsa, and D. Assimacopoulos, 2000. Design of two-storey final settling tanks using mathematical models. J. Hydroinformatics, 2(4), 235-45.
53. Swamee, P.K. 1996. Design of occulating baffled channel, J. Env. Engg, 122(11):1046-48.
54. Swamee, P.K. and A. Tyagi, 1996. Design of class-I sedimentation tanks, J. Env. Engg, 122(1):71-73.
55. Szalai, L., P. Krebs, and W. Rodi, 1994. Simulation of flow in circular clarifiers with and without swirl. J. Hydr. Engg. 120(1):4-21.
56. Taebi-Harandy, A. and E.D. Schroeder. 1995. Analysis of structural features on performance of secondary clarifiers. J. Environ. Engg. 121(12):911-19.
57. Tamayol, A. 2005. Effects of Baffle Configurations on the Performance of Settling Tanks, MS thesis, Sharif Univ. Technology, Iran.
58. Tamayol, A. and B. Firoozabadi, 2006. Effects of turbulent models and baffle position on hydrodynamics of settling tanks, Scientia Iranica J., 13(3):255-60.
59. Tamayol, A. and B. Firoozabadi, 2006. Effects of turbulent models and baffle position on the hydrodynamics of settling tanks, Scientia Iranica, J. 13(3):255-60.
60. Tamayol, A., B. Firoozabadi, and G. Ahmadi, 2006. Increasing performance of final settling tanks by using baffles. 7th International Conference on Hydroinformatics, HIC 2006, Nice, France.
61. Tamayol, A., B. Firoozabadi, and G. Ahmadi, 2008. Determination of settling tanks performance using a eulerian-lagrangian method, J. Applied Fluid Mechanics, 1(1):43-54.
62. Tamayol, A., B. Firoozabadi, and G. Ahmadi, 2008. Effects of inlet position and baffle configuration on the hydraulic performance of primary settling tanks, J. Hydraulic Engg. 134(7):1004-09.

63. Tamayol, A., B., Firoozabadi, and M.A. Ashjari, 2010. Hydrodynamics of secondary settling tanks and increasing their performance using baffles, J. Environ. Engg, 136, No.1:32-39.
64. Tamayol, A., M., Nazari, B. Firoozabadi, and A. Nabovati, 2004. Effects of turbulent models and baffle position on hydrodynamics of settling tanks, Int. Mech. Eng. Con., Kuwait.
65. Tamayol, A., M., Nazari, B., Firoozabadi, and A. Nabovati, 2005. Numerical modeling and study of effects of inlet position and height of inlet baffle on the performance of settling tanks. Proc., Fluid Dynamics Conf. (In Persian).
66. Vitasovic, Z.C., S., Zhou, J.A. McCorquodale, and K. Lingren, 1997. Secondary clarifier analysis using data from the Clarifier Research Technical Committee protocol.Wat. Environ. Res., 69(5):999-07.
67. Yoon, Tae Hoon and Lee, Seung Oh. 2000. Numerical modeling of sedimentation basins with a Baffle, KSCE J Civil Engg, 4(4):227-32.
68. Zhou S. and J. A. McCorquodale 1992. Mathematical modeling for a circular clarifier, Canadian J. Civil Engg, 19:365-74.
69. Zhou, S., and J. A. McCorquodale, 1992. Modeling of rectangular settling tanks.'' J. Hydr. Eng., ASCE, 118(10):1391–05.
70. Zhou, S., J. McCorquodale and Z. Vitasovic, 1992. Influences of density on circular clarifiers with baffles. J. Environ. Engg, ASCE, 118(6):829-47.