Journal of Engineering and Applied Sciences 13 (Special Issue 13): 10730-10734, 2018
ISSN: 1816-949X

Effects of Shape and Dimensions of Plain Sedimentation Basins

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Abstract: Pre-sedimentation process is a preliminary treatment process which is by and large used before coagulation and flocculation process in order to eliminate substantial suspended particles from the raw water. These particles can diminish the productivity of coagulation and flocculation forms. A pilot plant is designed according to the theoretical equations and design criteria in order to simulate the problem of practical site conditions, studying the effect of shape and geometry dimensions and explain the behaviour of plain sedimentation tanks for proper tank design and operation. Four pre-sedimentation tanks was conducted on a lab scale models in order to study the effects of shape and dimensions of plain sedimentation tank on the treatment of water of Shatt-Al-Hilla. Based on the investigation results, it was concluded that using of circular pre-sedimentation basin with design parameters of SOR <0.78 m/sec gave removal efficiency exceeds 50% for treatment of Shatt -Al Hilla water. The removal efficiency of turbidity of the raw water using rectangular tank of L = 4W was higher than the rectangular tank of L = 2W and the squared tank by about (4-8)%.

Key words: Flocculation process, particles, raw water, pre-sedimentation, geometry dimensions, parameters

INTRODUCTION

Pre-sedimentation is a simple process that decrease settable solids and a few microorganisms from water affected by gravity preceding use of other cleansing strategies via. low cost technology. It likewise enhances the visual characteristics of the water and builds its acknowledgment by shoppers (Jahanshahi and Taghizadeh, 2018).

Discrete settling occurs when there is no variation in size, shape, surface characteristics or density between particles. Particles tend to settle parallel to each other without interference between particles and with uniform velocity, so that, particles do not interact vertically or horizontally. In this case, particles settle in accordance with Stoke's Law (Alley, 2007). Because of turbidity, the water appeared cloudy, it's aesthetically unattractive and it is harmful to consumers. Turbidity, likewise, the temperature of water and Dissolved Oxygen Concentration (DOC). Where, decreasing the amount of light infiltrating the water caused by higher turbidity that reduces photosynthesis, the creation of dissolved oxygen and it was observed that the Pre-Sedimentation Tanks (PST) cause some problems in the water treatment plants (Iqbal *et al*., 2010). The performance and efficiency of the sedimentation basin will influence to the concentration and suspended particle characteristics (Al-Sammarraee *et al*., 2009), however, the Pre-Sedimentation Tanks (PST), low turbidity causes water to be hardly and can be tackled in consequent units of the water treatment plant (Al-Rawi and Bilal, 2013). A common Species in many water treatment plants and problematic algae are not simply removed by water treatment processes (Joh *et al*., 2011). The operators need to control algae and pathogens in the Pre-Sedimentation Tanks (PST) because it's a suitable place for growing some species of algae and pathogens, in conventional water treatment process the pre-chlorination is a common method that used for to control of algal development (Ibrahim *et al*., 1982). Sum of chlorine consumption is associated with the mass of algae. One of the drawbacks of chlorine use (PST) in inadequate situations when increase in consumption of chlorine. Pre-chlorine products harmful by-products like a Tri-Halo Methane (THM) (Sadiq and Rodriguez, 2004; Al-Hashemi *et al*., 2013; Ozdemir, 2014; Sharp *et al*., 2006).

Tay (1986) assumed three arrangements of length to width ratio (2:1, 5:1 and 10:1) to calculated the effect of Length to Width ratio (L/W) on performance of rectangular settling tanks. And varied the flow rates from (5-25 L/min) to provide 5 overflow rates (20, 30, 50, 75 and 100) m^3/m^2.day. To control the flow rates, Tay used tap water to achieve each experiment and combination of pumps and valves. Tay establish that a better efficiency happened when the ratio of length/width for the settling tanks is higher and the performance of settling tanks is

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not affected when install a baffle wall ominously, specifically when Length to Width ratio (L/W) of the settling basin is 10:1.

Yoon and Lee (2000) displays the hydraulic behavior and removal efficiency by used a model tank of 1.35 m long, 0.2 m wide and has a water depth of 0.17 m of settling tanks. Clay turbid water are used which was produced by addition clay powder into water as settling suspension for the more significant tests of tank efficiency. By decreasing overflow rate (Q), injecting baffle and insertion effluent as farther from the inlet as possible, they indicated that, under non-flocculent condition, the removal efficiency can be enhanced substantially likewise (Walling *et al*., 2000) considered the particle size characteristics of fluvial suspended sediment in the Humber and Tweed catchments, UK. They indicated the average mediam particle size (d50) for the individual streams ranged of 4.1 and 13.5 μm individually.

MATERIALS AND METHODS

In order to study the effects of shape and dimensions of plain sedimentation tank on the treatment of water of Shatt-Al-Hilla, the present study was conducted on a lab scale of pre-sedimentation tank and also, for explaining the behavior of plain sedimentation tanks to get proper tank design and operation. The pilot plant designed according to the recommended design criteria and hydraulic simulation standard mostly used in water treatment plant design.

The present study includes a 48 experiments to test the performance of plain sedimentation tanks. Through each experiment, the two parameters (temperature and the flow rate) for the treated water along with the influent and effluent waters turbidity were measured. The 4 pre-sedimentation tanks was designed to study the performance of each one as its own. The first tank was of a rectangular shape with a length equal four times of its width (L = 4W), the second tank was of a rectangular shape with a length equal to double its width (L = 2W), while the third tank was of squared shape and the fourth tank was of circular shape. The surface area and the depth of water were kept a constant parameter for all tanks in order to achieve fair. The details of the other variables were as follow:

- The Length to Width ratio (L/W) which was selected to be (4:1, 2:1 and 1:1)
- The inlet flow rate were of values of range (7, 13, 23, 30 and 40) L/min
- The Surface Overflow Rate (SOR) was of range (0.32, 0.6, 0.78, 1.06, 1.3 and 1.85) mm/sec and
- The initial turbidity was being in range of 25 and 60 NTU

Experimental set-up and operation: The experimental apparatus of the pilot plant was used to simulate a sedimentation process that occurred in each tank. The pilot plant consisted of feed tanks, mixer, pumps, connected units, pipes, flow meter and settling tanks installed as shown in Fig. 1. Where each tank was feeding individually from the main feed tank. Finally, a samples of raw and treated water taken from the pilot plant for each experiment to perform the efficiency of turbidity removal, suspended particles size distribution and also suspended solid particles density in order to determine the theoretical percent of suspended solids removal in terms of turbidity removal percent and compare it with the experimental results for each tank.

Plain sedimentation tanks: Four pre-sedimentation tanks used to study the optimization of plain settling behavior of suspended solid particles of the raw water. The water depth of all sedimentation tanks was 37 cm and the surface area was (0.36 m^2). The height of tanks was 50 cm. The tanks differed among others by the geometry shape and dimensions. The tanks were designed using standard design criteria of the plain settling basin. The rectangular and square tanks were manufactured from glass (10 and 6) mm thickness and glued with silicon. Inlet structure of each tanks was chosen as a U-shape elbow discharging against the wall in influent structures for rectangular and square tanks. The raw water was received via the inlet pipe in this section then passes it to the settling section. The dimensions of rectangular tanks are summarized in Table 1. The fourth tank was circular shape manufactured from 2 mm plate thickness. The exterior diameter was 70 cm connected with the box of the outlet zone of 15×15 cm. From the settling section, the water is flow to the outlet section via. v-notch weir with a dimeter of 50 cm. At the base of settling section, effluent pipe was fixed for cleaning the settling particles after each run. Also, effluent pipe was fixed in the base of outlet zone to collect the treated samples. The circular tank receives the raw water via. central inlet pipe and ended with a T-shape connection unit discharge the raw water in orifice box to prevent turbulent and eddies in order maintain to acceptable outlet velocity of the settled water.

Table 1: The summary of rectangular tanks dimensions

Tank No.	Shape	Length of settling zone (cm)	width of settling zone (cm)	Length /width	Length of outlet zone (cm)
1st	Rectangular	120	30	4	15
2nd	Rectangular	84	42	2	15
3rd	Square	60	60	1	15

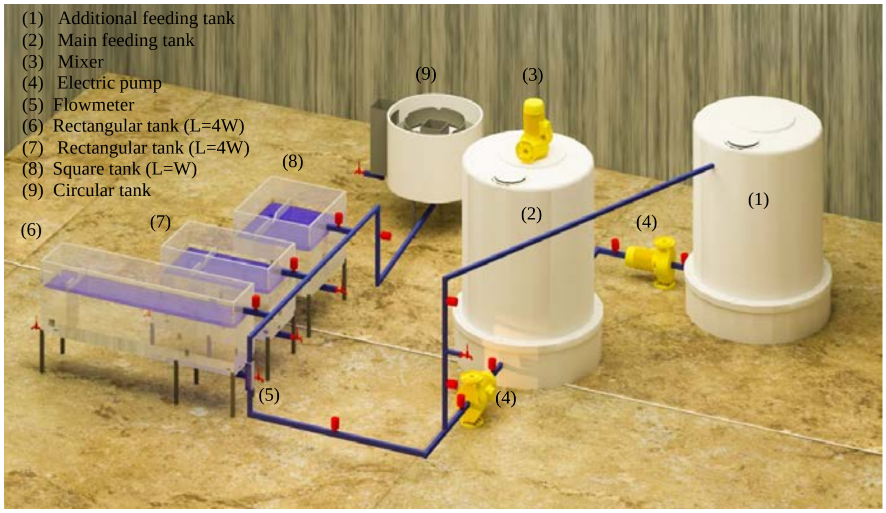

Fig. 1: Schematic diagram of the pilot plant used

RESULTS AND DISCUSSION

Through the period from (15 Nov. 2017-12 Jul. 2018), 20 collected samples from Shatt-Al-Hilla water analyzed for PSD using Bettersizer 2000 laser particle size instrument. The complete analysis results for suspended solid particles in all water sample obtainable of d_{10}, d_{50} and d_{90}. Where, d_{10}, d_{50} and d_{90} values show that 10, 50 and 90% of the particles measured were smaller than the size stated. The most parameter used to illustrate PSDa is (d50) the average size of particles that displays in Table 2.

The settling velocity for each prevailing size sample of Shatt-Al-Hilla water was considered in order to calculate the theoretical removal efficiency percent based on PSD of suspended solids by the following Eq. 1 (Ghawi, 2008):

$$F = (1X-X_s)+\frac{1}{SOR}\sum_{i=1}^{i=n} Vs_i \Delta x_i \quad (1)$$

The designed value of Surface Overflow Rate (SOR) was applied in Eq. 1 and in the experimental research to make a real comparison between the theoretical and experimental research.

The examination of the results reveals that the removal efficiency of water turbidity tends to decrease as the SOR increased as shown in Fig. 2 and 3. While Fig. 4 and 5 showed the variation in the removal efficiency of water turbidity with the variation of the detention time. Also, the analysis of results in Fig. 1-3 show that the circular basin has better efficiency as compared with the other type of basin and this conclusion can be attributed to the fact that in a circular settling basin, the flow velocity increased in a peripheral feed clarifier. Since, a reduced flow velocity is needed to settle the smaller particles, more efficient use is made of the settling basin volume when the larger particles are settled first (Alley, 2007).

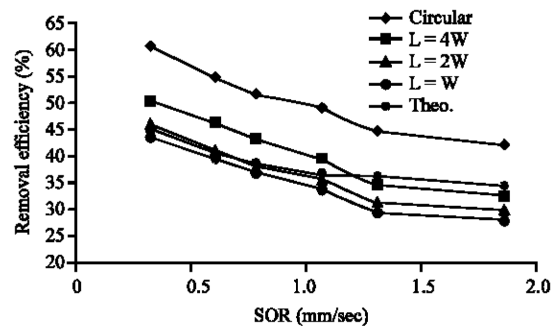

Fig. 2: The Relationship between removal efficiency of pre-sedimentation basins and SOR of raw water 25 NTU turbidity

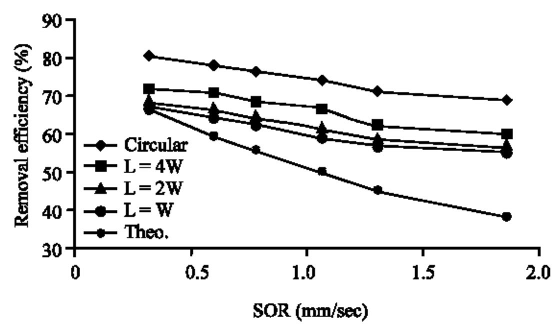

Fig. 3: The relationship between removal efficiency of pre-sedimentation basins and SOR of raw water 50 NTU turbidity

Table 2: Characteristic parameters of PSD for suspended solids in various surface water bodies

Water body	d_{10} (μm)	d_{50} (μm)	d_{90} (μm)	References
Nidd River in UK	NS	9.2	NS	Hejduk *et al.* (2006)
Burn River in UK	NS	13.5	NS	Hejduk *et al.* (2006)
Laver River in UK	NS	11.3	NS	Hejduk *et al.* (2006)
Zagozdzonka River in Poland which	9.9-21.1	49.8-98.3	165.1-297.9	Kiurski *et al.* (2010)
Dragica Spring in Serbia	9-10	35-59	98-410	Tay (1986)
Djetinja River in Serbia	3-16	40-70	100-198	Tay (1986)
Shatt Al-Arab River	2.8- 8.1	7.4-20.9	12.8-324.7	Abdulhasen in 2016
Shatt Al-Hilla River	9-10.9	10.4-15	89-103	Present study

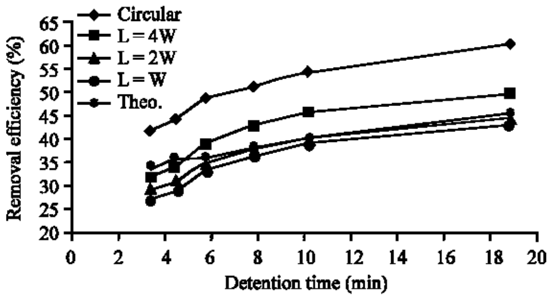

Fig. 4: The relationship between removal efficiency of pre-sedimentation basins and detention time of raw water 25 NTU turbidity

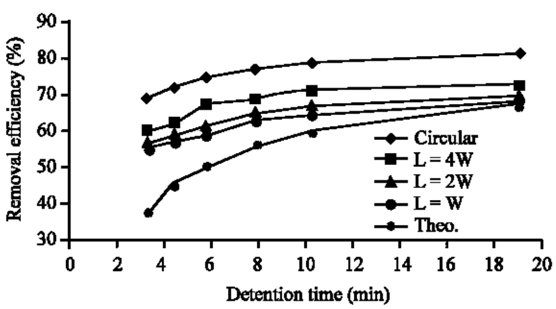

Fig. 5: The relationship between removal efficiency of pre-sedimentation basins and detention time of raw water 60 NTU turbidity

The circular basin gave a maximum removal efficiency of 60% for samples of 25 NTU with SOR value of 0.32 mm/sec) and detention time value of 19.03 min. While the minimum removal efficiency for the circular basin was reached to a value of 42% which has happened at SOR value of 1.85 mm/sec and detention time value of 3.33 min. As a results of the comparison between the three basins of rectangular shape, it can be observed that the basin with (L/W = 4) has a maximum removal efficiency which has recorded as (50%) under SOR value equal to 0.32 mm/sec and detention time value of 19.03 min. And this conclusion was in a good agreement with (Tay, 1986). While the maximum removal efficiencies of the other two rectangular basins are (46%) for (L/W = 2)) and (43%) for (L/W = 1). It is important to mention that the minimum removal efficiencies of the rectangular basins were arranged as follows: (32%) for L/W = 4 and (30%) for (L/W = 2) and (28%) for squared basin at SOR value of 1.85 mm/sec and detention time value of 3.33 min. It can be concluded that the removal efficiency decreased with the decreasing the L/W ratio and this conclusion meet with (Tay, 1986). Also, it can be noticed that the removal efficiency of the raw water of initial turbidity of 25 NTU was lower than raw water of high initial turbidity by about (25-30)% and such finding can be explained to the fact that with high turbid water there is more pathogens and suspended solids will be settle to the bottom of the tank (Jahanshahi and Taghizadeh, 2018).

CONCLUSION

Based on the investigation of the variables of design and operation of the pre-sedimentation basins concerning of water treatment, the following conclusions are obtained; It was concluded that using of circular pre-sedimentation basin with design parameters of SOR<0.78 m/sec gave removal efficiency exceeds 50% for treatment water of Shatt-Al-Hilla.

Removal efficiency of the turbidity of raw water using circular tank was higher than the rectangular tank by about (9-13)%. The removal efficiency of turbidity of the raw water using rectangular tank of L = 4W was higher than the rectangular tank of L = 2W and the squared tank by about (4-8)%. The removal efficiency of the raw water of initial turbidity of 25 NTU was lower than of raw water of high initial turbidity by about (25-30) %.

It was found that, the values of d50 of suspended solids of Shatt-Al-Hilla River was ranged from (10.4-15) μm. These values indicated that the particles appeared to be comparatively fine when associated with the other indicated streams, the values of d50 are ranged from <1-100 μm. Based on the PSD tests, density tests and visual inspecting of the suspended solids of Shatt-Al-Hilla water, it can be concluded that the suspended solids is a mixture of silt, clay and fine sand.

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