Effectiveness Design Parameter for Sedimentation of Calcium Carbonate Slurry

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Abstract**—**The behavior of a discrete system in a rectangular settling tank was investigated in order to determine the best design parameters in terms of the baffle horizontal spacing (HBS) from the inlet of the tank, the vertical baffle spacing (VBS) from the bottom of the tank, and the flow rate in order to achieve a minimum solid concentration in the effluent. This was achieved qualitatively by visualization study utilizing a dye injection system. Later, quantitative analysis was performed. It was found that at a flow rate of 7 L/min, and vertical baffle spacing from the bottom of 14.1 cm, the sedimentation would be more effective according to the dye injection results. However, the quantitative analysis reflected a better sedimentation reduction at a baffle spacing (VBS) of 11.7 cm. The contradictory results were justified by two effective variables: the baffle area available to hinder the inlet flow; thus reducing its momentum and the cross sectional area available to the flow at the inlet.

Keywords**—** continuous process, sedimentation tank, calcium carbonate, design parameters.

I. Introduction

SEDIMENTATION is widely used method for the separation and removal of solids from liquids. It is used intensively in water and wastewater treatment and biochemical facilities [1]. Sedimentation is utilized in water treatment facilities to remove turbidity and color by removing impurities, which can settle due to coagulation and flocculation effect. According to sedimentation principles, the removal of solids from any waste stream depends on the settling rate of the particles in the mixture as a function of the particle's size, shape, concentration, specific gravity, shear resistance, and the geometry of the system [2]. The sedimentation process is a rate-governed process, which is a combination of a constant rate falling rate [3].

Highlight a section that you want to designate with a certain style, then select the appropriate name on the style menu. The Some correlations were plotted between sedimentation rate constants (overall sedimentation rate constant (Ko), sedimentation rate constant for constant rate period (Kc) and falling rate constant (Kf)). Variation of Ko on various particle sizes and slurry consistency has also been reported in this work. Sedimentation tanks are divided into four functional basin zones namely the inlet zone, the settling zone, the sludge zone and finally the outlet zone. It is essential to note that each zone should provide a smooth transition between the zone before and the one after. Fig 2 is a diagrammatic illustration of the aforementioned four zones:

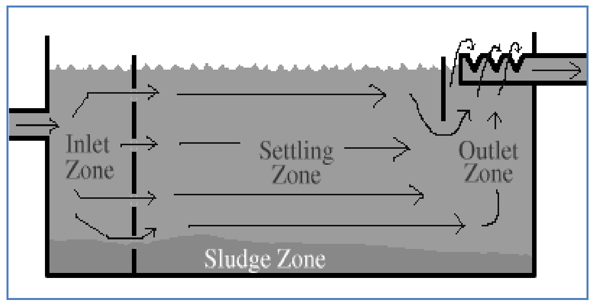

Fig. 1 Sedimentation basin zones

One of the main design parameters in sedimentation to be considered is the surface loading rate, Q/A, since it represents the critical particle settling velocity for completes removal [4-5]. Uniform flow distribution cannot always be assumed in practice owing to density currents, insufficient dissipation of momentum at the tank inlet and drawdown effects at the weirs. Consequently, surface loadings and detention times derived from theory should be multiplied by a suitable safety factor to allow for practical design.

II. Experimental work

Sedimentation Tank consists mainly of a settling tank with a capacity of 80 L, a sediment sump tank with a capacity a specific capacity, a water flow meter (one for tap water and one for the concentrated solution), a motor of 0.1 kW, a sparging device, a dye injection system, a dye tracer and a centrifugal pump [6-7]. Horizontal Baffle Spacing (HBS) is the space between the baffle and the tank inlet. Vertical Baffle Spacing (VBS) is the vertical spacing between the bottom edge of the baffle and the bottom of the tank.

Profiling was carried out in order to study the flow patterns and turbulence of water while being pumped into the sedimentation tank using a dye to trace the pattern. This analysis is important to determine the suitable conditions for the sedimentation process in terms of the solution flow rate, the vertical baffle spacing from the bottom of the tank and the horizontal baffle spacing from the inlet of the tank by keeping

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the horizontal baffle position fixed at 5 cm from the tank inlet and the vertical baffle spacing at 14.1 cm from the bottom of the tank. The entire tank was filled with tap water and then starts adjusting the water flow rate at 12 L/min. Pump the dye using the dye tracer injection system and observe the flow patterns. Repeat the work with different flow rates of 10 (L/min) and (7 L/min) at the same baffle specification. Reduce the vertical baffle spacing to 11.7 cm from bottom of the tank and at the same horizontal spacing from the tank inlet (5 cm). Repeat for different horizontal spacing from the tank inlet (i.e.: x=10 cm, x=15 cm). For concentration measurements with varying baffle spacing, slurry of calcium carbonate (CaCO3) of 5 wt % in water was prepared and feed it to the slurry tank. Adjust the flow rate of the mixed solution (water + slurry) to a starting value of 7 L/min by setting the water flow rate to 5.5 L/min and the slurry flow rate to 1.5 L/min. Wait till tank reaches its residence time and then Start withdrawing samples from different positions of the tank inlet.

III. RESULT AND DISCUSSION

A. Visualization study

Blue dye was injected with pumped tap water and the flow patterns were studied. The visualization study was utilized by dye injection system. Figs 2-a, 1-b, and 1-c for HBS of 5cm and VBS of 11.7 cm. Figs 3-a, 3-b, and 3-c for same above Fig but with HBS = 10 cm. While Figs 4-a, 4-b, and 4-c was plotted with VBS of 14.1 cm and HBS of 10cm. Figs 5-a, 5-b, and 5-c for VBS of 11.7 cm and HBS of 15 cm. Figs 6-a, 6-b, and 6-c for VBS = 14.1 cm and HBS of 15 cm. all these plots with flow rates of 7 l/min for a, 10 l/min for b, and 12 l/min for c plots.

Fig. 2-a Dye pattern at Q=7 L/min, VBS = 11.7 cm, and HBS = 5 cm

Fig. 2-b Dye pattern at Q=10 L/min, VBS = 11.7 cm, and HBS = 5 *cm*

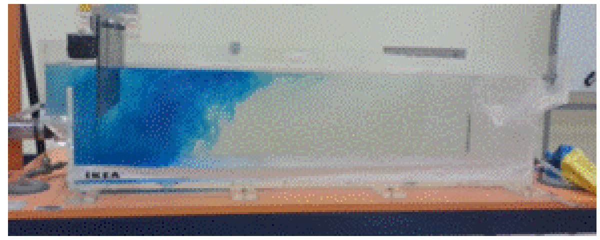

Fig. 2-c: Dye pattern at Q=12 L/min, VBS = 11.7 cm, and HBS = 5 cm

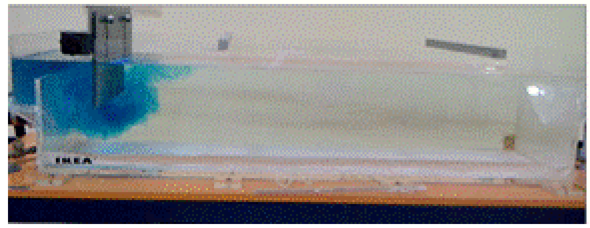

Fig. 3-a: Dye pattern at Q=7L/min, VBS = 11.7 cm, and HBS = 10 *cm*

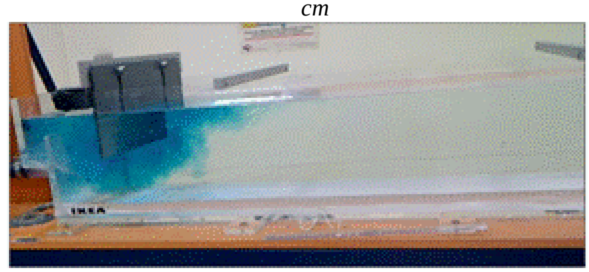

Fig. 3-b: Dye pattern at Q=10 L/min, VBS = 11.7 cm, and HBS = 10 cm

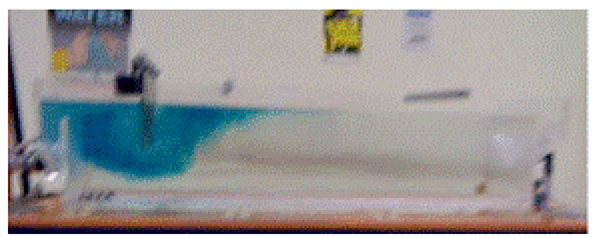

Fig. 3-c: Dye pattern at Q=12 L/min, VBS = 11.7 cm, and HBS = 10 cm

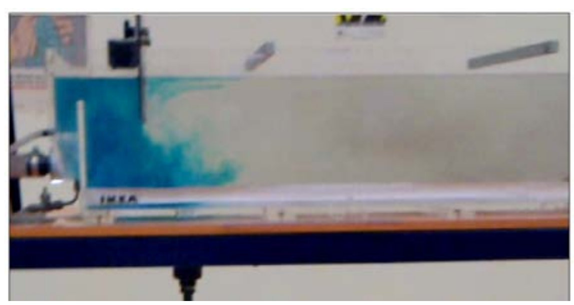

Fig. 4-a Dye pattern at Q=7L/min, VBS = 14.1 cm, and HBS = 10 cm

Fig. 4-b Dye pattern at Q=10 L/min, VBS = 14.1 cm, and HBS = 10 cm

Fig. 4-c: Dye pattern at Q=12 L/min, VBS = 14.1 cm, and HBS = 10 cm

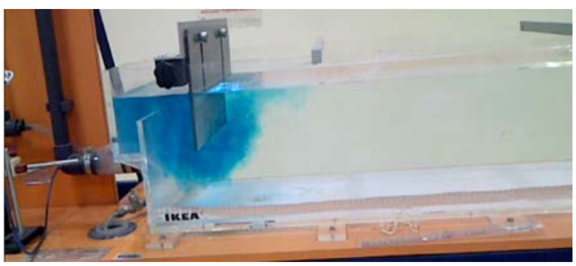

Fig. 5-a: Dye pattern at Q=7 L/min, VBS = 11.7 cm, and HBS = 15 cm

Fig. 5-b : Dye pattern at Q=10 L/min, VBS = 11.7 cm, and HBS = 15 cm

Fig. 5-c: Dye pattern at Q=12 L/min, VBS = 11.7 cm, and HBS = 15 cm

Fig. 5-c: Dye pattern at Q=12 L/min, VBS = 11.7 cm, and HBS = 15 cm

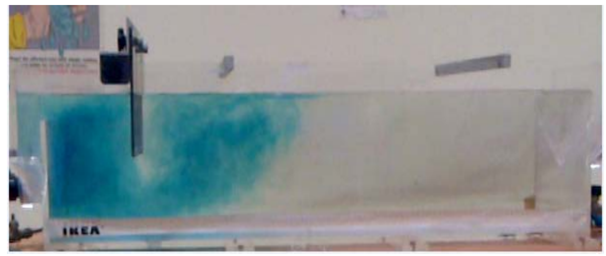

Fig. 6-a: Dye pattern at Q=7 L/min, VBS = 14.1 cm, and HBS = 15 cm

Fig. 6-b: Dye pattern at Q=10 L/min, VBS = 14.1 cm, and HBS = 15 cm

Fig 6-c: Dye pattern at Q=12 L/min, VBS = 14.1 cm, and HBS = 15 cm

From these Figs, it is clear that turbulence controls sedimentation to some extent. Turbulence refers to the spots inside the tank where disturbance may occur, and should be avoided especially in the sedimentation regions since it results in re-suspension of the particles. Many factors control turbulence varying from reverse velocity to the disturbance caused by flocculated particles while settling. In the preformed experiments no reverse flow was detected. Profiling was carried out to investigate the accessible areas inside the tank where sediments may ultimately settle. The slower the transmission of the dye inside the tank, the more stable the region is for sedimentation. Also, the wider the tank area invaded by the dye, the better the efficiency of sedimentation assuming that dye represents the sediment particles. Refer to Fig, where dye invaded approximately 40% of the tank reflecting a good sedimentation, while Fig 3-a represents a poor distribution of dye; hence low sedimentation.

High velocities result in dead zone areas where sediments cannot access water and ultimately this reduces the efficient tank volume required for sedimentation. The phenomenon of dead zones is tested using a dye injection system assuming that dye represents sediments in its way to the tank outlet. At high flow rate, see Fig 4-a (Q=12 L/min), most of the dye rises back to the surface in a short time after being redirected and hindered by the baffle. Whereas, at lower flow rates refer to Fig 2-c, the dye invades a greater zone after being hindered by the baffle and this corresponds to better sedimentation. Therefore, lower flow rates are always desirable; however, too low flow rates should be avoided since they result in high sedimentation close to the baffle where the feed inlet may be blocked.

B. Measurements study of concentration with varying baffle spacing

For Horizontal Baffle Space (HBS) = 5 cm and VBS of 11.7 and 14.1 cm with different flow rates of slurry and tapa water. Fig 7 showed the concentration of solid material with the position from the tank inlet.

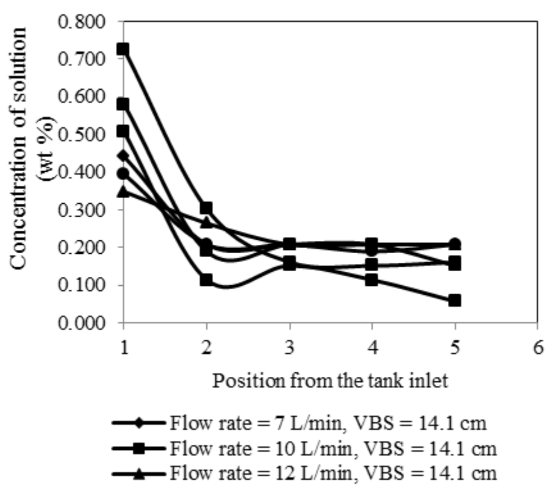

Figure 7: Concentration versus position of sample withdrawn at HBS of 5 cm

Due to the variation of concentration of inlet material in this study according to the flow rate variables, normalized value was measured by dividing all the concentrations (wt%) by the inlet concentration for each trial to investigate which has the most sediment removal. Since sample withdrawn at location 1 is considered to be the inlet concentration so that the normal concentration will be equal to 1 as shown in Fig 8.

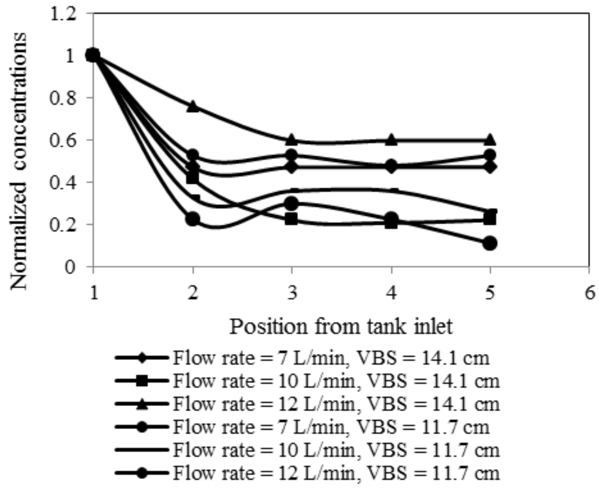

Figure 8: Normalized concentration Vs position of sample withdrawn for previou plot

If the HBS is increased to 10 cm with other same variables, then the concentration vs. the position from tank inlet will be shown in Figs 9 and 10.

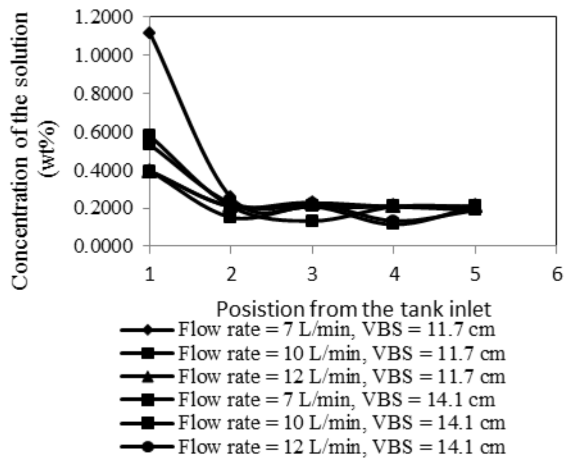

Figure 9 : Concentration Vs position of the withdrawn sample at HBS of 7 cm

C. The Effect of Horizontal and Vertical Baffle Spacing (VBS) on Sedimentation:

Baffle is utilized in sedimentation tanks to reduce the momentum of the inlet flow rate to the minimum. In typical sewage water treatment plant, flow is pumped to the settling tank at high flow rate where it got reduced substantially by the baffle once it enters the tank. This behavior provides a stable environment for sedimentation, otherwise short circuiting may take place. According to the dye injection analysis in the performed experiment, baffle spacing of 14.1 cm allows a better invasion by the dye through the tank; thus, better sedimentation. This result was expected a priori since higher spacing between the baffle and the bottom of the tank gives higher cross sectional area for the flow and hence reducing the velocity of the flow for a given flow rate (according to equation Q= vA), refer to Figs 8 at a minimum flow rate of 7 L/min. Contradictory, the experimental work shows a better sedimentation when VBS = 11.7 cm. This was concluded from *Fig 26* where more efficient reduction in sedimentation was found at VBS = 11.7 cm than that at 14.1 cm at both at a minimum low rate of 7 L/min.

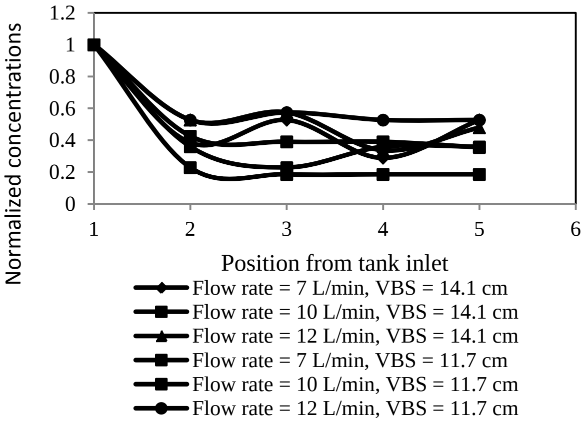

Figure 10: Normalized concentration Vs position of sample withdrawnat HBS of 7 cm

IV. Conclusion

Visualization and profiling study was conducted using a dye tracer, samples collection at different baffle horizontal and vertical height, and different flow rates and concentration changes with respect of time. The flow rate of 7L/min was acceptable because dye invaded greater area, and it achieved lowest sedimentation concentration. As for the vertical baffle spacing, a height of 14.1 cm from the bottom of the tank can be used for effective sedimentation. Baffle vertical distance of 11.7 cm showed better reduction of sedimentation at 7L/min. This could be justified by the fact at lower spacing more particles are exposed to baffle area, y the baffle or the baffle's exposed area to incoming flow, more experimental work is required and human error must be minimized.

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