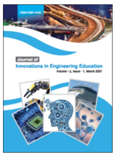

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Kinetics of suspended solids removal in tube settler

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Abstract

Water treatment plant plays a principal role for the purification and supplying of the potable water. Several modifications were made in the conventional sedimentation tank to improve its efficiency as a results of which concept of tube settler was developed. Tube settler is commonly used due to less detention time of about less than 15 minutes. The present study is aimed to highlight the performance of tube settler unit. The tube settler installed in the Siddhipur Water Treatment Plant (SWTP) was selected and detailed study was conducted. The kinetics of suspended solids removal was obtained from the turbidity removal mechanism at various flow rates. Evaluation of tube settler was conducted for three discharges viz., 7, 8.5 and 10 litre per seconds (lps). Removal efficiency of tube settler was evaluated by measuring the turbidity at various turbidity ranges and flows. For influent turbidity of 4 – 93, 4 – 97 and 2 – 89 NTU, the effluent turbidity was found to be 2 – 41, 2 -49 and 1 - 45 NTU at 7 lps, 8.5 lps and 10 lps respectively. The average turbidity removed at 7 lps, 8.5 lps and 10 lps were found to be 17.1769 NTU (48.482% of influent turbidity), 15.57 NTU (47.097% of influent turbidity) and 14.85 NTU (45.348% of influent turbidity) respectively. Increasing the flow rate from 7 lps to 10 lps decrease the removal efficiency from 48.482 to 45.348%. This indicates the effectiveness of the tube settler. The maximum effluent turbidity of tube settler was found more than WHO and NWDQS guidelines, however, the slow sand filter installed operated after the removal of turbidity by the tube settler brought the effluent turbidity within the limit i.e., 5 NTU. Also the results indicated that, in the suspended solids removal mechanism of tube settler in terms of average efficiency of turbidity removal it was found to be more for low flow rates and low for high flow rates, however, their effectiveness in removing suspended solid concentration at any flow rates is uncompromised.

1. Introduction

Five essential requirements for human existence are air, water, food, heat, light (*Pancha Tatwa*) [1] . The water found in the nature contains a number of impurities in varying amounts. Even the rain water which is absolutely pure at the instant it is formed becomes impure because it absorbs gases, minerals, dust, bacteria. The water required for public water supply should be potable and beneficial to human health [2]. Increasing deforestation, overgrazing of cattle's, unplanned excavation in construction activities results mass movement and landslides, which causes the water in the rivers and streams rich in suspended solids causing turbid water [3] O & M fund in our country Nepal is very poor only 4.5% [4].

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Surface water sources consists large quantity of suspended solids. These suspended solids results turbidity in water and thus turbidity removal has been a challenge in domestic water supply. Nepal Drinking Water Quality Standards (NDWQS) has fixed the limit of turbidity as 5 NTU but in exceptional case 10 NTU is also used for water supply [5]. High Suspended solids and turbidity have been major problems in water sources and has made the water aesthetically and palpably impure.

For the removal of suspended solids sedimentation under the action of gravitational force is considered as one of the most economical separation methods. Sedimentation is the most widely used method for the solid removal from the raw water. Several modifications in sedimentation tank were made to reduce the cost, detention time, footprints of land.

The idea for shallow-depth settling was suggested by

Hazen in 1904 [6], and in 1946 Camp explored it [7]. Finally in 1967 Hazen and Culp demonstrated its practical application. Sedimentation tanks including small sized tubes of various shapes with detention times of 15 minutes or less can achieve more or better settling efficiencies than conventional sedimentation tank [8].

"Essentially horizontal ($\theta < 7.5°$)" and the "steeply inclined (θ up to 60°)" are the two market available compositions of tube settlers, where θ is the angle to the horizontal [9]. Tubes inclined at an angle of 60° i.e. steeply inclined is used for the completion of the work. Tube settlers have retention time less than 15 min and average removal efficiency of about 70 – 80% in comparison to sedimentation tank [10].Tube settlers are simply multiple tubular channels sloping at certain angle. Tube settlers requires less footprint compared to plain sedimentation tank. Cleaning of the tube settler is also easier and faster compared to conventional sedimentation tank. This awakened a strong interest of studying removal kinetics of suspended solids and comparison of average removal efficiency of suspended solids for various flow rates in tube settler.

2. Research objectives

The general objective of this study was to study the kinetics of suspended solids removal mechanism in tube settler. Furthermore, the actual removal efficiency was also compared for varying flow rates and removal mechanism of particular influent turbidity is also checked at varying flow rates.

3. Materials and methods

Firstly, natural water samples are taken from the inlet pipe of the tube settler to check the removal of suspended solids. During the rainy days suspended solids concentration was high so it resulted high turbidity. During dry days, the influent water contains low turbidity. For finding the removal mechanism of suspended solids, turbid water was classified in three ranges. The turbid water was prepared by mixing the influent water with artificial sludge. Natural influent water is the water coming from the source naturally whereby artificial prepared sludge water is the prepared turbid water for finding the mechanism of suspended solids removal in tube settler. For preparation of turbid water, sludge was taken as clay which was the sludge settled in sludge zone of tube settler and was mixed in 50 liter container and introduced in the inlet zone of tube settler. The turbid water was used in three ranges initially less than 20 NTU and then introduced 20 to 90 NTU and then 90 to 160 NTU. For 20 – 90 NTU range of turbid water interval class was made i.e. 21 to 30 NTU, 31 to 40 NTU, 41 to 50 NTU, 51 to 60 NTU, 61 to 70 NTU, 71 to 80 NTU, and 81 TO 90 NTU. In each interval class 5 number of samples of turbid water were analyzed. Also, when there is change in weather pattern or rainfall, natural turbidity also has high turbidity in the range of about artificially prepared turbid range. Similarly, the turbidity removal at the 3 flows rate viz. 7 lps, 8.5 lps, and 10 lps for particular influent turbidity was also analyzed to find out the mechanism of suspended solids removal in tube settler.. For the measurement of particular influent turbidity, turbidity up to 160 NTU was analyzed and finally sensitivity curve was plotted and shown in the figure 6 in results and discussion. The study was mostly focused for the kinetics of suspended solids removal in the tube settler. Three flow rates of water were operated viz. 7 lps, 8.5 lps, and 10 lps and the kinetics of suspended solids were observed. The turbidity removal efficiency is calculated based on measured influent and effluent turbidity. Suspended solids concentration is responsible for causing turbidity in water sources. Understanding the removal mechanism of turbidity leads to analyze the kinetics of suspended solids concentration in tube settler. Kinetics of suspended solids particles removal efficiency is then calculated based on turbidity removal efficiency through tube settler.

The experimental setup tube settler was located as Siddhipur Water Treatment Plant, Siddhipur Lalitpur. The detention time for tube settler is 8.5 minutes. 85 cm long with 50 mm dia. HDP pipes have been placed in 4*2.8*2 m tank. The pipes or tubes has been installed at a 60° inclination to horizontal [11]. These design parameters are taken from Engineering Design Report, 2006 of the Siddhipur Water Treatment plant. The removal efficiency depends upon the nature and size of suspended particles present in water. If suspended particles have size less than 400 microns, removal efficiency is less, as tank is designed to remove particles above 400 microns. The sludge from the tube settlers during the cleaning operation is collected through a drain pipe located at the bottom side of the tube settler tank unit. The sludge generated is collected and disposed of in the open fields near the treatment plant. The schematic diagram of tube settler is shown in Figure 1.

3.1. Result and discussion

The turbidity removal capacity of the tube settler is observed by measuring influent and effluent turbidity at discharges 7, 8.5 and 10 lps and SOR: 0.45, 0.597 and 0.643 m/hr., at different turbidity ranges from 20 to 160 NTU. The removal capacity decreases with the increase of overflow rate or discharge. SOR increases, flow velocity increases resulting lower settlement of particles leads decrease in turbidity removal.

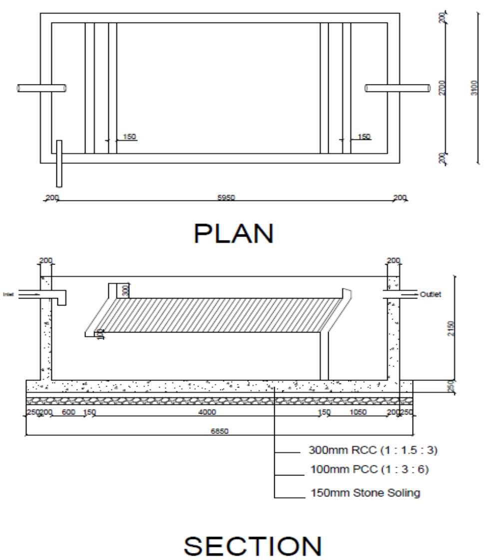

Figure 1: Schematic diagram of tube settler

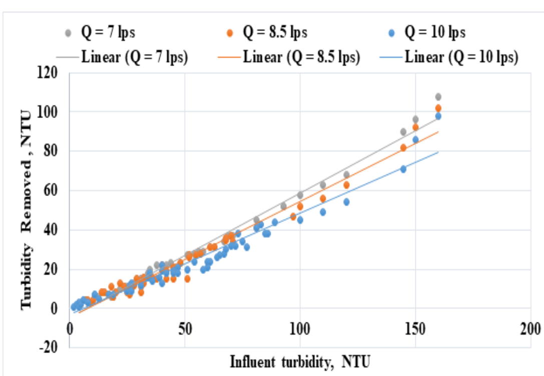

Figure 2: Turbidity removal at various flow rate

Figure 2 shows the turbidity removal for various flow rates. The turbidity removal decrease as the flow rate increases and the turbidity removal increases as the flow rate decreases. From the results, it shows that average turbidity removal efficiency of tube settler increases to a certain level and becomes consistent at that level and finally decreases slowly. The increase in the suspended solid concentration rises the number of particle of very small size which requires relatively longer duration of detention time to be removed, as a result of which effluent turbidity increases.

With the increment in discharge, average removal efficiency of the tube settler reduces. The turbidity removal capacity decreases with the increase of discharge or overflow rate. While increasing the flow rate or overflow rate from 7 lps to 10 lps (0.45 to 0.643 m/hr), removal

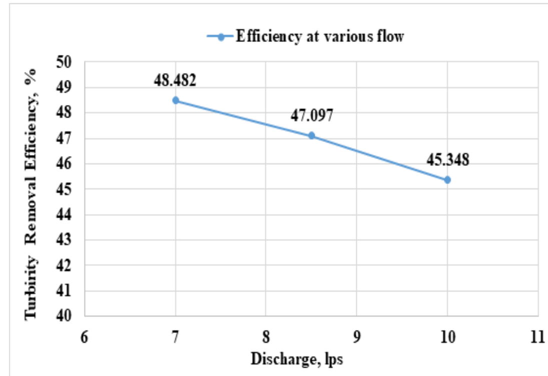

Figure 3: Manganese concentration at three different sets of discharge

efficiency of the tube settler decreases from 48.482 to 45.348%. This change in the removal efficiency gives idea about the turbidity removal mechanism in the tube settler as presented inf Figure 3.

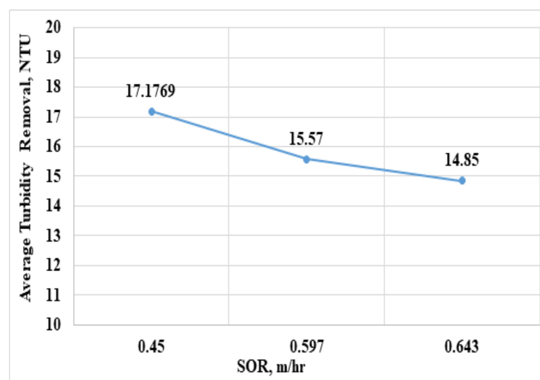

Figure 4: Average turbidity removal at various SOR

SOR increases, flow velocity increases resulting lower settlement of particles leads decrease in turbidity removal. From the Figure 4, it can be observed that the effluent turbidity was decrease as a result of which turbidity removal also decreases with increase in the overflow rate. The low flow rate was significant to remove suspended solids concentration in the tube settler.

Figure 5 shows sensitivity curve for turbidity removed vs. discharges for particular influent turbidity. For high influent turbidity, it is found that at low flow rate turbidity removal is more in comparison to high flow rate. For the low range of influent turbidity i.e. up to 34 NTU there is utmost same removal in all flow rates. So from study it can be said that for low influent turbidity removal, flow rate does not affect turbidity removal. Comparing the turbidity removal at various flow rates it is found from the study that turbidity removal changes with the flow rates for same range of influent turbidity.

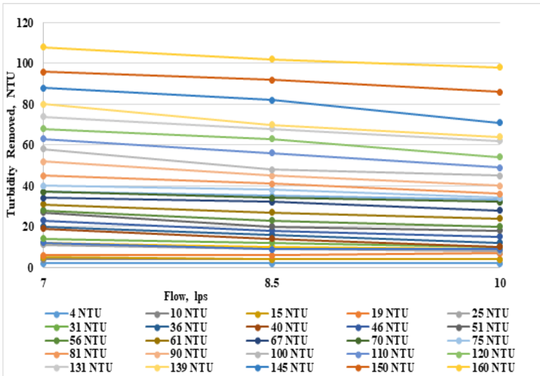

Figure 5: Comparison of particular influent turbidity at various flow rates

With the same influent turbidity range, turbidity removal was found less in higher flow rates at the same time for same range turbidity removal was found more in lower flow rate.

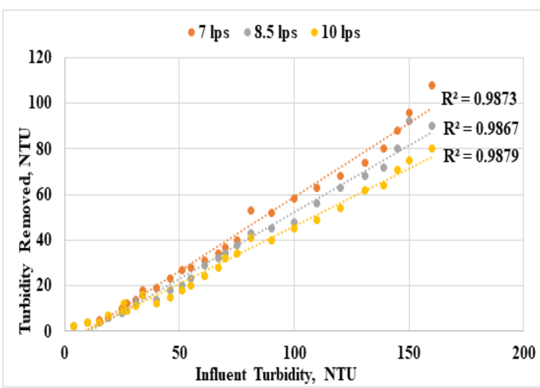

Figure 6: Turbidity removed for particular influent turbidity at various flow rates

Figure 6 shows a plot of influent turbidity vs. turbidity removed for particular influent turbidity. Establishing a linear relationship model between the various removal turbidity for different overflow rate at 0.45 m/hr, 0.597 m/hr and 0.643 m/hr, it was find that the value of R^2 is 0.9873, 0.9867, 0.9879 for the flow rates of 7 lps, 8.5 lps, and 10 lps respectively. Figure 5 and Figure 6 are plotted for the same data. Figure 6 shows how with the same particular influent turbidity the turbidity removal changes

4. Conclusion

This study was aimed to determine the suspended solids removal efficiency of tube settler in SWTP at various flow rates. From the results and discussion, as the turbidity in the influent is increased, more suspended particles are removed as a result turbidity removal is also increased. The increment in the more suspended particles removal is due to more contact area in tubes. Increment in the influent turbidity leads to the increase in the effluent turbidity because the increased in the influent turbidity increases the suspended solid concentration on the tube settler. The increase in the suspended solid concentration leads to the rise in the number of particles of very small size which requires relatively longer detention time for removal. As a result of which effluent turbidity increases. In addition, at constant turbidity, turbidity removal was found less in higher flow rates in comparison to lower flow rates. Finally, it is concluded that actual observed efficiency and turbidity removal mainly depends upon the nature of suspended solids in the influent. The maximum turbidity removal efficiency in tube settler is obtained as 48.482%, 47.096% and 45.348% at SOR of: 0.45 m/hr, 0.597 m/hr and 0.643 m/hr respectively.

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