

UPGRADING OF SECONDARY CLARIFIERS BY INCLINED PLATE SETTLERS

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ABSTRACT

Secondary sedimentation is one of the most commonly used unit operations in wastewater treatment plants. It is customary designed to achieve solids separation from biologically treated effluent through clarification of biological solids and thickening of sludge. As treatment plants receive increasingly high wastewater flow, conventional sedimentation tanks suffer from overloading problems which result in poor performance. Inclined plate settlers, a form of tube settlers, may have good potential in upgrading sedimentation tanks. This study was conducted to examine the possibility of applying inclined plate settlers in secondary sedimentation in order to upgrade conventional rectangular sedimentation tanks and improve their performance.

An extensive experimental study was conducted at Al-Awir sewage treatment plant in Dubai using a pilot-scale inclined plate settler which received a mixed liquor stream from the high-rate activated sludge aeration tank. The experiments were divided into two sets. In the first set of the experiments, the pilot-scale tank was used as a conventional settling tank (without inclined plates). The second set of experiments were conducted using the same tank with inclined plates. Different flow rates were used in each continuous experiment during which several samples were collected from influent and effluent of the tank. The samples were analyzed to determine suspended solids, total solids, biochemical oxygen demand and chemical oxygen demand. In addition, some samples were taken from the settled sludge to determine solids concentration.

The results of this study showed that inclined plate settlers perform slightly better than conventional type settlers during normal operation of plants but during peak flows, the inclined plate settlers showed much better performance than conventional settlers. The inclined plate settlers are less affected by overloading in comparison to conventional settlers. The solids removal efficiency increased as the hydraulic residence time was increased or as the surface loading rate was decreased. Application of these plates will not cause any interruption of daily operation of treatment plants and could be achieved at minimal cost when compared with other methods such as addition of chemicals, application of deep tanks, ... etc. The study revealed that SS is a better parameter than TS, BOD, COD to evaluate the performance of sedimentation tanks. A statistical model was formulated to describe tank performance and design parameters were obtained based on the experimental results.

KEYWORDS

Inclined plate settlers, upgraded sedimentation tanks, conventional secondary clarifiers

INTRODUCTION

The increasing concern which is being voiced as to the destruction and pollution of our environment has produced a growing worldwide awareness of the need for more effective wastewater treatment. In addition the contribution of wastewater treated effluents and sludge to the spread of many types of human and animal infection is now being quantified. This has emphasized the vital need for improved water supply and sanitation, especially in developing countries. Operation of wastewater treatment works are thus no longer the exclusive domain of the engineer and chemist; multidisciplinary teams of engineers and scientists are required in order to maximize the benefits to the community which should occur from the installation of sewage treatment. In modern societies proper management of wastewater is a necessity, not an option. Wastewater collected from municipalities and communities must ultimately be returned to receiving waters or to the land. The complex question of which contaminants in wastewater must be removed to protect the environment - and to what extent - must be answered specifically for each case. The answer to this question requires analyses of local conditions and needs, together with the application of scientific knowledge, economic analysis, and engineering judgment based on past experience and consideration of national requirements and regulations.

Upgrading of existing wastewater treatment plants (WWTPs) may become necessary for a variety of reasons. Growth within the service area, or the desire to serve additional areas, may result in the need to increase the capacity of an existing treatment facility. New, more stringent requirements may be imposed on a treatment facility, resulting in a need to upgrade treatment processes. Older facilities may need upgrading to replace existing equipment that no longer functions as intended or to allow installation of newer, more efficient and cost-effective technology. In this case, the objective of the upgrading may be to improve plant reliability and / or reduce operating cost. Of course, more than one of these reasons may combine for a particular plant. The subject of upgrading existing wastewater plants is particularly important at this time. It is important both because of the large number of existing facilities and because of the increasing stringent requirements imposed on wastewater treatment facilities.

The objective of this study is to examine the possibility of upgrading conventional secondary clarifiers in an operating wastewater treatment plant by applying inclined plate settlers. In order to achieve the such objectives, field experiments were conducted in the main wastewater treatment plant in Dubai using pilot-scale sedimentation tanks with and without inclined plate settlers for secondary clarification of activated-sludge mixed liquor.

MATERIALS AND METHODS

The experimental Set-up is shown in Fig. 1. A pilot plant was set up at the Al-Awir sewage treatment plant near the activated sludge pumping station and aeration tanks. The inflow of the pilot tank was from the second compartment of an aeration tank. The settled sludge was frequently removed to maintain the sludge blanket nearly at same level throughout the test period. The effluent of the pilot tank as well as the settled sludge were diverted to inlet of returned activated sludge screw pumps of the plant.

The pilot plant consisted of the following:

1. A pilot scale settling tank made of Plexiglas, with dimensions of Length: Width: Height 1.2m:0.4m:1.2-1.5m.

Ten removable Poly vinyl chloride (PVC) plates of 2mm thickness were placed at the outlet side of the tank to form a plate settler module. The dimension of each plate was 0.4x0.5m except the last one which was of dimension 0.4x0.6m. The plates were fixed at 50 mm space from each other and at an angle of 60° to the horizontal. The bottom of the tank is inclined towards the outlet side at a slope of about 20%. At the bottom of the tank, a drain pipe was fitted to withdraw the accumulated sludge. Another pipe was fitted just below the level of the plate settler to withdraw the sludge blanket. Inlet and outlet pipes were fitted to the tank. An inlet channel was fixed to distribute the flow uniformly over the inlet weir. Also, an outlet channel was fixed to collect the effluent uniformly. The water level in the tank is 5cm above the plate settler module. Two baffle plates were provided, one at the inlet (fixed 10cm. apart from the inlet weir) and the other plate was fixed just before the plate settler module.

2. A submersible pump to deliver the influent from the high-rate aeration tank to the pilot scale tank

The pilot plant was operated at different flow rates to determine the effect of Hydraulic Retention Time (HRT) and Surface Loading Rate (SLR) on the performance of the Inclined Plate Settler (IPS). Influent and effluent samples were collected at different operating periods. The liquid temperature ranged between 23-29 °C during the experiment. The samples were analyzed according to procedures outlined in "Standard Methods For The Examination of Water and Wastewater" , 17th edition, APHA, (1989) to determine the following parameters: Suspended Solids (SS), Total Solids (TS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Volatile Suspended Solids (VSS), Total Volatile Solids (TVS) and Settleable Solids.

RESULTS AND DISCUSSION

Performance of Conventional Sedimentation Tank

The pilot-scale tank was used as conventional sedimentation basin by removing the plates. The experiments consisted of five runs with different influent flow rates to simulate actual operating conditions of the secondary clarifier in the plant. Each continuous run lasted for a minimum of 50 hours. The influent to the pilot tank was the mixed liquor from the second compartment of a high rate aeration tank in Dubai's sewage treatment plant. The operating conditions during the testing period are presented in Table 1.

Table 1 Operating conditions during experiment of conventional settling tank

Q (m ³ /hr)	HRT (hour)	MLSS (mg/l)	SVI (ml/g)	Temperature, (°C)	
				Liquid	Air
0.3	2.17	2085	149	29.0	33.8
0.75	0.87	2170	148	24.8	28.6
1.0	0.65	2770	130	30.0	33.6
1.4	0.47	3120	131	30.6	34.3
2.0	0.33	2390	125	27.0	30.6

From the above table it is clear that there was no much fluctuations in the influent characteristics, i.e. Mixed Liquor Suspended Solids (MLSS), which could affect the performance of the pilot tank during testing period. Similar to SS removal efficiency, the BOD and COD removal efficiencies were more or less constant during the operating period at each flow rate. This emphasizes that the tank performance was stable during the period of study. Also the relationship between HRT and the removal efficiency of both SS and TS are shown in Table 2 and Figure 2.

Table 2 Performance of conventional settling tank in SS and TS removal

Q (m ³ /hr)	HRT (hour)	SLR (m ³ /m ² .hr)	SS removal (%)	TS removal (%)
0.3	2.17	0.63	94.8	59.6
0.75	0.87	1.56	94.7	67.4
1.0	0.65	2.08	94.1	62.0
1.4	0.47	2.92	93.6	66.0
2.0	0.33	4.17	94.1	68.1

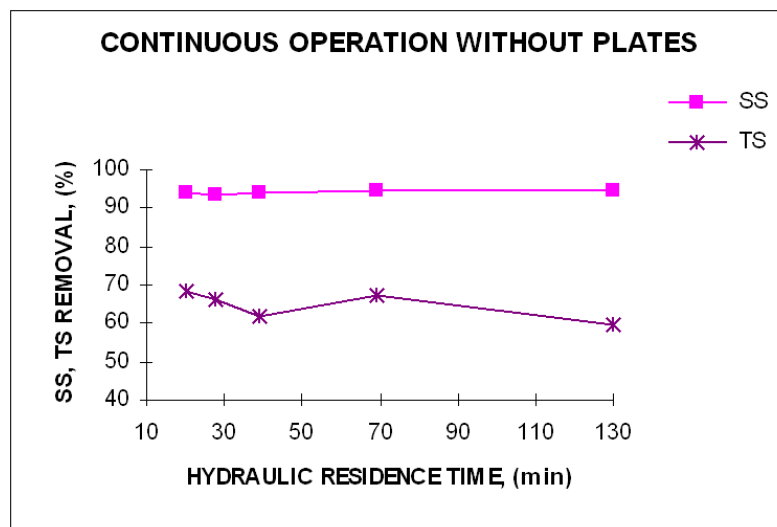


Figure 2 Performance of conventional settler at different hydraulic residence times.

It is clear from Figure 2 that while the %SS removed is increased as HRT was increased, the %TS did not show a similar trend since %TS was almost constant, if not slightly decreasing, as HRT was increased. This may indicate that biological activities took place in the sedimentation tank especially at longer HRT's thus transforming the biological SS into dissolved solids. Such transformations would ultimately increase the TS concentration at longer HRT, i.e. decreases the %TS removal efficiency. This emphasizes the importance of evaluating sedimentation tank performance based on SS (rather than TS) as usually reported in the literature. The effect in the case of the relationship between SLR and removal efficiency of SS and TS is opposite to that observed for HRT as shown in Table 2 and Figure 3.

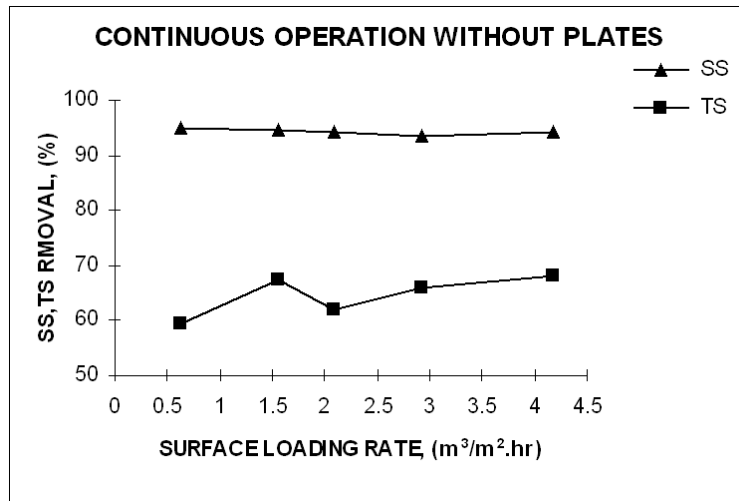


Figure 3 Performance of conventional settler at different surface loading rates.

The good performance of the sedimentation tank during this study is possibly due to the good settleability of the biological solids as indicated by the Sludge Volume Index (SVI) values being in the optimum range of (125-149 ml/g) as presented in Table 1.

Performance of Sedimentation Tank Using Inclined Plate Settler

The performance of the inclined plate settler was examined by applying nine different influent flow rates ranging from 0.3 m³/hr to 2.0 m³/hr in separate experimental runs. The duration of each continuous run was at least, 50 hours during which different samples were collected from the influent and effluent of the tank. The main parameters (i.e. SS, TS, BOD,...etc.) were determined and the removal efficiencies were calculated at different influent flow rates. The performance was stable during each operating period studied. The values of HRT in the pilot tank were calculated for each experimental run as illustrated in Table 3 and the corresponding SLR values are presented in Table 4.

Table 3 Operating conditions during experiment of inclined plate settler

Q (m ³ /hr)	HRT (hour)	MLSS (mg/l)	SVI (ml/g)	Temperature, (°C)	
				Liquid	Air
0.3	2.04	1735	116	24.7	25.2
0.5	1.22	2470	122	28.8	29.3
0.75	0.82	2172	461	22.2	27.2
1.0	0.61	1784	476	21.9	27.6
1.2	0.51	2256	147	22.2	28.0
1.4	0.44	2308	208	23.5	27.9
1.6	0.38	1561	547	21.7	28.1
1.8	0.34	2494	128	24.9	27.9
2.0	0.31	2093	107	23.8	26.8

Table 4 Performance of inclined plate settler in SS and TS removal

Q (m ³ /hr)	HRT (min)	SLR (m ³ /m ² .hr)	SS removal (%)	TS removal (%)
0.3	2.04	0.24	97.7	56.1
0.5	1.22	0.4	97.5	69.2
0.75	0.82	0.6	97.9	54.6
1.0	0.61	0.79	97.5	43.8
1.2	0.51	0.95	97.1	64.2
1.4	0.44	1.11	96.7	47.6
1.6	0.38	1.27	94.7	46
1.8	0.34	1.43	97.2	64.8
2.0	0.31	1.59	96.2	66.1

The relationships between HRT and the removal efficiencies of both SS and TS were established as presented in Figure 4, from which it is clear that the removal efficiency increases as HRT increases. Figure 5 shows the relationship between SLR and removal efficiencies for both SS and TS. It is evident that removal efficiency decreases as SLR increases. Such trends are similar to those observed in the conventional sedimentation tank regarding percentage removal of SS and TS in relation to HRT and SLR. In these experiments on the upgraded sedimentation tank, similar observations to those made during the experiments on the conventional sedimentation tank were evident regarding trends in TS, BOD, and COD removal.

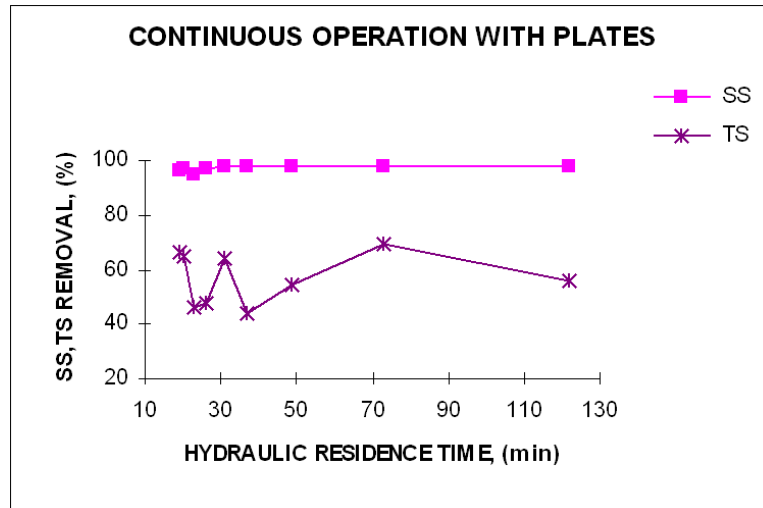


Figure 4 Performance of inclined plate settler at different hydraulic residence times.

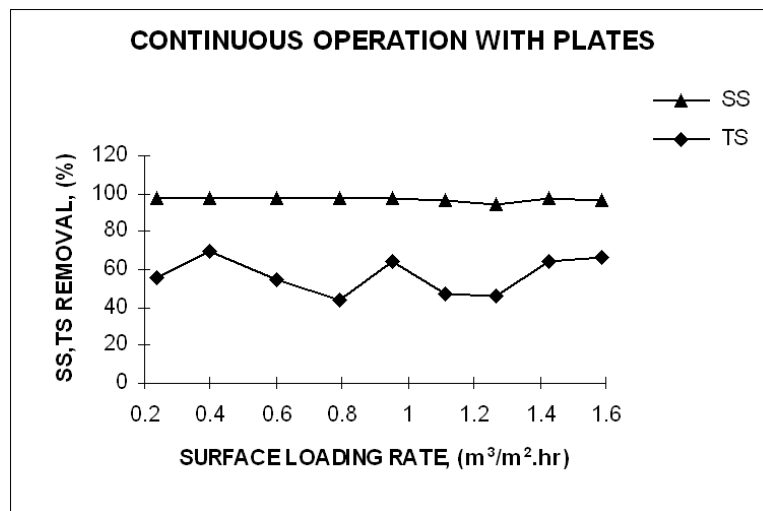


Figure 5 Performance of inclined plate settler at different surface loading rates.

Comparison between Conventional and Inclined Plate Sedimentation Tanks

In order to perform such a comparison, the removal efficiency for SS has been determined for both types of settlers at five different influent flow rates ranging from 0.3 m³/h to 2.0 m³/h. Comparing the results obtained from operating the pilot scale tank as a conventional sedimentation basin and as a high rate settler, i.e. without inclined plates and with plates, it is apparent that during operation with plates the SS removal efficiency is better than in case of conventional tank by 2% - 3% which is a marginal increase in efficiency. However, the tank with plates was capable of maintaining high removal efficiencies even when the biological solids had high SVI as shown in Table 1 and 2, knowing that high SVI values (>200 ml/g) are indicative of poor sludge settleability.

The merit with plate settlers is more apparent when settling rather than thickening is controlling the tank design. This may indicate that application of plate settlers in secondary clarification of biological sludge may not be as advantageous as their application in primary clarification of wastewater solids. However, when secondary clarifiers are overloaded or suffer from rising sludge problems, upgrading of such clarifiers using plate settlers is definitely advantageous. This is in addition to savings in costs of land area covered by settlers which is much less in case of plate settlers than in case of conventional type gravitational settling tanks. Based on the results obtained for plate settler, a statistical model could be formulated by applying linear regression analysis for the

relationship between SLR and %SS removal. Figures 6, 7, and 8 illustrate the relationship obtained which could be expressed by the following equation:

$$\% \text{ SS removal} = 98.27 - 1.38 \text{ SLR} \quad \dots\dots\dots (1)$$

This is a statistical model describing the removal efficiency of SS in the upgraded plate settlers. Similarly the following equations had been obtained for BOD and COD:

$$\% \text{ BOD removal} = 96.25 - 1.02 \text{ SLR} \quad \dots\dots\dots (2)$$

$$\% \text{ COD removal} = 95.53 - 0.8 \text{ SLR} \quad \dots\dots\dots (3)$$

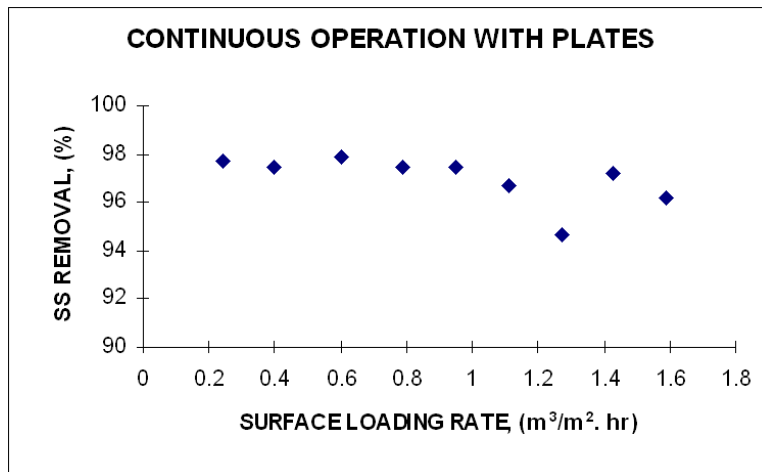


Figure 6 Effect of surface loading rate on SS removal of inclined plate settler.

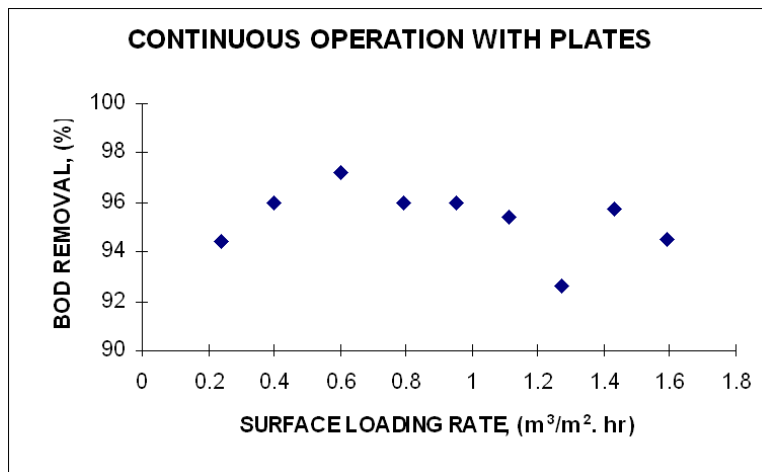


Figure 7 Effect of surface loading rate on BOD removal of inclined plate settler.

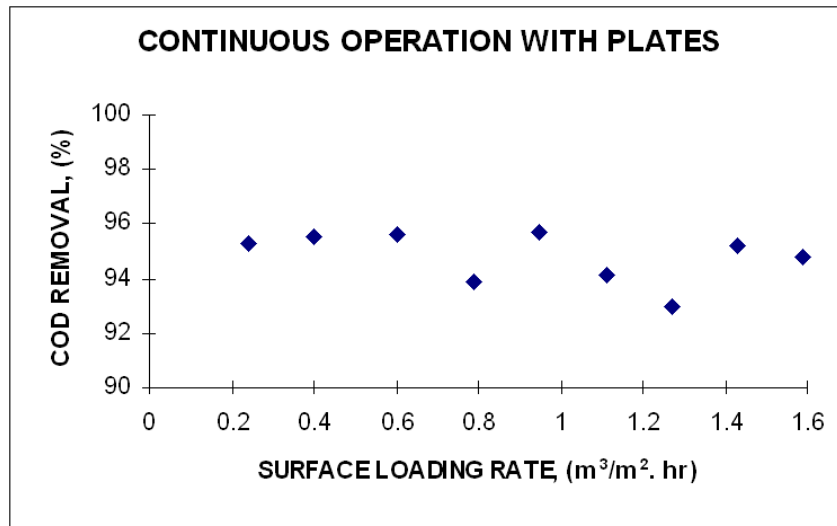


Figure 8 Effect of surface loading rate on COD removal of inclined plate settler.

CONCLUSIONS

The following conclusions can be drawn based on the pilot plant testing of conventional and upgraded (inclined plate) settlers:

1. The inclined plate settler has proved effective in improving the performance of secondary sedimentation of biological solids at the studied surface loading rates in the range of 0.2 to 1.6 m³/m².hr.
2. Removal efficiencies of suspended solids, biochemical oxygen demand, and chemical oxygen demand were slightly higher in the inclined plate settler.
3. In comparison with conventional settler, the inclined plate settler is less affected by overloading. If the design surface loading rate criteria for conventional settling tanks are used for designing high-rate settlers, the latter should perform better within the range of surface loading rates normally used in practical design.
4. The solids removal efficiencies increase with the increase of HRT and decrease of SLR.
5. Suspended solids removal efficiency is a better parameter to describe the performance of sedimentation tanks compared to total solids. Meanwhile, biological transformations of solids in the secondary sedimentation tank could contribute to BOD and COD which results in higher BOD/SS and COD/SS ratios in the effluent than in the influent. This emphasizes the uniqueness of SS as a better parameter in performance evaluation.
6. The main advantage of inclined plate settlers in secondary sedimentation of biological solids lies in their capability of coping with plant overloading conditions. Such settlers could be easily installed in existing rectangular sedimentation tank as a solution to rising sludge problems at minimal cost compared to other solutions such as increasing tank depth, addition of chemical coagulants, ...etc. Installation or removal of inclined plates would not interfere with normal operation of existing sedimentation tanks.

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