Design Of Lamella Separator For Enhanced Pollution Removal From NED University Wastewater

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Abstract

The wastewater treatment process incorporates various settlers in the treatment train such as primary, secondary, or tertiary. The conventional settlers used are not adequate to remove suspended solids and create hindrances in the operation of further treatment processes. Therefore, to effectively remove suspended solids lamella clarifier was used in combination with the existing primary settler at the NED wastewater treatment plant. The water quality parameters analyzed include TSS (mg/l), BOD5 (mg/l), and COD (mg/l) in phase 1 before lamella clarifier installation and phase 2 after lamella clarifier installation. Satisfactory results for TSS removal were achieved before and after lamella clarifier i.e., 227-277mg/l to 87-163 mg/l. Similarly, BOD 5 was reduced from 49-277mg/l up to 35-163mg/l. Also, the COD was reduced from 229-277mg/l and was reduced up to 156-163mg/l. Therefore, the lamella clarifier installed at the NED wastewater treatment plant seems to be an effective technology to remove suspended solids along with COD and BOD removal.

Keywords—Suspended solids, lamella clarifier, wastewater.

1 Introduction

One of the major problems with conventional clarifiers is to cause inhibition in solid settlement due to small depth and delayed separation efficiency [1][2]. The settling in conventional clarifiers takes place as the water flows from the bottom and is discharged through the top while gravity settles the particulates at the bottom of the clarifier. Inclined plates are used in improved gravity separators in the settling zone to direct the flow[3]. This resolves the issue of unstable mixing currents and flow regimes which impede the settling of particles. Besides, the development of laminar flow patterns, the inclined plates shortened the travel distance that particle covers before settling. The lumps of the particles begin as immediately as the particles encounter the surface of the plate. Consequently, rapid settlement occurs in the case of newly formed clustered particles in comparison with fine particles and smoothly slides through the support of a parallel surface reaching the bottom of the clarifier following the collection, and heading towards the outlet. In the horizontal, flow the efficiency of settling of solids is dependent upon the availability of area for settling. The inclined plates increase the surface area for particles settling in lamellar settler enabling them to be of small footprint in comparison with conventional clarifiers [2], [4], [5]. The process of sedimentation is one of the fundamental steps in water and wastewater treatment which is carried out in a sedimentation tank based on gravity to settle suspended particles [6]. The efficient working of the settling tank is majorly subjected to the removal of suspended solids. It is difficult to achieve the low settling velocity required in settling tanks comprising enhanced surfaced areas, particularly where space restrictions are implemented. Therefore, to improve the performance of settling tanks inclined plates are introduced which leads to enhanced surface area and hydraulic patterns. [7]. For this reason, several studies were considered to measure the performance of lamella settlers using in-

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clined plates such as [8] used lamella settler for storm wastewater treatment and found efficient performance for removing suspended solids up to 80 to 90% operated at short time intervals. Similarly, [9] treated stormwater as surface runoff in lamella clarifier and achieved satisfactory, results particularly in the case of sufficient sewer storage volume. Lamella clarifier can be equipped with the advantage of mechanical cleaning that saves operational costs. Whereas [10] used lamella clarification along with biofiltration which significantly removed various organic chemicals such as PCBs, and pesticides in wastewater treatment, and efficient results were obtained up to 85%. Nonetheless, removed TSS and several organic chemicals such as pesticides, and metals with the use of lamella clarifier and biofiltration and efficiently removed TSS up to 86%. On the other hand, [11] determined sedimentation efficiency by using lamella packets in sedimentation tanks and obtained satisfactory results.

The lamellar clarifier has the following advantages in comparison with typical clarifiers. It can be easily incorporated with the wastewater treatment process following the floatation process. Also, it is used in high-performance wastewater treatment systems which treat peak wastewater loads. Whereas, the typical clarifier requires a huge footprint to achieve the similar particle removal efficiency of a lamella settler [9]. Similar loading rates can be easily subjected to the traditional settlers as to the size of the lamella clarifier by placing the projected area for the surface settling area of a traditional settler[11], [12]. Typical clarifiers have the disadvantages of hydraulic unsustainability posed by wind and temperature variations when installed outdoors. While in lamella settlers' stable and balance flow regime occurs which causes the uniform distribution of flow towards each plate and the plate surface area overcoming short-circuiting of currents. The installation cost is lower as units and lamellar packs are easily assembled on-site which saves installation time. Lamellar uses basic moving parts which means lower maintenance costs [9], [13],[14].

Other benefits include uninterrupted operation. Smaller volume eliminates the need of allocating huge storage while unloading. Loading and unloading time is short. The modular design makes it flexible to be incorporated in plant up-gradation. Although there are some disadvantages i.e., particle resuspension may occur due to the nonexistence of buffer volume to handle flow variation. Surfaces can be affected by deposit collection. The absence of a storage facility for settled sludge particles but the modular design makes it flexible to be incorporated in existing plant up-gradation [9]. Also, simple operation. minimum reagents and minimum energy requirements make it suitable to use. Therefore, it has been widely used to treat different types of wastewater such as [15] treated acid mine drainage in South Brazil with two different types of floc one aerated and the other non-aerated by using two different floc separation methods in which aerated flocs were separated by solid-liquid separation method and non-aerated was settled in lamella clarifier. Similar results were obtained by both methods. On the other hand, [16] determined the suspended solid removal efficiency of three lamella settlers to treat stormwater and achieved remarkable efficiency of 68%. Whereas [17] used a lamellar clarifier integrated with coagulation, flocculation, and UV radiation as a tertiary treatment to remove contaminants discharged from secondary treatment in a Spanish wastewater treatment plant and found it potentially effective to remove contaminants such as diclofenac and carbamazepine successfully. Furthermore, [18] removed iron sludge from oil surfactant effluent using lamella settler followed by electrooxidation and Fenton reaction and determined that the overall process proved satisfactory results in COD removal up to 88%. The lamellar clarifier was significantly useful in iron sludge with the completion of the overall process in less time.

Besides, [19] stated that when a lamellar plate is installed with an orifice thus head loss is prevented. The elevating flow rate in the lamellar plate is leveled which eventually gives stable flow in the lamellar plate as the distribution of flow rate is leveled.

Mostly, lamella plates should be installed at an angle of 50-70° from the horizontal direction to have easy self-cleaning [20]. Besides,[4] emphasized that the efficiency of the lamellar secondary tank can be enhanced with the placement of angles at a specific angle i.e 60°. Whereas, [20] proposed an optimized angle for most of the particles to be settled in at 30° after treating turbidity at the angles 30°, 45°, and 60°. Altogether, the traditional lamella plates have dimensions i.e., 150 cm wide by 240 cm long with channel spacing of 4 cm and settler angles between 45° and 60'. Mostly traditional tube settlers are operated at an angle of 60° [21]. Compared to modern technologies such as Reverse Osmosis (R.O) and Ultrafiltration (UF) membrane fouling is a crucial unpreventable problem that reduces the efficiency of the R.O system i.e. declined water production and quality [22]. Additionally, chemicals such as sodium hypochlorite and chlorine are commonly used to reduce mineral scaling and biofouling. All things considered, chlorine has several disadvantages in producing by-products and is not effective in the case of specific microorganisms [23]. Furthermore, the yearly cost to prevent reducing bio-

fouling is estimated to be US$ 15 billion[24]. Another, limitation of the R.O process is the amount of rejected water production [25]. The R.O systems are energy intensive for both high and small units [26]. The usual R.O plants' energy consumption is estimated to be 3.7 to 5.3 kWh/m3 and is dependent on feed water attributes and acceptable quality standards [27]. In the case of a multi-step RO stage setup complexity and configuration expense increase due to parts replacement and service requirements; therefore is not convenient for even a decentralized system[28].
Despite the advantages that UF is effective in the reduction of suspended solids and microorganisms; still enables a pathway to small organic molecules to cause biofouling [29]. Besides, even high-quality biocide applied cannot completely eradicate biofouling as even if some microorganisms remain may adhere to the membrane and grow to develop biofilm and cause disturbance in permeate water flux [30]. Also, membranes require regular maintenance i.e. cleaning and replacement in plants[23]. The UF system is expensive related to the energy requirement. The cost in UF is due to rotating pumps, air compressors, and blowers. In the case of proper raw water treatment for acceptable standards, UF can be more expensive than a traditional treatment system [31]. For instance: The build-up cost of ultrafiltration set-up was exorbitant in 2013 estimated at USD 3,710,000 as compared to the traditional system to a high extent [28]. In general, the UF processes cost (USD 35.40) which has 3 times higher functional cost as compared to media filtration (USD 11.06) to generate 1000 m3 of treated water [32]. The drawbacks of the membrane process are high functional cost and intensive energy requirements[33], [34]. Despite the optimization in the traditional R.O. process, the energy and function costs remain high and yet no significant technology has been proven to be useful to the extent of less energy consumption. Therefore, efforts are made to find solutions to optimize the cost and energy consumption[35], [36]. The objective of this study is to improve the sedimentation process using an inclined plate at a 60° angle of a rectangular tank of the wastewater treatment plant at NEDUET.

2 Materials and Methods

2.1 Study Area

This wastewater treatment plant is located on the premises of NED University, Pakistan. and the wastewater was collected from the NED staff colony and all departments present in the university.

TABLE 1: Technical and operational information relating to the lamella clarifier

No. of Plates	Thickness (mm)	Area plate (ft^2)	Space between plates (inch)	Inclined angles of plates
19	3	12.5	First four plates:4" Others: 2"	60^0

2.2 Wastewater Treatment Plant Description

NED University Wastewater Treatment plant receives 15000 Gallons per day of wastewater. The treatment facility consists of the following stages preliminary treatment via a septic tank, followed by a primary sedimentation tank, Aeration tank, Disinfection, and a secondary clarifier tank. Primary sludge is disposed of in a separate sludge digestion tank. At the preliminary stage, wastewater goes to the septic tank followed by screening, grit, and oil removal. In primary treatment coagulation and flocculation takes place in which suspended solids settle in primary sedimentation tanks. As a secondary treatment, the water is passed through an aeration tank to treat organic contamination through biological treatment. Followed by tertiary treatment in which water goes through a disinfection process to remove microbial contamination. The water is settled in a secondary sedimentation tank. Finally, water moves in the treated effluent tank. The sludge from the primary and secondary tanks is collected in the sludge tank. The reclaimed water is used for irrigation purposes.

2.3 Lamella Clarifier Configuration

Lamella clarifier design consists of a series of inclined plates inside a primary treatment tank. Space for sludge collection is 2.5 feet at the bottom of the tank and one foot from the surface of the tank for the plate's submergence into the water as shown in figure 1. Further details are described in the following table.

The untreated feed water enters from the top of the tank and flows down underneath the inclined Plates. Wastewater flows into the clarifier between the inclined plates. Due to lamella plates, the velocity of wastewater is decreased, so the settling velocity will increase automatically. During this time suspended solids settle down onto the bottom of the tank. The particle takes a route that will be dependent upon the flow rate of the suspension and settling rate of the particle. From the bottom of the tank, sludge was collected through a sludge pump for proper disposal. Sludge was discharged within 60 days.

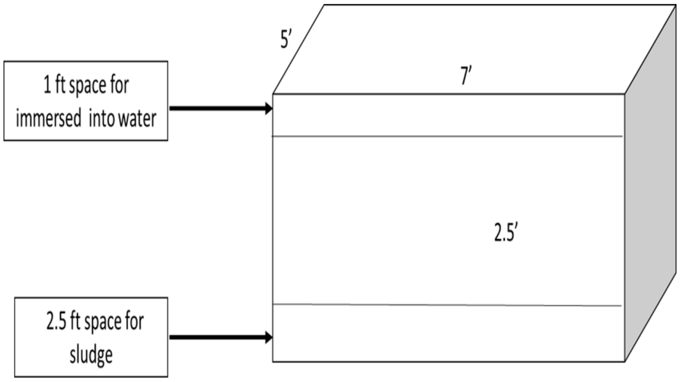

Fig. 1: Represents the design of the Primary clarifier tank

Fig. 2: Construction of the frame for holding plate

Wastewater flows through a series of plates, all particles were settled and clarified effluent from the outlet of the tank. The construction of holding plates is shown in figure 2. This study was performed in two phases i.e phase 1 before lamella clarifier installation and phase 2 after lamella clarifier installation. The effluent samples were evaluated in phase 1 and phase 2.

2.4 Description of the Sample

The efficiency of the lamella clarifier was evaluated in comparison with the traditional primary clarifier installed already. Sampling was performed two days per week Monday and Friday. Testing was performed from different locations including the influent and effluent of the primary sedimentation tank and the final effluent of the wastewater treatment plant. Figure 3. represents the final design of the lamella clarifier. The analyzed water quality parameters are suspended solids (SS), Biological oxygen demand (BOD_5), and Chemical Oxygen demand (COD). However, the efficiency of the system was calculated using Eq.(1), below:

$$RE(\%) = \frac{C_0 - C_i}{C_i} x100 \qquad (1)$$

TABLE 2: Represents water quality parameters before lamella clarifier installation

Parameters	Influent (mg/l)	Effluent (mg/l)
TSS	247	130
BOD_5	63	56
COD	162	153

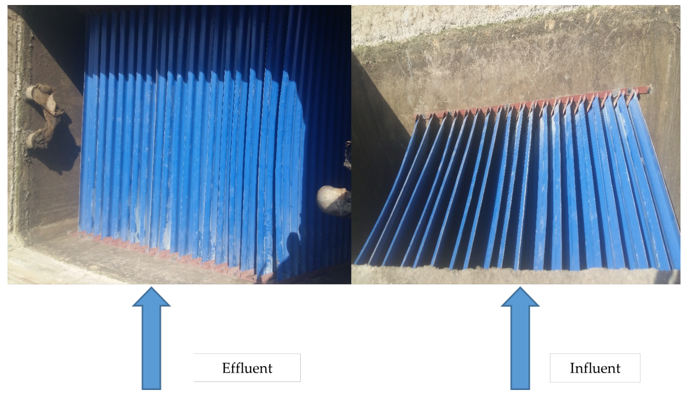

Fig. 3: Represents the final design of the lamella clarifier

Where, RE (Removal Efficiency), C_o (Initial COD), and C_i (Final COD).

3 Results and Discussion

A total of seven influent and effluent samples were obtained after the installation of a lamella clarifier at the NED wastewater treatment plant. The samples were collected for 3 months after every 15 days to determine the concentration removal by lamella clarifier. The water quality parameters considered are TSS, BOD_5, and COD.

Figure 4. shows the concentration of TSS, BOD(5), and COD removal of different samples and Figure 5.

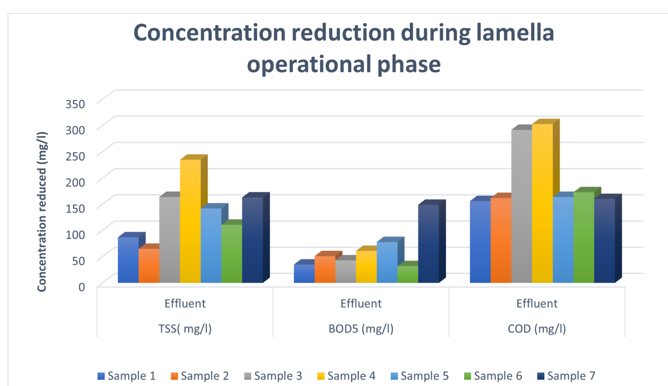

Fig. 4: The concentration of TSS, BOD(5), and COD removal of different samples

shows the TSS, BOD, and COD in (% age) removal efficiency to sample. During the first sample, the efficiency of the lamella clarifier was found to be 61%. After the next 15 days i.e., for a month it was slightly reduced i.e., 47 and 29 but was overall maintained up to 61, 60, and 63 %, 41%. Consequently, the average TSS removal efficiency was up to 52%. The influent TSS was found to be in the range of 227-277mg/l. whereas, after lamella clarifier, a significant reduction was observed i.e., 87-163 mg/l. Similar results were obtained when l lamella clarifier settler was installed in comparison to the traditional primary sedimentation tank, with BOD5 and SS removal efficiencies of 30% and 57%[6]. Then, COD was measured for the same samples, and for the first sample, it was found to be 31%, 34%, 7%,41%,25%, 24%, and 41% with an average removal efficiency of 26%. The wastewater characteristic did not have high COD, but the fluctuation was observed on rainy days which produced slightly higher values. Mostly COD of domestic sewage lies in the range of 700 - 1368 mg/l and treated wastewater lies in the range of 140 - 295 mg/L [26] while stormwater has 22mg/l -325 mg/l [37]. The effect of flow rate is one of the reasons for less COD removal in the present study, as a steady flow rate in the wastewater treatment plant is set to remove suspended solids. On the contrary, for improvement of COD removal, a higher flow rate is required which can further decrease the suspended solids removal efficiency. Similarly, wastewater samples were analyzed with a COD concentration range of 280-1900 mg/L and were reduced up to 158-565 mg/L COD. Further improvement in COD removal was done with PAC coagulants. Although COD removal was 36% [38]. Similarly, in the present study the overall, influent COD range was less i.e., 229-277mg/l, and was reduced up to 156-163mg/l having an average removal efficiency of up to 26%. Similarly, for the first sample, the BOD5 removal efficiency was 28% which gradually increased to 64%, 73%, 65%, 64%, 52%, and 41%. The average BOD removal was observed to be 55%. The influent BOD range was found to be 49-277mg/l and was noticeably reduced to 35-163mg/l. In a similar study, the lamellar settler was used to treat domestic wastewater with BOD removal of 30% [6] whereas, in this study, a gradual increase has been observed for enhanced BOD5 removal efficiency. The average BOD removal was observed to be 55%. The reason for increased BOD5 removal is as BOD was slightly less in influent and wastewater the value of COD is higher than BOD [39].

The two phases results shown in tablw 1. show that some parameters are above the limit of SEQs but mostly all parameters are under the limit.

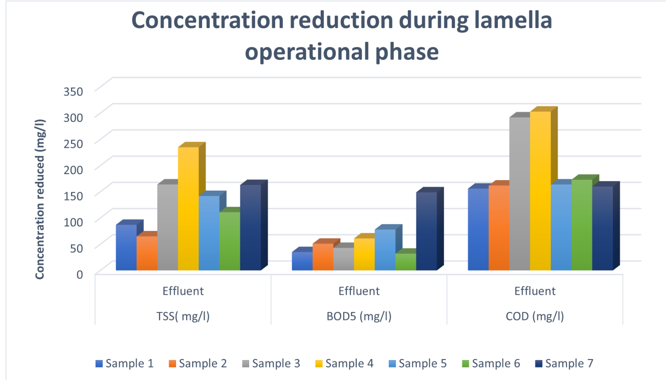

Fig. 5: TSS, BOD, and COD in % age) removal efficiency to sample

4 Conclusion

The lamella clarifier installed in wastewater treatment plants has the potential to treat wastewater, particularly for suspended solids. It was observed that in the early stages, unsustainability was observed in the system, but gradually suspended removal was increased with stability above 50%. Also, with a gradual reduction of BOD 5 and COD. The final average efficiency of the lamella clarifier was 52% with efficient suspended solids removal. Although, improved results can further be achieved when a lamella clarifier is used with the integration coagulation or electrochemical methods at optimized settling velocity.

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TABLE 3: Shows the average results of the after-lamella clarifier

No. of Sample	TSS mg/l		BOD5 mg/l		COD	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Sample 1	227	87	49	35	229	156
Sample 2	124	65	145	51	247	162
Sample 3	232	164	163	43	316	292
Sample 4	603	235	176	61	514	303
Sample 5	364	142	220	78	220	164
Sample 6	301	111	67	32	229	173
Avg.	308.5	134	136.667	50	292.5	208.33

TABLE 4: Shows SEQs limits

S. No	Parameter	UoM	Into Inland water	Into sewage treatment	Sea
1	TSS	mg/L	200	400	200
2	BOD		80	250	80
3	COD		150	400	400

TABLE 5: Lamella clarifier efficiency for suspended solids removal (%) in different types of wastewater

S.NO	Technology used	Parameter	Type of wastewater	Removal Efficiency	References
1.	Lamella clarifier integrated with coagulation	Suspended solids	Stormwater	80%	[8]
2.	High-rate lamella clarifier	Suspended solids	Rainwater	68	[28]
3.	Lamella clarifier	Suspended solids	Municipal wastewater	69	[7]
4.	Lamella clarifier	Suspended Solids	Domestic wastewater	57%	[6]
5.	Lamella clarifier	Suspended Solids	Domestic wastewater	52%	Present study

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