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Experimental investigation of enhancement in sedimentation of particle species in a modified settling tank

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ABSTRACT

Sedimentation is an important phenomenon and finds its application in various industrial processes such as wastewater treatment, coal and mineral processing industries. The segregation of solid particles from liquid streams through sedimentation is a crucial process, however, it is a slow and needs time. Nevertheless, the sedimentation of solid particles can be enhanced by utilizing inclined channels in settling tanks, which provide a larger settling area compared to vertical channels. This research work utilized a modified settling tank to investigate the settling behavior coal particles of size 250 microns. The experimental work shows a higher settling rate of particles. Furthermore, a comparison between the settling rate of solid particles in the modified settling tank and a conventional vertical settling tank was also conducted. The results indicated a significant increase in the settling rate within the modified settling tank compared to the conventional vertical tank. The results in the form of solid volume fraction along the tank height have been demonstrated.

Keywords:

Boycott Effect, Inclined Channels, Settling, Segregation, Wastewater treatment.

1. Introduction

Water is the source of life on earth, the amount and quality of available water is essential as it is usually caused by the human for various purposes like drinking, irrigation, livestock, industrial purposes etc. Overpopulation, increased urbanization and sewerage systems have increased the use of water. Industrial activities have increasing world demand for water. Water is a key component of many industrial applications, as economic activity enhances the demand for water. The main point is to provide sufficient quantity of water to meet this increasing demand for water. The more the overall usage of water resources, the more the amount of wastewater, this needs the wastewater treatment and the making of additional treatment plants all over the globe. Separation of solid particles from suspension is a main process in wastewater treatment [1].

According to Boycott effect, inclined channels provide a large effective settlement area in the settling of solid particles from the liquid-solid stream [2]. Chemical engineers commonly employ lamella settling as a separation technique for the removal of solid particles from liquid solutions. This method relies on gravity-induced sedimentation and employs lamellae, which are slanted plates, to enhance the efficiency of particle settling [3].

The inclination of the lamellae relative to the horizontal plane, multiple inclined settling surfaces can be created. In comparison to conventional settling tanks, these surfaces provide solid particles with a lengthier path for settling, thereby enhancing the separation performance [4]. Gravity causes the sedimented particles to descend along the lamellae, subsequently accumulating at the bottom of the tank, ultimately forming a sludge layer. The clarified liquid, devoid of solid particulate matter, ascends within the tank by passing over an overflow weir [5].

The treatment of huge volumes of suspension in a relatively small space is made possible by the use of inclined plates, which considerably increases the effective settling surface. Because of this, lamella settling is especially well suited for applications requiring high throughput or having limited area [6]. Lamella settling is an essential instrument in many sectors due to its adaptability and effectiveness, which helps with the efficient processing of chemical solutions and the sustainable management of water resources [7].

Recently a high-scale testing research of higher rate lamella settlers described that they could improve the solid particles capture by up to 33% when compared to conventional settling tanks designs [8]. Different research explained that surface area calculates the settling performance in inclined channels or lamella settlers [9].

Separation of solid particles from suspension using settling tanks is a major process in wastewater treatment and mineral processing industry. However, this process is a time-consuming process in terms of large residence time. Moreover, large settling tanks are required to be designed to achieve the set targets.

The main objective of this research work is to develop an advance double effect inclined channel settler which will be used to enhance settling rate of solid particles in a suspension. The proposed new design has a reflux settling phenomenon in which *settling* and *reflux action* occur at same time within a same settling tube which will increase the settling efficiency up to a great extent.

2. Material and Methods

2.1. Modified settling tank Design

A small lab scale equipment was prepared having a newly proposed design of the settling tank comprising an inclined section at the base and an inclined section at the top. The newly proposed settling tank has been named Modified settling tank (MST). The MST provides an enhanced settling facility near the base due to presence of an inclined section. Similarly, the inclined section available at the top provides a reflux action by providing an additional chance for the solid particles to settle. The particles in this section will settle and move back thus creating a reflux action and providing a chance to operate the device under continuous process conditions.

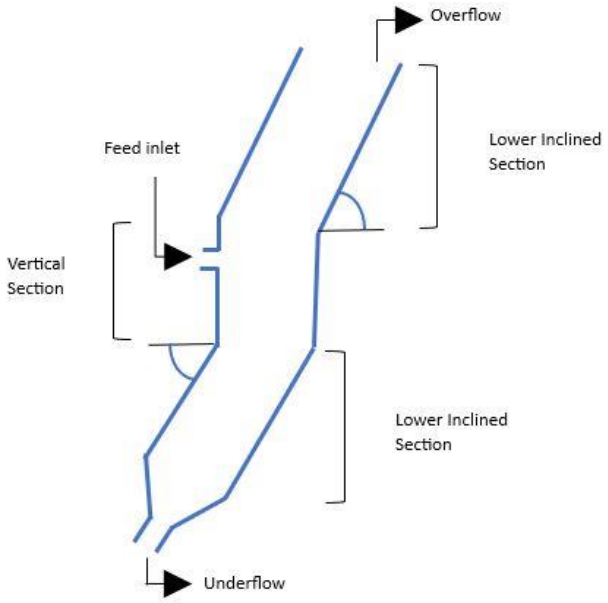

Fig. 1: Modified settling tank (Schematic)

Fig. 2: Modified settling tank

Figs. 1 & 2 show schematic and actual representations of fabricated prototype modified settling tank. The dimensions, Upper inclined section: 17 cm, Vertical section: 20 cm, Lower inclined section: 15 cm, Internal diameter: 4.8, External diameter: 5.2 cm, Inclination angle: 60^0. Figs. 3 & 4 show a Conventional vertical column having length of 100 cm.

2.2. Sample Preparation

Experiment was carried out using solid coal particles of mass 60 g with a constant solid particle size of 250 microns. The mass of water taken is 822 g which were taken constant throughout the experiment. Solid coal particles having mass of 60 g weighted on a digital balance were added to the 822 g of water and were mixed in a container manually. The mixture was poured into modified settling tank and vertical conventional column.

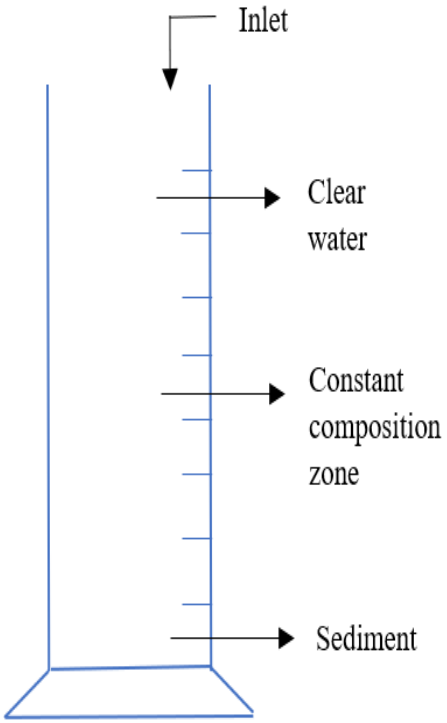

Fig. 3: Conventional Vertical Column (Schematic)

Fig. 4: Conventional Vertical Column

3. Results and Discussions:

Experiment was done for 1 hour and readings were noted after every 10 minutes, both for modified settling tank and vertical conventional column.

Table 1: Time and Height of the Clear Water

Time(min)	Vertical column (Clear water height, cm)	Modified settling Tank (Clear water height, cm)
10	3	10
20	12	22
30	20	35
40	30	40
50	36	43
60	40	44

Table 1 shows the clear water height and time for both modified settling tank and vertical column in the initial 10 minutes of observation, solids began settling in the inclined settler, with approximately 60% of the solid particles accumulating at the bottom of the column. However, the remaining water still contained a significant quantity of suspended solids. In contrast, the vertical column exhibited a less efficient settling process, with only about 35% of the solids settling at its

bottom. Moreover, there was no discernible separation zone at the base of the vertical column, unlike the inclined settler.

Continuing the observation into the subsequent 20 to 40-minute period, significant improvements were noted in the inclined settler. After 20 minutes, approximately 90% of the solids had settled at the bottom, resulting in the formation of two distinct separating zones. The water in the inclined settler also exhibited a reduced solids content. Moreover, at the 40-minute mark, settling was nearly complete, with 98% of the solids having settled, resulting in clear water above the solid contents. On the other hand, the vertical column, while showing some improvement, remained less effective. After 20 minutes, approximately 65% of the solids had settled, with no clear separation zone at the bottom. Even after 40 minutes, although two separating zones were observed, the water still contained an intermediate quantity of suspended solids, with around 80% of the solids settled at the bottom.

Volume fraction calculations at T=20 min

Table 2: Height (cm) and Volume Fraction

Height (range) cm	**Volume Fraction (Modified Settling tank)**	**Volume fraction (Conventional vertical column)**	**Difference in Volume Fraction**	
46 to 24	0.03	0.10	0.07	Clear water
24 to 13	0.07	0.25	0.18	Constant composition zone
13 to 0	0.90	0.65	0.25	Sediment

Table 2 shows the volume fraction for modified settling tank and vertical column at different height ranges and at different separation zones. The solid particle settled at the bottom as sediment while the remaining solids are in constant composition zone just below the clear water zone.

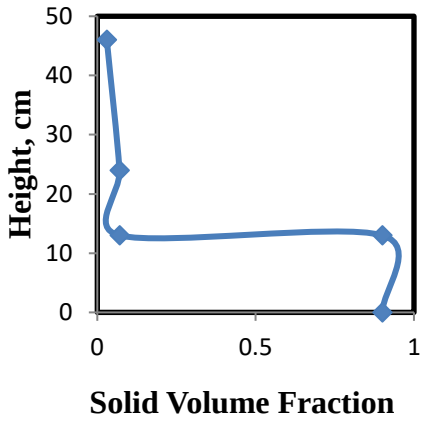

Fig. 5: Solid Volume Fraction Vs Height (Modified settling tank)

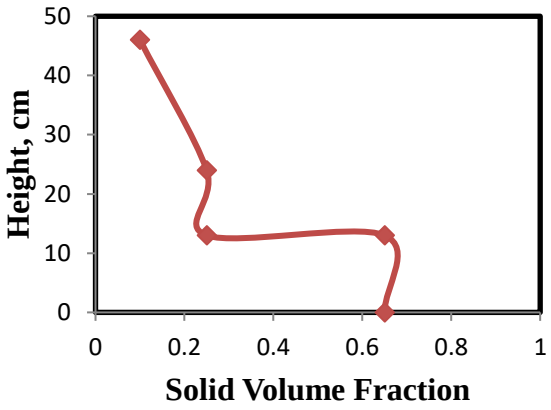

Fig. 6: Solid Volume Fraction Vs Height (Conventional vertical column)

Fig. 5 shows an impressive 90% of the solid particles had effectively settled at the bottom, resulting in the emergence of two distinct separating zones within the column. Consequently, the water in the inclined settler exhibited a significantly reduced solid content, indicative of its efficient separation capabilities.

In contrast, the vertical column exhibited a less efficient performance during the same timeframe, with only approximately 65% of the solids settling at the bottom as shown in Fig. 6. In the vertical column, there was a noticeable absence of clear separating zones at the bottom, as compared to the well-defined separating zones observed in the inclined settler. These observations underscore the superior solid-liquid separation efficiency achieved in the inclined settler, leading to clearer water and more distinct separation zones compared to the vertical column.

4. Conclusions

A modified settling tank comprising inclined sections was designed and experiments were performed to investigate the settling behavior of solid particle species. The inclined sections were incorporated in order to enhance the settling rate of the solid particle species. Moreover, a comparison of modified settling tank and conventional vertical settling tank was carried out. It was observed that the settling time of the solid particles was enhanced in modified settling tank as compared to the vertical settling tank. After 40 mins settling was almost complete in modified settling tank with 98% solids at the bottom whereas in the vertical settling tank 80 percent of solids settled at the bottom.

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