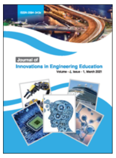

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Efficiency of tube settler at various angle of inclinations in controlled discharges

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Abstract

High-rate tube settlers are one of the cost-effective ways to update and improve the efficiency of treatment plants, particularly sedimentation tanks. In comparison to a typical sedimentation tank, the tube settler's detention time is shortened to 10-15 minutes [1]. They take up far less area than traditional sedimentation tanks and improve their removal efficiency. For the Nayabazar Townplanning Groundwater Project (NTGWP), the study aims to calculate the turbidity removal efficiency of tube settlers at various angles of inclination at various discharges. The study has been carried out at varying flows of 9.33 lps, 10.5 lps, and 11.5 lps for the 77° inclination angle and 60° inclination angle, and the data were analyzed to find the best flow conditions. The removal efficiencies of tube settlers increased for each flow condition at 60º inclination compared to 77° inclination, but decreased as the discharge increased.

1. Introduction

According to the Nepal Demographic and Health Survey (DHS) , 95% of the urban population of Nepal has access to improved water sources like piped water, public taps, standpipes, boreholes to improved spring sources, and rainwater. The operation, accessibility, quality, and efficiency of the water systems, on the other hand, do not fulfill WHO water quality standards. Only 25% of them are working, while 36% require minor repairs and 39% require replacement or significant repair. In addition, just 65% of the population has access to modern sanitation facilities [2].

In the densely populated cities like Kathmandu, where surface water sources are few and polluted, the ground water sources may be a good option [3]. There are a multitude of treatment solutions available for a variety of groundwater issues. The most prevalent treatment process includes tray aerator, collection chamber, chlorination, chemical treatment, flocculation, tube settler, rapid sand filter, and distribution chamber in order [1].To generate a greater effective settling area, the tube settler combines many tubes inclined at a 60° angle of inclination. This results in a lowering of particle settling depth and settling time [4]. Tube settlers improve the settling capacity of circular clarifiers and rectangular sedimentation basins by lowering the vertical distance. The floc particles would settle before agglomerating to form larger mass. Solids are collected and compressed in the settler's channel, allowing them to flow down through the tubes [5].

The removal efficiency of tube settler declines as the discharge of influent water is increased (Rajbanshi, 2009). Additionally, increasing the length of tube settler results in higher turbidity removal and decreasing the inclination of tubes, results in higher turbidity removal [6].These established theories regarding tube settler can be utilized to achieve optimum removal efficiency.

2. Objectives

The main objective of the study is to determine removal efficiency of tube settler at various angles of inclinations. Moreover, the specific objective is to compare existing

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models and practical removal efficiencies at different angles of inclinations.

3. Background

At the "Chavasseryparamba" water treatment plant in Kerala, [7] conducted a laboratory size tube settler model. They made five tube settler modules, each with a different inclination angle. The tubes utilized in this pilot scale have an inner diameter of 4 cm and a length of 40 cm, with an inclination angle of 30 °, 35 °, 40 °, 55 °, and 60 ° with the horizontal for each setup. They demonstrated that both discrete particle settling and flocculent settling theories are applicable to the treatment of filter backwash water through studies on tube settlers. For settling the flocculent particles, the best inclination angle was 55°, and the optimum settling velocity was 2.76 mm/min, according to the findings [7].

Kshitija Balwan, [6], developed an experiment to study the effect of the length and angle of the tube settler on the effluent quality, they conducted a pilot scale model and installed at Ichalkaranji municipal water treatment plant. The model had one closed base tank which connected from the top by four PVC tubes of 4.5 cm diameter representing the tube settler which was connected from the other end to the bottom of collector basin. The influent water to the base tank has been aerated and coagulated. The length and inclination of the tubes were adjustable. The length of these tubes varied as 60 cm, 50 cm and 40 cm and they were installed at inclination angle 45º and 60º with the horizon. After successful completion of project obtained conclusions are: [6]

(a) Increasing the length of tube settler, results in higher turbidity removal.

(b) Decreasing the inclination of tubes, results in higher turbidity removal.

YAO created the following model by converting the time it takes a particle to travel the length L of a tube to the time it takes a particle to settle the distance D between the top and bottom of the tube at the center.

$$V_s = \frac{U}{sin\theta + Lcos\theta} = \frac{SV_o}{sin\theta + Lcos\theta} \quad (1)$$

Simplified form can be,

$$V_s = \frac{kSV_o}{L} \quad (2)$$

Where,

$K = \frac{L}{sin\theta + Lcos\theta}$
V_o = Average velocity
θ = Slope of tube
L = Relative length of pipe (l/d)
l = Length of pipe
d = Diameterof pipe
S = Shape factor depends on tube cross section.

Upon First differentiation keeping experimental data of site,
$dV_s/d\theta = 0$, Maxima condition check,
Mathematically, Angle of inclinations is obtained to be 59.10° which is rounded to 60° angle of inclination for standardization of measurement at site.

4. Methodology

The tube settler's influent and effluent were chosen as sampling stations. Table 1 lists the parameters that were studied and the frequency with which they were tested.

4.1. Measurement of discharge

A discharge meter positioned at the source was used to measure the inlet discharge The study was conducted in various discharges i.e., 9.33 lps, 10.5 lps, 11.5 lps. The flow was measured using a flow meter and the change in discharge was controlled by a valve. The discharge meter installed on site is a Class B type meter that meets ISO 4064 criteria.

4.2. Measurement of angle of inclinations

Using a Handy-protractor, the angle of inclination of the tube installed at the location was measured. The range rod was put into the tube settler's hollow HDEP pipes, leaving no movement gaps between them. After that, a leveling rope was attached parallel to the tank's horizontal surface. A commercially available level pipe

Table 1: Schedule of measurements

S.N.	Experimental Parameters	Unit	Frequency of Test	Methods
1	Turbidity	NTU	Every 2 days in a week	Nephelometric method
2	Flow Rate	l/min	Every time before measurement	Discharge Meter and Volumetric method (Beaker and Timer)
3	Angle of inclination	Degree (^{o})	Twice during study	Protractor, level pipe

was used to correct the leveling. At the intersection of the level rope and the ranging rod, a protractor zero point was placed. Finally, the installed tubes' inclination was determined. The study was carried out for the 77^o and 60^o inclination of tubes.

4.3. Measurement of turbidity

The turbidity meter was calibrated with 100 NTU solution and distilled water, i.e., 0 NTU, before being used to measure the turbidity. After calibration the turbidity of ground water entering the tube settler's influent was measured. After that, the turbidity of the effluent sample was measured.

Figure 1: Discharge meter

Figure 2: Two inclinations of tubes

5. Results and Discussions

The, equations on the graphs indicate efficiency of tube settler for various influent turbidity in NTU for 77° inclination angles. From the Figure 3, it can be concluded that the effluent to influent turbidity ratio goes on increasing for the higher turbidity range whereas, the efficiency decreases. The, equation on the Figure 4 indicate efficiency of tube settler for various influent turbidity in NTU for 60° inclination angles.

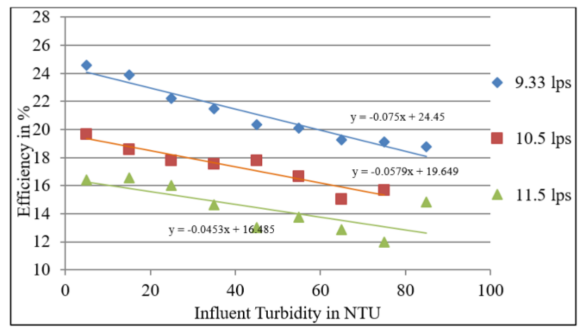

Figure 3: Efficiency of tube settler for various influent ranges at 77° inclination

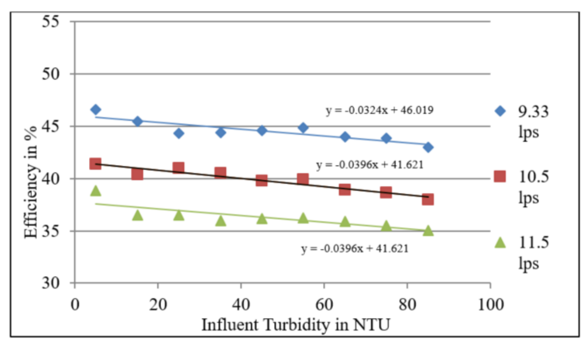

Figure 4: Efficiency of tube settler for various influent ranges at 60° inclination

From the Figure 3 and 4, the efficiency of tube settler at 60° angle of inclination is higher than efficiency at 77° inclination angle. From figure 3 and 4, the efficiency of tube settler increases for the lower angle of inclination of tubes.

The experimental results for the settlement test using the beaker test are shown in Figure 5 for 77° and Figure 7 for 60° inclination angle. The turbidity of 13,34,45,55 and 78 NTU were tested at 77° and the turbidity values of 24,33,48,69 and 82 NTU were tested in a beaker for 60°. Figure 5 and 7 depicts the power trend line curves with the power lines.The equations on power lines are compared with YAO (1973) formula:

$$T_e = aV_s^b \tag{3}$$

The power lines for varied turbidity provide the values for a and b. The values generated from the YAO (1973) and [8] models are compared to the observed values. The comparisons of observed value with values obtained from Models are shown in Figure 6 and 8 The equations on power lines are compared with [8] formula:

$$T_e = aV_s^b\left(\left(\frac{3}{3b+4}\right)+0.25\right) \quad (4)$$

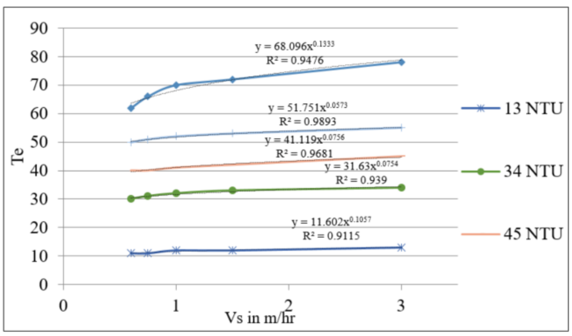

Figure 5: Beaker test results for 77°

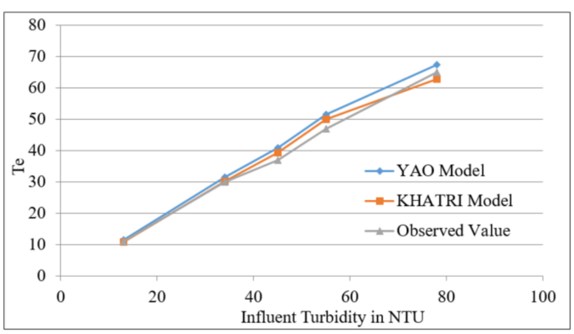

Figure 6: Comparison of observed value with models for 77°

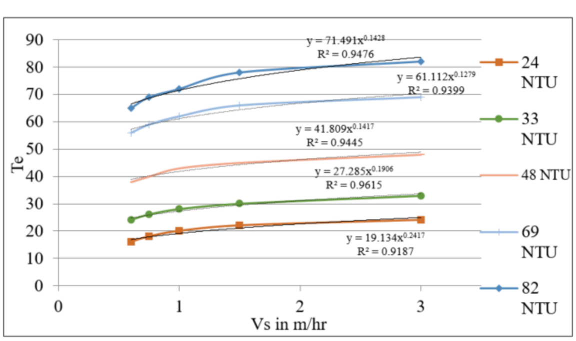

Figure 7: Beaker test results for 60°

Where,

a and b = Empirical constants depends on influent turbidity

V_s = Settling velocity in m/h

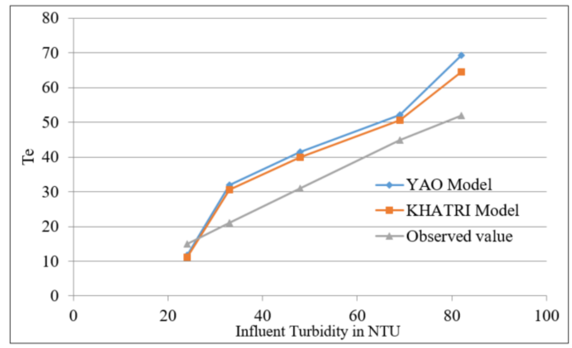

Figure 8: Comparison of observed value with models for 60°

The efficiencies at 77° inclination is given by the equation:

$$\text{Efficiency in \%} = 49.542 - 3.0695 \times Q \quad (5)$$

$$\text{Efficiency in \%} = 77.035 - 3.5086 \times Q \quad (6)$$

Where,

Q = Discharge in Lit/Min

The Equation 5 and 6 predicts removal efficiency of tube settler at two inclination angles.

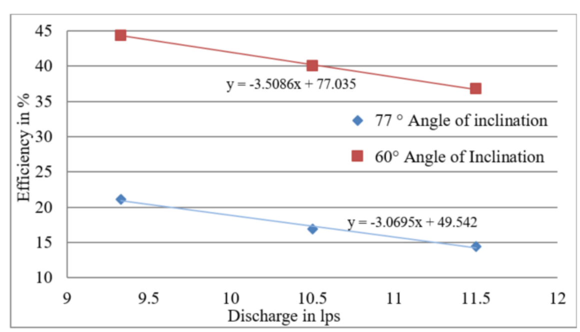

Figure 9: Efficiency at various discharges

The Figure 10 shows the relationship of angle of inclinations with the optimum efficiency in percentage. The efficiency of tube settler in percentage developed from model is :

$$E = 416.36 - 91.82\,ln(\theta) \quad (7)$$

Where,

Table 2: Results of turbidity with different inclinations discharges

S.N.	Inclination	Discharge in lps	Removal of Turbidity in % (Tube settler)	Remarks
1	77°	9.33	21.08	-
2	77°	10.5	16.93	-
3	77°	11.5	14.45	-
4	60°	9.33	44.38	Optimum
5	60°	10.5	40.02	-
6	60°	11.5	36.78	-

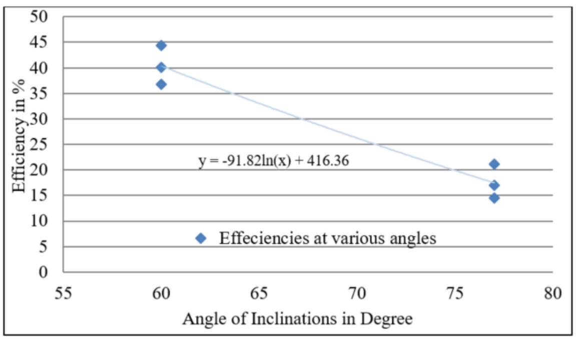

Figure 10: Mean efficiency at various angles of inclination

E	$=$	Efficiency in percentage
θ	$=$	Angle of inclination in degree
		(range = 40 to 80 degree)

The Equation 7 predicts the average efficiency of tube settler at various inclination angles expressed in degrees. Thus, it helps to calculate optimum efficiency.

6. Conclusion

The goal of this research was to see how well a tube settler in the NTGWP removed suspended materials at different degrees of inclination and different flow rates. Based on the findings and discussion, it is concluded that when the discharge increases, the tube settler's removal efficiency declines. This occurs as a result of an increase in the value of effluent turbidities due to an increase in surface overflow rate. This conclusion can be drawn from data collected at three different flow rates of 9.33, 10.5, and 11.5 lps. Additionally, re-inclining the tubes to 60° from the initial angle of inclination of 77° improves tube efficiency from 21.08 percent to 44.38 percent for 9.33 lps discharges, 16.93 percent to 40.02 percent for 10.5 lps discharges, and 14.45 to 36.78 percent for 11.5 lps discharges. As a result, it can be deduced that as the angle of inclination of the tubes decreases, the efficiency of the tube settler increases.

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Conflict of interest

No conflict of interest

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