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Computer Aided Engineering of Circular Sedimentation Tanks

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A B S T R A C T

An algorithm was created for the design of a primary circular clarifier used in wastewater treatment processes. Based on this algorithm, a computer program was developed using the Python programming language. The results obtained from the program closely matched those derived through manual calculations, with no significant differences observed. To validate the algorithm, operational data, including influent and effluent parameters, were obtained from the primary clarification unit at SMS Waluj CETP Pvt. Ltd., Sambhajnagar, India, and input into the program. The outcomes from the program aligned well with the original design specifications of the wastewater treatment plant, confirming the reliability of the developed approach.



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1. Introduction :

The primary sources of wastewater, which include organic matter, phosphate, nitrogen, hydrocarbons, heavy metals, and pathogenic microbes, are industries and residential water use. Consequently, before releasing wastewater into natural resources, stringent water quality criteria must be maintained. Untreated wastewater contains harmful chemicals that affect the environment, human health, and soil quality. Primary, secondary, and tertiary treatments are all part of a wastewater treatment plant. Flocculants are used in primary treatment to remove the suspended particles. Through aerobic biological processes like bio-filtration, aeration, oxidation ponds, etc., biological contents are eliminated in secondary processes. Remaining inorganic components, including nitrogen and phosphorus, are eliminated during the tertiary treatment. Sedimentation is a crucial step in the basic treatment process that lets wastewater particles settle due to gravity. There are several different techniques for sedimentation, including inclined plates, vertical flow, and horizontal flow. An important consideration in clarifier design is Stokes' law. The nature and settling behavior of the particles, as well as their concentration in the influent stream, is other significant factor. Metcalf and Eddy [1] recommends surface loading rates (SLRs) of 30–40 m³/m²/day for primary clarifiers. Authors emphasized the importance of detention time (2–3 hours) and weir loading rates (<300 m³/m•day). CPHEEO Manual

(2013) [2] sets official guidelines for Indian municipalities and engineers. It also aligns closely with Metcalf & Eddy, but adapts to Indian conditions. It recommends $30 \text{ m}^2/\text{MLD}$ for surface loading and 3 m minimum depth. It also emphasizes the minimum number of tanks unless redundancy is justified. According to the U.S. EPA Design Manual (1983) [3], a standard weir loading rate of $250\text{--}300 \text{ m}^3/\text{m}\cdot\text{day}$ is required for uniform flow distribution. It recommends detention times of 1.5–2.5 hours for primary clarifiers. It encourages the use of baffles and energy dissipation devices to enhance settling. Qasim (1999) [4] offers practical insight into clarifier sizing and performance. He pointed out that larger clarifiers offer better sludge consolidation and reduced operational cost. Hammer and Hammer (2013) [5] suggested that the clarifiers should be designed to balance hydraulic and solids loading. The authors provided a simple algorithm for circular clarifier dimensioning, based on settling velocities and flow characteristics. They recommended that a single large tank is often preferred operationally over multiple units, if feasible.

- a) Circular Clarifier Design Features : Wastewater usually enters a big, circular tank at the center of circular primary clarifiers. Solids and liquids are separated by gravity in this arrangement. In a circular primary clarifier, several operational factors need to be carefully regulated to attain the maximum efficiency:
- b) Hydraulic load : For best settling, the rate at which wastewater is added to the clarifier should match the design parameters.
- c) Solids load : The capacity of the system must be weighed against the quantity of suspended solids entering the clarifier, which will impact settling efficiency.
- d) Detention time : For efficient separation, the wastewater must spend this amount of time in the clarifier.
- e) Sludge removal : To keep the system functioning properly, settled solids must be regularly and effectively removed from the clarifier's bottom.

When designing a standard clarifier, the following design parameters must be specified: Surface Overflow Rate, Tank Depth, Weir Overflow Rate, Detention Time, and Solid Loading Rate.

2. Materials and methods :

The algorithm and computer based program are discussed briefly as follows:

2.1 The Algorithm :

An algorithm for sizing clarifiers was developed. The algorithm's flowchart is shown in Figs 1(a-c). Flow rate (VFR), suspended solids concentrations in the influent stream (TSS_{in}), and maximum suspended solids concentrations in the effluent stream (TSS_{out}) are inputs into the algorithm. Tank depth (H), tank diameter (D), retention time (DT), surface overflow rate (OR), total suspended solids percent removal (TSSG), BOD5 percent removal (BODG), weir length (WL), number of tanks required (N), and number of weirs (NW) are the data that the algorithm produces. The following are the main steps of the algorithm.

Step 1: Input Values

- Read Influent Flow Rate (MLD)
- Read Influent Suspended Solids (mg/L)
- Read Effluent Suspended Solids (mg/L)
- Read Number of Tanks

Step 2: Set Constants / Assumptions

- Surface Loading Rate = $30 \text{ m}^2/\text{MLD}$ (standard)
- Detention Time = 2 hours (typical)
- Minimum Tank Depth = 3 meters
- Weir Loading Rate = $300 \text{ m}^3/\text{m}\cdot\text{day}$ (standard)

Step 3: Calculate Flow Per Tank

- Flow per tank_MLD = Total Flow / Number of Tanks
- Flow per tank_m3_per_day = Flow_per_tank_MLD × 1000

Step 4: Calculate Surface Area and Diameter

- Surface_Area_m2 = Surface_Loading_Rate × Flow_per_tank_MLD
- Diameter_m = $\sqrt{(4 \times \text{Surface_Area_m2}) / \pi}$

Step 5: Calculate Volume and Tank Depth

- Volume_Required_m3 = (Flow_per_tank_m3_per_day / 24) × Detention_Time
- Calculated_Depth = Volume_Required_m3 / Surface_Area_m2
- Final_Tank_Depth = max(Calculated_Depth, Minimum_Depth)

Step 6: Calculate Overflow Rate

- Overflow_Rate = Flow_per_tank_m3_per_day / Surface_Area_m2

Step 7: Calculate TSS and BOD Removal

- %TSS_Removal = ((Influent_SS - Effluent_SS) / Influent_SS) × 100
- %BOD_Removal = 30% of TSS_Removal (i.e., TSS_Removal × 0.3)

Step 8: Calculate Number of Weirs

- Weir_Length_Required = Flow_per_tank_m3_per_day / Weir_Loading_Rate
- Tank_Circumference = $\pi \times \text{Diameter}$
- Number_of_Weirs = ceil(Weir_Length_Required / Tank_Circumference)

Step 9: Display Output

- Flow per tank (MLD)
- Tank diameter (m)
- Tank depth (m)
- Detention time (hr)
- Overflow rate (m³/m²•day)
- Number of tanks
- Number of weirs
- %TSS removal
- %BOD removal

2.2 Computer Program :

The computer programs developed to size the clarification units were done using Python program. The algorithm was validated using data (such as the Influent flow rate and TSS Removal efficiency) from SMS Waluj CETP Pvt. Ltd., Sambhajinagar.

3. Results and Discussion :

The created computer programs were tested using the input values obtained from SMS Waluj CETP Pvt.

Ltd., Chhatrapati Sambhajnagar. The scenario was selected in accordance with Table.1 general design specifications for main clarifying units [1]. The outcomes of the computations are displayed in Table 2.

Table 1. Basic dimension of rectangular and circular clarifiers

Parameter	Value	Description
Surface Loading Rate	30 m ² /MLD	Standard for primary sedimentation
Weir Loading Rate	300 m ³ /m ² •day	For weir count
Minimum Depth	3 m	Standard tank depth
BOD Removal	~30% of TSS removal	As per typical correlation
Detention Time	2–3 hrs	Typical range
Number of Tanks	1 (assumed, can be customized)	

Table 2. Result of program

Input Parameters			
Influent Flow Rate (m ³ /d)	750		
TSS _{in} (mg/l)	220		
TSS _{out} (mg/l)	90		
Output Parameters			
	Python Program	Manual Calculations	Remarks
Flow rate per tank (MLD)	250	250	Both approaches evenly distribute flow across 3 tanks; consistent results.
% Removal, TSS (%)	59.09	59	Nearly identical. Minor variation due to rounding or decimal precision in calculations.
Tank Diameter (m)	97.7	97.45	Very close—Python output likely includes extended precision. Both indicate very large tank diameters.
Tank Depth (m)	3	3	Matches the standard minimum depth as per design norms (e.g., CPHEEO Manual).
Number of Tanks	3	3	Same in both; based on optimal flow split and weir loading rate.
Detention Time, hr	2	1.50	Slight variation. Program assumes upper limit of typical range (2–3 hr); manual uses lower end (1.5 hr). Both are acceptable.
% BOD Removal (%)	18	17	Aligned with the rule of thumb (30% of TSS removal). Minor difference from decimal precision.
Number of Weirs	3	3	Consistent. Likely based on allowable weir loading rate.
Overflow rate m ³ /m ² .day	33.33	32.30	Slightly higher in the Python calculation; both are within standard range (20–40 m ³ /m ² •day).

4. Conclusion :

Although a straightforward mathematical formula cannot be directly applied to the design of clarifier units, the algorithm presented here offers a quick and practical method for conducting a preliminary design of a primary circular clarifier. When multiple solutions arise particularly in terms of the number of tanks material cost alone may not be sufficient for selecting the optimal configuration. Generally, operating a single large tank is more manageable than handling several smaller ones. Therefore, as a practical guideline, the design should aim for the minimum number of tanks feasible when multiple options are available. The Python program provides results very close to manual calculations and can be confidently used for design automation of circular clarifiers. However Tank diameter output suggests that design refinement is necessary for practical implementation. Detention time and number of tanks can be adjusted as per site constraints and performance goals. Overall, the tool ensures design consistency and speeds up decision-making, but engineering judgment remains essential for finalizing feasible and cost-effective designs.

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