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Feasibility Study on Construction of Sewage Treatment Plant at College Campus

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Abstract: Waste water in the Anna University campus is being disposed off by means of septic tanks; nowadays these septic tanks are not sufficient for disposal of these waste waters. Based on the waste water analysis and report which depend upon the characteristics of the raw sewage it has been decided to construct activated sludge process treatment plant in the university campus to protect the good environmental conditions. The treatment unit process consists of screening chamber, grit chamber, primary treatment, aeration tank, secondary treatment and sludge disposal etc. The treatment plant will be designed for an ultimate period of 30 years with CPHEEO norms. The treated waste water shall be utilized for developing the plants, trees and landscaping works in the university campus.

Key words: BOD, reuse, sewage, sludge, treatment.

Introduction

Importance of Treatment

Anna University of Technology Tiruchirappalli is functioning from 01-02-2007 at Tiruchirappalli. The University area is in 145.692 hectares with various departments. Waste water from this university campus has been collected through the closed sewer lines and disposed in the large septic tanks. Now these septic tanks not sufficient for disposal of these waste waters. Hence the activated sludge process method has been adopted to treat the waste water. After that treated effluent is being used for the cultivation of the trees, plants and landscaping works. The product of the sludge is being converted in to manure and used for the plants.

Layout of Treatment Plant

The following points should be adopted while preparing the layout of this sewage treatment plant: All the plants should be located in order of sequence, so that sewage from one process should directly go to other process, under its force of gravity only. Sufficient area should be provided for future extension; Bypass and overflow weir should be provided to cut off the operation in any unit when required; Self-cleaning velocity should be adopted at every place and stage; and the design of the treatment units should be economical and easy in future maintenance.

Design Period

This scheme involves the laying of underground sewer pipes and construction of costly treatment units structure, which cannot be replaced or increased in their capacities in future. Hence the future period shall be kept in mind while designing the capacities of various components of the sewerage line and treatment plant structures. This sewage treatment plant has been designed for an ultimate period of 30 years.

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Methodology

Sample Collection

Five samples were collected from different locations of the university campus, analyzed in the environmental laboratory and compared with standard parameters. Physico-chemical and biological parameters are tabulated in Table 1. Based on the sewage characteristics, the removal efficiency of Biochemical Oxygen Demand (BOD) of the activated sludge process shall be in the range of 85% to 95%. The activated sludge process method has been adopted for this waste water treatment system in the university campus.

Observations and Discussion

Treatment processes are classified as Preliminary treatment, Primary treatment, Secondary treatment and Tertiary treatment. It helps in removal of oils and greases and reduces the BOD by 15% to 30%. The processes under this are: Screening to remove floating papers, rags, clothes and Grit chamber to remove grit and sand.

Primary Treatment

Primary treatment consists in removing large suspended organic solids. It is usually accomplished by sedimentation in settling basins. The liquid effluent from the primary treatment often contains a large amount of suspended organic material and has a high BOD (about 60% of original).

Secondary Treatment

Here the effluent from primary treatment is treated through biological decomposition of organic matter carried out in aerobic conditions.

Tertiary Treatment

The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment (sea, river, lake, ground etc.). The total population are surveyed and listed in Table 2.

Population strength in year 2002 = 7000

Projected population has been calculated based on ultimate period 2042, by Geometrical Increase method

$$= P_o\ (1 + r/100)^2$$

where P_o is initial population and r is assured growth in %.

$$r = \sqrt{\frac{p_2}{p_1}} - 1$$

where

P_2 initial known population and P_1 final population

$$= 1\sqrt{\frac{8500}{700}} - 1 = 0.10 = 10\% \text{ per decade}$$

1st decade (2022)

$$P_o\ (1 + 10/100)^1$$

$$= 8500\ (1+0.1) = 9350 \text{ nos}$$

2nd decade (2032)

$$P_o\ (1 + 10/100)^2$$

$$= 8500\ (1 + 0.1)^2 = 10285 \text{ nos}$$

3rd decade (2042)

$$P_o\ (1 + 10/100)^3$$

$$= 8500\ (1 + 0.1)^3 = 11314 \text{ nos}$$

Table 1: Physico-chemical and biological parameters

Sl No	*Samples location*	*Colour*	*Odour*	*TSS mg/l*	*Oil and crease*	*Turbidity NTU*	*pH*	*TDS mg/l*	*COD mg/l*	*BOD mg/l*	*E.Coli (Mpn/ 10 × 4 100 Ml)*
S1	Academic block	Grey	Earthy	320	70	136	7.2	450	395	210	2569
S2	Canteen	Grey	Earthy	310	90	100	6.9	300	375	190	7802
S3	Ladies hostel	Grey	Earthy	410	65	125	6.8	309	420	243	12730
S4	Gents hostel	Grey	Earthy	325	70	173	7.3	340	465	290	6540
S5	Gents hostel (bath water)	Grey	Earthy	189	75	96	7.4	400	380	185	690
	Average influent	-	-	310.9	74	126	7.3	359.8	427	223.6	30331

Raw sewage characteristics, tested in the Anna University Environmental laboratory.

Table 2. Population estimate (2012)

No	*Population details*	*Population strength*
1	Boys' hostel	1467
2	Girls' hostel	1001
3	Regular students	5134
4	University teachers	398
5	University staff	500
	Total strength	8500

Calculation of Sewage Generation

Ultimate design period = 30 years; Per Capita Water Supply = 135 lpd

Per capita consumption per day = 135 lits/head

Average water supply per day = 135×11314
= 1527390 lit/day

Consider Avg. sewage generation per day = 80% of supplied water

1527390 × 80/100 = 1221912 lit

say = 1.25 mld

Avg. sewage generation per day = 1.25 MLD

Avg. discharge = 12,25,000/1000 × 24 × 360 = 0.0142 cumec

Max. discharge = 3 × avg. discharge = 3 × 0.0142 = 0.0426 cumec

say 0.0426 m^3/sec

Receiving Chamber

Receiving chamber is the structure to receive the raw sewage collected through the closed underground sewage pipe lines within the University campus. It is a rectangular shape tank constructed at the start of the sewage treatment plant.

Design flow = 0.0426 cumec, Detention time = 60 sec

Volume required = flow × detention time = 0.0426 × 120 = V_{rqd} = 5.10 m^3

Provide depth = 1.0 m, area = 5.10 m^2, Length:Breadth = 2:1

$$L \times B = 2B \times B = 2B^2 = 5.1$$

$$B = 1.6 \text{ m}, L = 2 \times B = 3.2 \text{ m}$$

Check: Volume designed = 3.2 × 1.6 × 1 = 5.12 m^3

$$V_{des} = 5.12 \text{ m}^3, V_{rqd} = 5.1 \text{ m}^3$$

$V_{des} > V_{rqd}$ hence safe

Receiving chamber is designed for the size = 3.2 m × 1.6 m × 1 m (SWD) + 0.5 (FB)

Screening

Screening is the very first unit operation in the sewage treatment system and it is deviced with spacing in uniform size, that is used to remove the floating matter such as tree leaves, paper, gravel, timber pieces, rags, fibre, tampons, cans, and kitchen refuse etc., in the influent. The principal role of screening is to remove coarse materials from the flow stream that could damage the subsequent process equipment. Reduce overall treatment process in reliability and efficiency.

Peak discharge of sewage = 0.0426 m^3/s

Assume the velocity at average flow is not allowed to exceed 1 m/s

The net area screen opening required = 0.0426/1 = 0.0426 m^2

Clear opening between bars = 30 mm = 0.03 m

Size of the bars = 75 mm × 10 mm. Assume width of the channel = 1 m

The screen bars are placed at 60° to the horizontal.

Velocity through screen at peak flow = 1 m^3/5 × 6 = 6 m^3

Clear area = 0.426.6 sin 60 = 0.22 m^2

No of clear openings = 0.22/0.03 = 10 nos. Provide width of the channel = 1 m

Screen channel is designed for the size of 3 m = 3.0 m × 1.00 × 0.75 m (SWD) + 0.5 m (FB)

Grit Chamber

Grit chambers are designed to remove the grit, sand, gravel and other heavy solid materials that have subsiding velocities. The grit chamber are mostly commonly located after the screening and before the primary sedimentation tanks.

Peak flow of sewage = 0.0426 m^3/s. Assume average detention period = 300 s

Aerated volume = 0.0426 × DP = 0.0426 × 300 = 12.78 m^3, say 13 m^3

For cleaning and maintenance, two chambers are used.

Therefore volume of one aerated chamber = 13 m^3/2 = 6.5 m^3

Assume depth of 1.2 m and width to depth ratio 2:1

Width of the channel = 1.2 × 2 = 2.4 m; Length of the channel = 1.5 × 2.4 = 3.6 m, say 4 m

Increase the length by about 20% to account for inlet and outlet

Provide length = 4 m × 20/100 m = 4.8 m

Grit chamber is designed for the size of 4.8 m × 2.4 m × 1.2 m = Designed size 13.82 m^3

Required size 13.82 >13. Hence safe.

Primary Sedimentation Tank

Primary sedimentation tank is the settling tank constructed next to grit chamber to remove the organic settleable solids having lesser size of 0.2 mm and specific gravity of 2.65. The designed tank is circular type which makes settling by allowing radial flow and removal of suspended solids as 50 to 70% and removal of the BOD as 25 to 40% from the sewage.

Max. quantity sewage = 1.25 MLD

Required surface area A = *Q*/OR 12,50,000/1000 m^3/day = 1250 m^3/day

Average overflow rate 4 m^3/day. Overflow area 1250/4 = 312 m^2

Therefore surface area =313 m^2

$$\text{Dia of the tank} = \frac{\pi}{4} D^2 = 313$$

$$D = 19.96 \text{ Say } 20 \text{ m}$$

Assume the depth of tank as 2 m.

The bottom of the tank is sloped at about 1 in 12 (vertical:horizontal) to form an inverted cone and the solids are scraped by the hopper located near the centre of the tank.

Primary sedimentation tank is designed as 20 m (dia) × 2.0 m (depth) + 0.5 (FB).

Activated Sludge Process

The activated sludge process is an aerobic, biological sewage treatment system that uses dissolved oxygen to promote the growth of micro organism that substantially removes organic material. The essential units of the process are an aeration tank, a secondary settling tank, a sludge return line from the secondary settling tank to the aeration tank and an excess sludge waste line. The activated sludge plant results 80 to 95% of BOD removal.

Aeration Tank

Aeration tank is the mixing and diffusing structure in the activated sludge plant and air is continuously supplied to the tank to promote the growth of micro organism.

No. of aeration tank = 2. Design flow = 1.25 mld. Average flow of each tank = 625 m^3

BOD at inlet = 0.8 × 300 (20% of BOD removed at grit chamber), Y_o = 240 mg/l

BOD at outlet Y_E = 20 mg/l. BOD removed in activated plant = 240 – 20 = 220 mg/l

Minimum efficiency required in the activated plant = 220/240 × 100

Min. efficiency = 91.7%

The adopted extended aeration process can remove 85-92%. Hence it is OK.

MLSS (*Xt*) = 3000 mg/l, F/M ratio = 0.3

Volume of the tank required $V = Q$ FM × $Y_o \times t$ = 3×20×2 = 120 m^3

Assume the liquid depth of the tank as 2.0 m, the width to depth ratio as 2:2

$$B/2 = 2, B = 4.0 \text{ m} \approx 4 \text{ m}$$

$$L = 120/2{\times}4 = 15 \text{ m}, L = 15 \text{ m};$$

$$B = 4 \text{ m}; D = 2.0 \text{ m}$$

Volume provided = 15 × 4.0 × 2.0 = 120 m^3

(i) C*heck for aeration period/HRT:*
Hydraulic Retention Time (HRT) = $t = V \times 24Q$ = 120 × 24 = 5.00 hrs
Since it lies between 3-6 hrs, it is OK.

(ii) *Check for volumetric loading:*
Volumetric loading = $Q \times Y V$ = 625 × 224/120 = 1073.0 g/m^3 = 1.07 kg/m^3. Since it lies between 1.0 and 1.2, it is OK.

Secondary Sedimentation Tank

A sedimentation tank is constructed next to the aeration tank. This tank will be as the primary sedimentation tank with certain modifications. As no floating materials are here, provisions for the removal of scum, floatage are not needed. The surface area for the secondary sedimentation tank is designed for both overflow rate basis and solids loading rate basis.

No. of secondary clarifier = 1.

Average flow = 1000 m^3/day

Recirculated flow = 53%, (53/100) × 1000 = 530 m^3/day

Total inflow = 1000 + 530 = 1530 m^3/day. Provide hydraulic detention period = 2 hrs

Volume of the tank (exclusive of hopper portion) = 1530 × 2/24= 127.5 m^3

Assume liquid depth = 1.5 m

Since L × B × D = 127.5, L × B × 1.5 = 127.5

Area is 85 M^2, Surface loading rate of average flow = 25 m^3/m^2/day

Surface area provided = 1 mld/25, or 1250000/25 × 100 = 500.0 m^2

Using greater area of the two values: $\pi D^2/4 = 85$ m^2

Provide diameter of 10.4 m.

Check for Solids Loading

Recirculated flow = 530 m^3/day, Average flow = 1000 m^3/day, MLSS in the tank = 3000 mg/l

Total solids in flow = (1150 + 609.5) × 3= 4590.5 kg/day

Solids loading = 5278.54 = 98 kg/day/m^2

It lies between 100-150 kg/m^2/day. Hence it is OK. Provide secondary sedimentation as 10.4 m (dia) × 1.5 m (depth) + 0.5 m (FB).

Hopper slope shall be 1 in 12.

Sludge Drying Beds

Sludge drying beds are open beds of 45 to 60 cm deep, filled with layers of gravel or crushed stone. Open jointed under drain pipes of 15 cm diameter are laid below the gravel layers.

Seepage collected in the under-drains is returned to the plant for treatment. In the hot areas it takes 6 to 12 days to dry. After the period the sludge cakes are removed with spades and they are used as manure as it contains 2 to 3% of NPK.

Specific gravity = 1.015, Solid content = 2%,

Volume of sludge = 30/.02 1000 × 1.015 = 1.47 m^3/day

At Anna University weather condition the beds get dried out in about 10 days.

Number of cycle in one year = 365/10 = 36.5 = 37 cycles.

Period of each cycle = 10 days, Volume of sludge per cycle = 1.47 × 10 = 14.47 m^3

Spreading a layer of 0.3 m per cycle,

Area of bed required = 14.77/0.3 = 48.33 m^2 ≈ 50 m^2

Provide 2 nos. of beds, 50/2 = 25 m^2

Area of each bed = 5 m × 5 m. Two beds of dimension 5 m × 5 m are designed

Conclusion

Based on the observation, it was decided to construct an activated sludge process sewage treatment plant in the university campus designed perfectly to meet the future expansion for the next 30 years in accordance with CPHEEO norms. The treated waste water has been utilized for the development of the trees, plants and landscaping activities in university campus.

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