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Design of Sewage Treatment Plant

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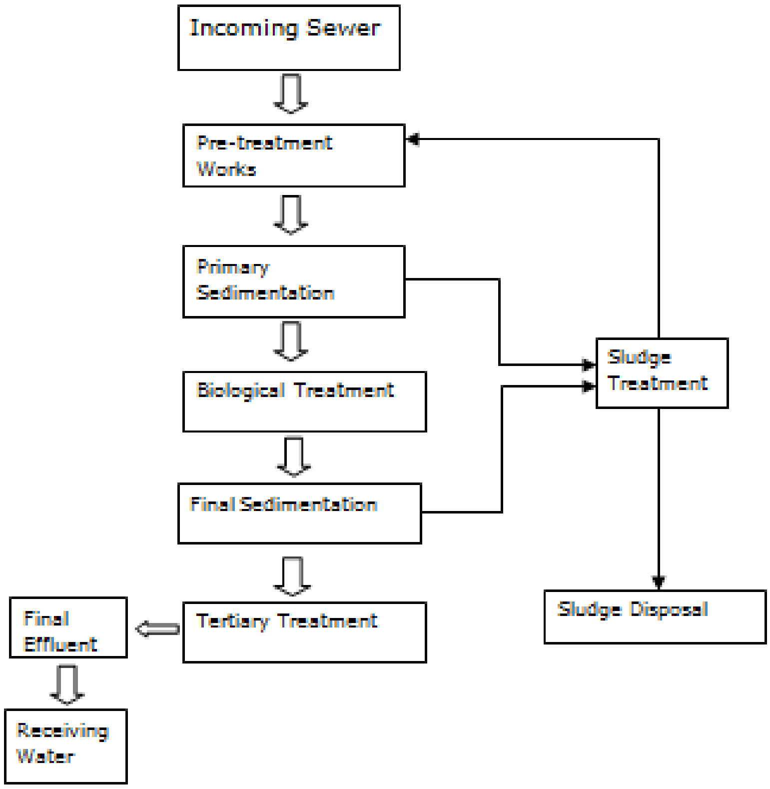
Abstract: *Metro satellite has become as important complex locality near the place Palasuni of Bhubaneswar. As the city of temples, occupied the top position in the recent survey of 100 smart cities, there will be an increase not only economically but also there will be rise in population along with infrastructural works. So there is a substantial possibility of rise in population in Metro Satellite area of Palasuni. With this steady increase of population, there will be more generation of household and domestic sewage. So there is a basic need of construction of a Sewage Treatment Plant with a view of sufficient capacity to treat the sewage. A sewage treatment plant is quite necessary to receive the domestic and household waste and thus removing the materials which creates harms for general public. Its basic aim or objective is to produce an environmental safe atmosphere by treated effluent or sludge which will be suitable for disposal or reuse. The project mainly deals with design of STP and its stages or components which are responsible for the sewage treatment like screening, grit chamber ,skimming tank, sedimentation tank, secondary clarifier, activated sludge tank and sludge drying beds. The projects covers the various dimensions of components such as which would cover an approximate population of 10000 including every building and complex of the area for a maximum period of time. By the execution of the project the entire sewage of the proposed area can be treated effectively and efficiently.*

I. Function decomposition



Product teardown and engineering specifications

- Sewage treatment plant
- Pre-treatment
- Primary treatment
- Secondary treatment
- Tertiary treatment

Equipment specification

a) Bar Screen
  Type – 1 : Manually cleaned with handbrake
  Construction : In MS flats of side 10 mm × 50 mm not more than 20 mm C/c and the width of the chamber be 60 cm.
  : 1 No. MS hand rack shall be provided with GI pipe rod.

b) Grit chamber
  Quantity : 2 Nos.
  Duty : Flow from screen chamber shall be taken into Grit chamber for the removing of oil or fats.
  Type : Vertical
  Size : Size of 1.7m × 1.2m grit chamber through a 600mm wide RCC channel with c/c spacing between the bars be 10mm.

c) Primary Sedimentation Tank
  Quantity : 1 No.
  Duty : Settles the sludge while grease and oil rise to the surface are skimmed off.
  Type : Circular tank
  Size : Dia of the tank is 3.9m or 4m with 23.89 m^3 capacity of sewage holding.

d) Aeration Tanks
  Quantity : 2 Nos.
  Duty : Tank which provide a location where biological treatment of the waste water takes place.
  Size : Overall size of 19m × 9m × 4.1m

e) Secondary clarifier
  Quantity : 1 No.
  Duty : The activated sludge converts organic substances into oxidized products & the floc gets settled in this tank.
  Type : Circular type
  Size : Dia of the circular tanks is 10m.

f) Sludge Pumps
  Quantity : 2 Nos.
  Duty : To transfer secondary sludge from clarifier to aeration tank & sludge thickness.
  Type : Horizontal certrifugal non clog self-priming open impeller Pump
  Motor : 400 – 440 v 50 Hz A/C

Analytical and numerical model solutions

Total Population = 4000
At 2016, population=4000
We are designing for future purpose,
so after 20 years, that means in 2036 the population;

P_n = 4000 X $e^{k(t2-t1)}$
= 4000 X $e^{\frac{5}{100}(2036-2016)}$
= **10,873**

So, let's take **10,000 people**.

Water Consumed= 10000 X (90/100) X 150
= 1350000 LPCD
= 1350 KLD (or) 1.35 MLD (or) 1350 m^3/day

Avg. Sewage generated = 85% of Supplied water
= 0.85 x 1.35
= 1.147 MLD
= 1147 KLD

Avg. Sewage per hour = 1147/24 = 47.79 m^3/hr
Peak Factor = 3

Design flow capacity = 47.79 X 3

= 143.37 m^3/hr

= **0.039 m^3/sec**.

II. Sizing Calculation For Collection Pit:

Retention time required = 4hr.
Avg. Design flow = 47.79 m^3/hr
Capacity of collection sump = 4 x 47.79

= **191.16 m^3**

Assume liquid depth = 5m
Area, required for collection pit = 191.16/5

Area = **38.23 m^2**

Let it is a circular tank.
Now,

$$38.23 = \pi r^2$$

r = $\sqrt{38.23/\pi}$ = **3.48 m**

Volume of the pit provided = $\pi/4$

III. Design of sewer chamber

$Q_{\max}$ = 0.039 m^3/sec
Assumption;
Shape of bar = M.S. Flats
Size = 10 mm X 50 mm
Clear spacing between the bars = 20 mm.
inclination of bars = 80 deg.
Assume avg. Velocity to sewer = 0.8 m/sec
At peak flow, net inclined area required = 0.03
9/0.8 = 0.048 sq. m
Gross inclined area = 0.048 x 1.5

= 0.072 sq. m

gross vertical area required = 0.072 x sin80

= 0.070 sq. m

Provide submergence depth = 0.3 m
Width of channel = 0.070/0.3 = 0.23 m ≈ 0.30 m
Provide 20 bars of 10 mm x 50 mm at 20 mm clear spacing. Screen chamber will be 60 cm wide.

IV. Design Of Grit Chamber

Flow from screen channels shall be taken into grit chamber, provided in duplicate 2 no C.I gates, one each at inlet and outlet are provided for each grit chamber.
Design Flow = (2.5 x 1.147)/2

= **1.433** MLD (OR) 1433 m^3/day

Surface Loading = **1100 m^3/sq. m/day**
To account for turbulence and short circuiting, reduce the surface loading to about 800 m^3/sq. m/ day.
Area required = 1433/800 = 1.79 sq. m
Provide 1.70m dia. Chamber (Circular)
detention time= 60 sec.
Volume = (1433 x 60) / (24 x 3600)

= 0.99 m^3

Liquid depth = $\frac{Volume}{Area}$ = $\frac{0.99}{1.79}$ = 0.553 m.

Size of the grit chamber = 1.70 x [0.553 + 0.6] (0.6 → Free board)

= 1.7 x 1.15m (1.7 → Dia; 1.15m → Depth)

V. Check for horizontal velocity

Cross sectional area of grit chamber = 1.7 x 0.553
= 0.940 sq. m
Velocity = 1433/ (1.7 x 0.553 x 24 x 3600) = 0.017m/sec.
= 1.7 cm/sec < 18cm/sec.

[Hence OK]
Grit generation assumed = 0.05 $\boldsymbol{m^3}$ per 1000 $\boldsymbol{m^3}$ of sewage flow.
Even though the grit is continuously raked, still grit storage is provided for avg. Flow.
Storage volume required = (1147 x 8 x 0.05) / (24 x 1000) = **0.019** $\boldsymbol{m^3}$
Grit storage area = (π/4) x1.7^2
= **2.27** $\boldsymbol{m^2}$
Grit storage depth = 0.019/2.27 = 0.0083 m
Total liquid depth = 0.553 + 0.008 = 0.561 = 0.6m
Provides grit chamber of size = 1.7 x (0.6 + 0.6)
= 1.7m x 1.2m

Out flow from grit chamber shall be carried to the aeration tank through a 600mm wide RCC channel provided with fine bar screen (manually operated). The clear spacing between the bars shall be 10 mm.

VI. Design Of Primary Sedimentation Tank

Detention time = 2hr.
Volume of sewage = max. Quantity of sewage/(detention time x 24)
= 1147/2 x 24 = **23.89** $\boldsymbol{m^3}$
Provide depth = 2m.
Surface area = Volume/Depth
= 23.89/2 = 11.95 sq. m
(π/4) x d^2 = 11.95
d^2 = 15.21
d = 3.9 m

VII. Design Of Aeration Tank

No. Of tanks = 2
Avg. Flow to each tank = 1.433 MLD/2 = 0.716 MLD
Q = 716 $\boldsymbol{m^3/\text{day}}$
Total BOD entering STP = 295 mg/L
Assuming that negligible BOD is removed in screening and grit chamber (since it mainly removes inorganic solids). The BOD of sewage coming to aeration tank= $Y_0 = 295\ mg/L$
BOD Left in the effluent= $Y_E = 20\ mg/L$
BOD removed in activated plant = 295 – 20 = 275 mg/L
Minimum efficiency required in the activated plant = 275/295 = 0.93 = 93% (OK)
Volume of aeration tank can be designed by assuming a suitable values of MLSS and 'θ_c' (or F/M ratio) = 3000 mg/L
(Between 3000 – 3500 mg/L)
F/M ratio = 0.15 (Between 0.18 – 0.10)
F/M = Q/V = $\frac{Y_0}{X_T}$
Therefore, Q = 716 $\frac{\boldsymbol{m^3}}{\text{day}}$
V= ?
Y_0= 295 mg/L
X(T) = 3000 mg/L
F/M = 0.12
0.15= (716 x 295)/v x 3500
V = (716 x 295)/(3000 x 0.12)
V = 586.7 $\boldsymbol{m^3}$
Aeration tank dimensions;
Let us adopt an aeration tank of liquid depth 3.5m, 9m width then;
length of the tank = V/ B x D

= 586.7/9 x 3.5 = 18.63 m = 19m

Therefore, Volume provided= 19x9x3.5

= **598 m^3**

(i) Check For aeration period;

t = (V/Q)x 24 hr = 598 x 24/716

t =20.04 hr = **20hrs (OK)**

(ii) Check for volumetric loading ;

= Q. $\frac{Y_0}{V}$ gm of BOD5/m^3 volume of tank.

= (716 x 295)/598 gm/ m^3

= 353.21 gm/m^3

= **0.35 kg/ m^3 (OK)** (It should lie between 0.2-0.4)

(iii)Check for return sludge ratio;

$$\frac{Q_R}{Q} = \frac{X_T}{\left[\frac{10^6}{S\,VI} - X_T\right]}$$

Using SVI = 100m/gm [between 50-150 m/gm]

$X_T = 3000\,\frac{mg}{L}$

$$\frac{Q_R}{R} = \frac{X_T}{\left[\frac{10^6}{100} - 3000\right]} = \frac{3000}{7000} = \mathbf{0.43}$$ [Should be between 0.5 to 1.0]

So taking SVI = 120ml/gm

$X_T = 3000\,mg/L$

$$\frac{Q_R}{R} = \frac{X_T}{\left[\frac{10^6}{120} - 3000\right]} = \mathbf{0.56}$$ [OK]

(iv) Check for SRT;

$$V.X_T = \frac{\{\alpha_y.Q(Y_0 - Y_E).\theta_c\}}{K_E.\theta_c.t.1}$$

Where,

α_y = 1.0

$K_e = 0.06\ d^{-1}$

$Y_0 = 295\frac{mg}{L}$

$Y_E = 20\frac{mg}{L}$

$X_T = 3000\frac{mg}{L}$

Q = 716 m^3/day

V = 598 m^3

=> 598 x 3000 = $\frac{[1\ x\ 716\ (295-20)\theta_C]}{1+0.06\ \theta_C}$

=> $\theta_C = \mathbf{20.09\ days}$ [OK] since it is between 10 to 25 days

The adopted tank size is thus OK.

Hence, adopt an aeration tank having an overall 19m x 9m x (3.5+0.6)m.

Overall depth, width 0.6m of free board. The outlet weir shall be adjustable type.

The effluent from the aeration tank will be taken to the final clarifiers. The inflow to the secondary clarifier shall be by means of 250mm Ø C.I pipes which will give a velocity of 0.78m/sec. of peak flow.

VIII. Design Of Secondary Clarifiers

No. of clarifiers = 1 no.

Avg. Flow = 1147 KLD = **1147 m^3/day**

Recirculated flow, say 50% = **716 m^3/day**

Total inflow = 1147 + 716= **1863 m^3/day**

provide hydraulic detention time = **2hr**s

Volume of tank = 1863 x 2/24 = **155.25 m^3**

Assume liquid depth = **3.5m**

Area = $\frac{155.25}{3.5}$= **44.35 m^2**

Surface loading rate of avg. flow = **15** $\frac{\frac{m^3}{m^2}}{day}$
Surface area to be provided = 1147/15 = 76.46 m^2 = **77** m^2
(Provide area greater of two i.e 77 m^2)
Dia of circular tank (d);
d = $\sqrt{77x\,\frac{4}{\pi}}$ = 9.9m = 10m

Actual area provided = 85 m^2
Check for weir loading;
Avg. flow = 1147 m^3/day
Weir loading = 1147/(π x 10) = 36.5 m^3/day/m (Ok) [as it is less than 185 m^3/day/m]
Provide a peripheral loading,
Check for solids loading:
Reciculated flow = 716 m^3/day
Avg. flow = 1147 m^3/day
MLSS solids inflow = 3000 mg/L
Total solids inflow = (1147 + 716) x 3
= 5589 kg/day
Solids loading = 5589/77 = 72.58 kg/day/ m^2
Provide a clarifier a 10m dia having liquid depth as 3.5m
Hopper slope shall be 1 in 12.
Free board will be 0.3m.

IX. Return Sludge Pump House

Total return flow = 716 m^3/day = 29.83 m^3/hr = 0.497 m^3/min
Detention time = 15min.
Volume of wet well = 0.497 x 15
Provide wet well = 2.5m x 1.5 x 1.8m SWD
provide dry well = 2.5m x 2.5m
Size of annexe control room = 2.5m x 2.5m
provide 2nos pumps each of 0.716MLD capacity in the dry well for returning the sludge to the aeration tank.
The return sludge pipe line should be 150mm Ø.

X. Design Of Sludge Drying Beds

Sludge applied for drying beds@100 kg/MLD
Sludge applied = 125 kg/day
Specific gravity = 1.015
Solid contents = 1.5%
Volume of sludge = $\frac{125}{1.5\,\%}\;X\,\frac{1}{1000\;X\;1.015} = 8.2\,\frac{m^3}{day}$
Considering monsoon etc. Total no of cycle in 1yr. = 33
Period of each cycle = 365/33 = 11 days.
Volume of sludge = 8.2 X 11 = 90.2 m^3
Spreading a layer of 0.3 m/cycle area of beds required = 90.2/0.3 = 300.67
Provide 4 beds of 1.2mX7m
thus providing = 336 m^2area.

XI. Filtrate Pump House And Sump

Actual BOD_5 20 deg. C removed per day = 1147 X (295-20)/1800 = 315.42 kgm.
Excess water sludge, $\theta_c = V.\frac{X_T}{Q_w . X_R}$

$20.09d = \frac{598\ X\ 3000}{Q_w . X_R}$
$Q_w .\ X_R$ = (598 X 3000)/20.9 = 85837 gm/d =85.8 gm/d

Thus excess sludge provided = 85.8 gm/d
Assuming the excess sludge to contain 1% solids and specific gravity = 1.015

volume of excess sludge = $\frac{85.8}{1000 \text{ x } 1.015 \text{ X } 1\%}$ $\frac{m^3}{\text{d}}$ = 8.45 $\frac{m^3}{\text{d}}$ = 0.35 m^3/hr
Taking detention time as 8hrs.
Volume of wet will = 8 X 0.35 = 2.8 m^3 for 1% concentration.
provide liquid depth = 1m
Area required for 1% concentration of solids = 2.8/1 = 2.8 m^2
Dia. of wet well = $\sqrt{2.8\, X \frac{4}{\pi}}$ = 1.88m
Assume 2.0 m dia

XII. Conclusion

A successful technical project involves the integration of various knowledge from different field. This is an attempt to combine several aspects of environmental, biological, part of chemical and mostly civil engineering from which the knowledge were acquired.

Since in Metro Sattelite, Palasuni, due to increase in population in recent days and looking on the future aspect, it was quite necessary to construct a sewage treatment plant. The plant is designed perfectly to meet needs and demands of approximate 10000 population with a very large period of time. The project consist of the design of complete Sewage treatment plant components starting from receiving chamber, screening, grit chamber, skimming tank, sedimentation tank, secondary clarifier, activated sludge tank and drying bed for sewage.

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