

# A CASE STUDY AND DESIGN APPROACH FOR SEWAGE TREATMENT PLANT IN KAKUMANU VILLAGE.

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**Abstract** - Many villages in the developing countries are facing problems on ground water and surface water. Kakumanu Village located in Guntur district of an Indian state Andhra Pradesh. Due to steady increase of population in the village, the generation of domestic sewage also increase and still there is no sewage treatment plant. So, the construction of sewage treatment is required with enough capacity. Wastewater treatment plant has many challenges for treating of excess sludge and its disposal. Several methods involved to reduce its water and organic content and finally to protect the environment.

This paper focal point is generation of sewage and design of Wastewater treatment plant in both Kakumanu. One day the generated sewage was estimated 0.739 MLD for the next 30-year projected population. Sewage treatment plant consists of three process are Preliminary treatment, primary treatment and secondary treatment. Screening, grit chamber, primary sedimentation tank, biological reactor, secondary clarifier, activated sludge tank, drying beds are the main components in wastewater treatment plant. Components are designed by considering the various standards and permissible limits of treating sewage water. Ultimately, treated sewage water is supplied to irrigation and the generated sludge can be used as manure helps in increase of soil fertility.

**Key Words:** Wastewater treatment plant, Design approach, Sludge, Population, Grit chamber, Aeration tank.

## 1. INTRODUCTION

This paper deals with design of wastewater treatment plant for Kakumanu village. The village Kakumanu is located at 16.3° North and 80.23° East altitudes in Guntur district. Over the years, with increasing population, industries and agriculture the demand for water also pushed up. Many efforts have done for water storage in the form of dams and reservoirs. The demand of water for agricultural, industrial and domestic activities are increased. Not only surface water resources but groundwater resources also resulting below the riverbed. Due to the low availability of water with increasing growth of population the serious water scarcity problems were increased. To minimize these problems the sewage treatment plant is to be constructed for treating of wastewater.

Sewage treatment plant consists of three process are Preliminary treatment, primary treatment and secondary treatment shown in Figure 1.[6] Preliminary treatment consists of separating like floating materials like papers, wood, rags, nappies, facewipes, bottle tops, broken bottles, diapers, plastics, cotton buds, sanitary items etc. are removed. Primary treatment consists of removing large suspended organic solid materials which are usually settled in the process of sedimentation. In the secondary treatment process, seed sludge is added to wastewater and the air is pumped into huge aeration tanks which helps to mix the seed sludge with wastewater. And the large particles will settle down and wastewater passes through the large tanks.

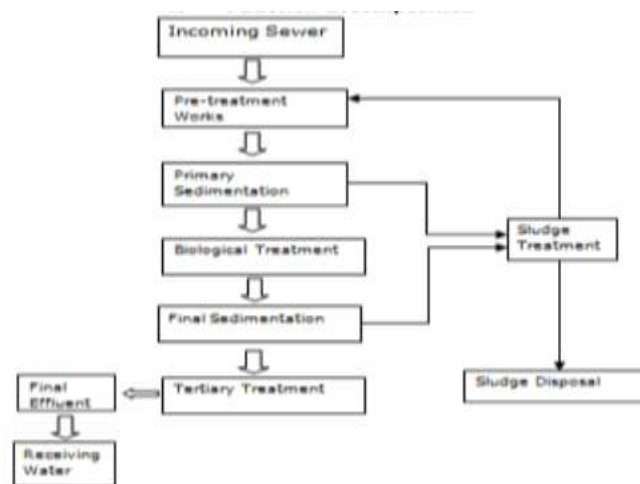


Figure 1: Screenshot of Function Decomposition.

## 2. Population Forecast

As per 2011 census, the population of kakumanu village is 5,777<sup>[4]</sup>. If the rate of population is increased as 50 per year, then the estimated population for 30 years is

$$P_{2050} = 5777 + (8 \times 20) + (30 \times 20) = 6537$$

Therefore, the estimated population of Kakumanu village is 6540 (assumed).

Quantity of water supply per person = 150LPCD.

Rate of water supply,

$$\text{Water consumption} = 6450 * 150 * \frac{90}{100}$$

$W_c = 870,750$  LPCD or 870 KLD or 0.87 MLD or 870 m<sup>3</sup>/day.

As per CPHEEO guideline, the generated sewage will be 80-85%

$$\text{Sewage generated} = \frac{85}{100} * 0.87 \text{ MLD} = 0.739 \text{ MLD or } 739 \text{ KLD}$$

Therefore, the quantity of sewage water generated is 0.739 MLD.

$$\text{Average Sewage per hour} = \frac{739}{34} = 30.79 \text{ m}^3/\text{hr}$$

Peak flow rate of sewage is 3 for population less than 20,000.

$$\text{Design Flow capacity} = 3 * 30.79 = 92.37 \text{ m}^3/\text{hr} = 0.0256 \text{ m}^3/\text{sec}.$$

## 3. Design Considerations

The points to be considered during design of sewage treatment plant are:

- Design period is taken as 30 years.
- The design is done on average domestic basis.
- Self-cleaning velocity is to develop at every place and stage.
- Design of treatment should be economical and easily to maintain.

## 4. Design of Collection pit

Storage tank, a container used to store the liquids also known for artificial lakes and ponds. It can be available in different shape: vertical and horizontal cylinder, open top and closed top, flat bottom, cone bottom and slope bottom.

Retention time = 4hr.

Average design flow= 30.79 m<sup>3</sup>/hr

Capacity of collection sump = 4\*30.79= 123.16 m<sup>3</sup>.

Assumed liquid depth = 5m.

Area required for collection pit,  $A = \frac{123.16}{5} = 24.63 \text{ m}^2$ .

The shape of the storage tank is taken as circular here.

Now,

$$r = \sqrt{\frac{24.63}{\pi}} \quad (\text{where } A = \pi r^2)$$

$$r = 2.8 \text{ m.}$$

Design of sewer chamber

$$Q_{\max} = 0.0256 \text{ m}^3/\text{sec}$$

Assumptions;

Shape of bar= M.S. Flats

Size+ 10mm\*50mm

Clear spacing between the bars= 20mm

Inclination of bars =  $80^\circ$

Assume average velocity of sewer= 0.8 m/sec

At peak flow, required net inclined area = 0.03

Gross inclined area =  $(9/0.8) * 1.5 = 0.072 \text{ sq.m.}$

Gross vertical area required =  $0.072 * \sin 80 = 0.070 \text{ sq.m.}$

Provide submergence depth = 0.3 m

Width of channel =  $0.070/0.3 = 0.23 \text{ m.}$

Therefore, provide 20 bars of 10mm \*50mm.

## 5. Design of grit chamber

The flow from screen channels is taken into grit chamber, provided with 2 duplicate C.I gates one at inlet and other at outlet.

$$\text{Design Flow} = (2.5 * 0.739)/2 = 0.923 \text{ MLD or } 923 \text{ m}^3/\text{day}$$

$$\text{Surface loading} = 1100 \text{ m}^3/\text{sq. m}/\text{day}$$

To account the turbulence and short circuiting, the surface loading is reduced to  $800 \text{ m}^3/\text{sq. m}/\text{day}$ .

$$\text{Therefore, required area} = 923/800 = 1.15 \text{ sq. m.}$$

Provide 1.15m dia. Chamber i.e. circular

Detention time = 60 sec.

$$\text{Volume, } V = (923 * 60)/(24 * 60 * 60) = 0.64 \text{ m}^3$$

$$\text{liquid depth} = \text{Volume} / \text{Area} = 0.64/1.15 = 0.556 \text{ m.}$$

free board = 0.6

$$\text{size of grit chamber} = 1.7 * (0.556 + 0.6) = 1.7 * 1.156 \quad (\text{dia} * \text{depth})$$

**Check for horizontal velocity**

Cross sectional area of grit chamber =  $1.7 \times 0.556 = 0.945$  sq.m.

Velocity =  $923 / (1.7 \times 0.556 \times 24 \times 60 \times 60) = 0.011$  m/sec. = 1.1 cm/sec < 18 cm/sec.

Hence OK.

Assumed Grit generation =  $0.05$  m<sup>3</sup> per 1000 m<sup>3</sup> of sewage flow.

Required storage volume =  $(739 \times 8 \times 0.05) / (24 \times 1000) = 0.012$  m<sup>3</sup>

Grit storage area =  $(\frac{\pi}{4}) \times 1.7^2 = 2.27$  m<sup>2</sup>.

Grit storage depth =  $0.012 / 2.27 = 0.0052$  m.

Total liquid depth =  $0.556 + 0.005 = 0.561 = 0.6$  m.

Provided size of grit chamber =  $1.7 \times (0.6 + 0.6) = 1.7$  m \* 1.2 m.

**6. Design of primary sedimentation tank**

Detention time = 2 hr.

Volume of sewage = max quantity of sewage / (detention time \* 24) =  $739 / (2 \times 24) = 15.39$  m<sup>3</sup>

Provided depth = 2 m.

Surface area = volume / depth =  $15.39 / 2 = 7.695$  sq. m.

$$D = \sqrt{7.695 \times \frac{4}{\pi}} \quad (\text{where } A = (\frac{\pi}{4}) \times d^2)$$
$$= 3.12 \text{ m.}$$

**7. Design of Aeration tank**

No of tanks = 2

Average flow in each tank =  $0.739$  MLD / 2 = 0.369 MLD

Q = 369 m<sup>3</sup>/day

Total BOD entering STP = 295 mg/L

The BOD of sewage coming to aeration tank  $Y_0 = 295$  mg/L

BOD left in effluent =  $Y_E = 20$  mg/L

BOD removed in activated plant =  $295 - 20 = 275$  mg/L

Required minimum efficiency in activated plant =  $275 / 295 = 0.93 = 93\%$

Volume of aeration tank can be designed by assuming a suitable value of MLSS and  $\theta$  or F/M ratio = 3000 mg/L

F/M ratio = 0.15

F/M = Q/V =  $Y_0 / X_T$

$0.15 = (369 \times 295) / (V \times 3500)$

$V = (369 \times 295) / (3000 \times 0.12)$

V = 302.3 m<sup>3</sup>

### 7.1. Aeration tank dimensions

Let us adopt a depth of 3.5m and width 9m aeration tank.

Length of tank =  $V/(B * D) = 302.3/(9*3.5) = 9.59 \text{ m} = 10\text{m}$ .

Therefore, provided volume =  $10*9*3.5=315 \text{ m}^3$

**Check for aeration period**  $t = (V/Q) * 24\text{hr} = (315/369) * 24 = 20.48 = 20 \text{ hrs}$

**Check for volumetric loading** =  $Q*(Y_0/V) \text{ gm of BOD } 5/\text{m}^3 \text{ volume of tank.}$

$$= (369 * 295)/315 \text{ gm/m}^3$$

$$= 345.57 \text{ gm/m}^3 = 0.34 \text{ kg/m}^3$$

**Check for return sludge ratio**

$$Q_R/Q = X_T / ((10^6/SVI) - X_T)$$

SVI should be between 50 m/gm – 150 m/gm. Using 120 m/gm

$$Q_R/Q = 3000 / ((10^6/120) - 3000) = 0.56 \text{ (between 0.5 - 1)}$$

**Check for SRT**

$$V * X_T = [\alpha_y * Q(Y_0 - Y_E) \theta_c] / (K_E * \theta_c + 1)$$

Where,  $\alpha_y = 1$ ,

$$K_E = 0.06/\text{d},$$

$$315 * 3000 = [1 * 369(295 - 20) \theta_c] / (0.06 \theta_c + 1)$$

$$945000 = 101475 \theta_c / (1 + 0.06 \theta_c)$$

$$1 + 0.06 \theta_c = 0.107 \theta_c$$

$$\theta_c = 1/0.047$$

$$\theta_c = 21.27 \text{ days.}$$

Adopted size of aeratin tank is  $19\text{m} * 9\text{m} * (3.5 + 0.6) \text{ m}$ .

### 8. Design of Secondary clarifiers

Average sewage flow = 739 KLD =  $739 \text{ m}^3/\text{day}$

Recirculated flow =  $461 \text{ m}^3/\text{day}$  (assume 50%)

Total inflow =  $739 + 461 = 1200 \text{ m}^3/\text{day}$

Detention time = 2hrs

$$\text{Volume of tank} = 1200 * (2/24) = 100 \text{ m}^3$$

Liquid depth = 3.5m (assumed)

$$\text{Area} = 100/3.5 = 28.57 \text{ m}^2$$

Average flow of surface loading =  $15 \text{ m}^3/\text{day}$

Surface area to be provided =  $739/15 = 49.26 \text{ m}^2 = 50 \text{ m}^2$

Diameter of circular tank,  $d = \sqrt{50 * \left(\frac{4}{\pi}\right)} = 7.97 \text{ m} = 8 \text{ m}$ .

### Check for weir loading

Average sewage flow = 739 KLD =  $739 \text{ m}^3/\text{day}$

Weir loading =  $739 / (\pi * 8) = 29.40 \text{ m}^3/\text{day/m}$ . ( $< 185 \text{ m}^3/\text{day/m}$ )

### Check for solids loading

Recirculated flow =  $461 \text{ m}^3/\text{day}$

Average sewage flow = 739 KLD =  $739 \text{ m}^3/\text{day}$

MLSS solids inflow =  $3000 \text{ mg/L}$

Total solids inflow =  $(739 + 461) * 3 = 3600 \text{ kg/day}$ .

Solids loading =  $3600/50 = 72 \text{ kg/day/m}^2$ .

Provide a clarifier with 8m dia and depth 3.5m.

Hopper slope = 1 in 12

## 9. Return sludge pump house

Total return flow =  $461 \text{ m}^3/\text{day} = 19.20 \text{ m}^3/\text{hr} = 0.32 \text{ m}^3/\text{min}$ .

Detention time = 15 min

Volume of wet well =  $0.32 * 15$

wet well provided =  $2.5 \text{ m} * 1.5 * 1.8 \text{ m}$

dry well provided =  $2.5 \text{ m} * 2.5 \text{ m}$

control room size =  $2.5 \text{ m} * 2.5 \text{ m}$

Provide 2 pumps with capacity 0.461 MLD and diameter of return sludge pipe should be 150mm.

## 10. Design of Sludge drying beds

Sludge applied for drying beds @  $100 \text{ kg/MLD}$

Sludge applied per day =  $125 \text{ kg}$

Specific gravity,  $g = 1.015$

Percentage of solid contents = 1.5

volume of sludge =  $(125 / 1.5\%) * (1 / (1000 * 1.015)) = 8.2 \text{ m}^3/\text{day}$ .

Total number of cycles in one year = 33

Therefore, period of each cycle =  $365 / 33 = 11 \text{ days}$

Volume of sludge =  $8.2 * 11 = 90.2 \text{ m}^3$

Area of beds required for 0.3m/cycle spreading layer =  $90.2 / 0.3 = 300.67$

Provide 4 beds with dimensions  $1.2 \text{ m} * 7 \text{ m}$  and hence the area provided is  $336 \text{ m}^2$

## 11. Filter Pumphouse and sump

Excess sludge water,  $\theta_c = V * (X_T / Q_w * X_R)$

$$21.27 \text{ d} = (315 * 3000) / (Q_w * X_R)$$

$$Q_w \cdot X_R = 44428.77 \text{ gm/d} = 44.4 \text{ kg/d}$$

Assume excess sludge contains 1% solids and specific gravity = 1.015

$$\text{Volume of excess sludge} = 44.4 / (1000 \cdot 1.015 \cdot 1\%) = 4.37 \text{ m}^3 / \text{day} = 0.18 \text{ m}^3 / \text{hr.}$$

Detention time = 8 hrs

$$\text{Volume of wet well} = 8 \cdot 0.18 = 1.44 \text{ m}^3 \text{ for 1\% concentration}$$

Liquid depth provided = 1m

Therefore, the area required for 1% concentration of solids =  $1.44 / 1 = 1.44 \text{ m}^2$

$$\text{Diameter of wet well} = \sqrt{1.44 \cdot \left(\frac{4}{\pi}\right)} = 1.35 \text{ m}$$

Assume 2m diameter.

## 12. CONCLUSION

Due to increase in population in Kakumanu village, looking on future aspect, it is quite necessary to construct wastewater treatment plant. In the present study, wastewater treatment plant in Kakumanu is analysed and designed perfectly to meet needs and demand for population 6540 for 30 years. The utilization of treated water will reduce the use of fresh water and ground water. Treated sludge can be used for manure helps to increase fertility in soil. The construction of wastewater treatment plant helps to prevent direct disposal of sewage into fields and reduce the freshwater consumption.

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## BIOGRAPHIES



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