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DESIGN AND ANALYSIS OF SEWAGE TREATMENT PLANT

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Abstract— **The College of Engineering Roorkee is one of the most important educational institutes in the state of Uttarakhand with a large number of people residing in its campus consisting of a number of laboratories of various departments, residential units, academic blocks and number of hostels. A study on wastewater characterization of treatment plant will be performed followed by the design of sewage treatment plant. The whole project study involves the analysis of pH value, total solids, total suspended solids, hardness, acidity, alkalinity, chloride, chlorine, BOD, COD, DO & turbidity.**

A sewage treatment plant is quite necessary to receive the hostels, college and laboratories waste and removes the materials which pose harm for general public. Its objective is to produce an environmentally-safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse (usually as farm fertilizer).

The main purpose of Sewage treatment process is to remove the various constituents of the polluting load: solids, organic carbon, nutrients, inorganic salts, metals, pathogens etc. Effective wastewater collection and treatment are of great importance from the standpoint of both; environmental and public health. Sewage/Wastewater treatment operations are done by various methods in order to reduce its water and organic content, and the ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socio-economic concerns. In this report Sewage/Wastewater treatment techniques, factors affecting selection and design Sewage/Wastewater systems are discussed briefly.

Keywords ----- Physicochemical parameters; population forecasting; wastewater collection; designing.

I. INTRODUCTION

The objective in domestic wastewater treatment is to provide a low- cost process that is reliable meeting effluent quality standards. The contaminants in wastewater are removed by physical, chemical, and biological means. The individual methods usually are classified as physical unit operations, chemical unit processes, and biological unit processes. These operations and processes occur in a variety of combinations in treatment systems, it has been found advantageous to study their scientific basis separately because the principle involved do not change. Traditional design procedures for wastewater treatment systems attempt to minimize total capital cost by considering steady state concepts for unit processes and design guidelines. Recent work has minimized capital as well as operation and maintenance costs using a single objective function and steady state models which are flawed because plant inputs vary as much as seven-fold during a 24-hour period.

This paper presents the technical aspects of the design for a sewage treatment plant with a capacity of 1100 cubic meters (m^3) per day in College of Engineering Roorkee.

II. NEED OF STUDY

The Sewage treatment plant of COER was designed in 1999 to treat the wastewater and sewage produced by the population at that time. The population of the college since 1999 has gone through a big increment in terms of no. of students (including hostellers as well as day scholars), no. of faculties and number of workers. Although the sewage treatment plant was designed for keeping in mind the future population growth yet the designed plant has failed due to high increment in population and the high demand of waste-water treatment thus increasing the total load on the plant.

III. Scope of study

The population for which the plant was designed was about the one-fourth to one-sixth of the present population. That's why the plant presently has failed to treat the water as per the standards laid according to the Indian Standards and Central Pollution Control Board (CPCB). The plant presently needs a serious attention towards its methodology as well as its treatment units. The plant is presently treating the waste water which is about four or five times more than its designed capacity. Thus the waste water at effluent has almost same parameters as influent. The hydraulic loading rate is also more than its peak capacity for which it was designed. Hence the treatment plant needs major checks to be performed to keep the waste-water at effluent to meet the standards and laws set up by the government and various authorities responsible for environment protection.

IV. Factors affecting selection and design of sewage/ wastewater treatment systems

The work meets the technical requirements of the governing laws for wastewater treatment and disposal. It includes the design, description, and technical specifications for the plant units. The plant's design takes into consideration the following conditions:

- Minimize construction costs
- Maximize use of existing facilities
- Maximize use of locally manufactured parts
- Optimize capabilities to meet variable loads
- Ease of erection and installation
- Ease of operation and maintenance
- Minimize required land area
- Respect for environmental laws.

The object of sewage treatment is to stabilize decomposable organic matter present in the sewage so as to produce an effluent and sludge, which can be disposed of in the environment without causing health hazards or nuisance. The degree of treatment will be as per the regulations stipulated by the Indian standard codes. The treated effluent parameters shall be considered for disposing into the natural water bodies.

Selection of suitable process for the sewage treatment is governed by factors like raw sewage characteristics, the capacity of the plant, availability of land, required effluent quality, proven technology and reliability of the process, intended disposal method or reusing the treated effluent, capital cost, O&M requirement and other local factors. In general for the treatment of domestic sewage for the intended disposal and reuse the process involves –

- Preliminary Treatment i.e. screening and Grit Removal
- Primary Treatment i.e. Primary Sedimentation and primary sludge disposal.
- Secondary Treatment i.e. Aerobic Biological Treatment followed by secondary sedimentation, digestion and/or drying of sludge and treated wastewater disposal if no reuse is intended.

A. Engineering factors

- Design period, stage wise population to be served and expected sewage flow and fluctuations,
- Topography of the area to be served, its slope and terrain; tentative sites available for the treatment plant, pumping stations, and disposal works,
- Available hydraulic head in the system up to high flood level in case of disposal into a river or high tide level in case of coastal discharges,
- Groundwater depth and its seasonal fluctuations affecting construction, sewer infiltration,
- Soil bearing capacity and type of strata to be met in construction and on-site disposal facilities, including the possibilities of segregating sludge and sewage and reuse or recycling of sludge water within the households.

B. Environmental factors

- Surface water, groundwater and coastal water quality where wastewater has to be disposed of after treatment,
- Odor and mosquito nuisance which affects land values, public health, and well-being, and Public health considerations by meeting the requirements

laid down by the regulatory agencies for effluent discharge standards, permissible levels of microbial and helminths quality requirements and control of nutrients, toxic and accumulative substances in the food chain.

C. Process consideration

- Wastewater flow and characteristics,
- Degree of treatment required,
- Performance characteristics, and
- Availability of land, power requirements, equipment and skilled staff for handling and maintenance.

D. Cost consideration

- Capital costs for land, construction, equipment etc., and
- Operating costs including staff, chemicals, fuels and electricity, transport, maintenance, and repairs etc.

V. EXPERIMENTAL RESULTS

Designing of sewage treatment plant involves the designing of various important units as well as taking into consideration the various other important steps that are mentioned below:

A. Physicochemical parameters

In the present study, two samples were taken from the old STP of COER at different time interval.

TEST	RESULTS	
	Sample 1(2 PM) after reaching the STP	*Sample 2 (10 AM)*
pH	7.34	7.5
Alkalinity	180 mEq/L	172 mEq/l
Acidity	256 g/L	576 g/L
Total hardness	200 mg/L	180 mg/L
Turbidity	142 NTU	155 NTU
Dissolved Oxygen	4.032 mg/L	6.048 mg/L
BOD5	210mg/l	212mg/l
COD	400mg/l	400mg/l

B. Population Forecasting

- College population
- Total student = 3500
- Total staff workers = 500
- Total population = 3500+500 = 4000
- Per capita sewage = 75 to 80% of per capita water supplied to public
- According to Indian standard-
- For Population less than 20,000 - Per capita water demand = 110 L/day/person (q)
- So,
- Per capita sewage production = 80% of q = 80%of 110 = 90 L/day/person (approx.)
- Quantity of sewage = (90x4000)÷(24x60x60x1000) = 0.00456 m^3/sec
- Maximum sewage discharge = 3 x Quantity of sewage = 3x0.00456 = 0.01286 m^3/sec
- = 1.0878 MLD (1 m^3/sec = 86.4 MLD)

C. Design of Inlet Chamber

- Q_{avg}= 0.004126 m^3/sec
- Q_{max}= 0.01278 m^3/sec
- Peak Flow = 0.01278 m^3/sec = 1.088 MLD
- Peak flow = 1.1 MLD = 1100 m^3/day
- Avg. Flow = 366.67 m^3/day
- Plan dimension of inlet chamber = 1.3m X 1m
- Free Board = 10m
- Size of the Bye-pass chamber by the side of inlet chamber = 1.3m X 1m (minimum size)

The outflow from the inlet chamber shall be taken to the screen chamber. A bye-pass channel 0.60m X 1m or 400mm Dia. pipe shall be provided from bypass chamber up to final effluent channel to meet with any exigencies of the S.T.P.

D. Design of Screen Chamber

2 numbers of screen chambers/ channels shall be provided as per sound engineering practice.
The flow from the inlet chamber to screen channels shall be controlled by C.I. penstock gates.
Q_{max}= 0.01278 m^3/sec
Assumptions:

- Shape and material of the bar = M.S. Flats
- Size = 10mm X 50mm (10mm facing flow)
- Clear spacing between the bars = 20 mm
- Inclination of bars with horizontal = 800 (cleaning manually)
- Assuming velocity normal to screen = 0.6 m/sec
- At peak flow, net inclined area required = (0.01278/0.6) = 0.0213 m^2

- Gross inclined area required = 0.0213 X 1.5 = 0.03195 m^2
- Gross vertical area required = 0.03195 X sin80^o = 0.031464 m^2
- Provide submergence depth = 0.3 m
- Width of channel = 0.069 / 0.3 = 0.23 m ; provide 0.30 m
- Check velocity in duct = 0.038/ (0.30X1.3) = 0.42 m/sec
- (Approach velocity u/s of screen) > 0.4m/sec
- Provide 20bars of 10mm X 50mm at 20mm clear spacing Screen chamber shall be 60cm wide.
- U/S of screens, 2 Nos. C.I. penstock gates shall be provided (one for each channel).
- Min. drop of 150 mm shall be provided in the bed of screen channel.
- The size of the penstock gates: 2Nos. of 350X450 mm size be provided.

E. Design of Grit Chamber

- Flow from screen chamber shall be taken into grit chamber, provided in duplicate. 2 Nos. C.I. gates, one each at inlet and outlet, are provided for each grit chambers. One more C.I. The gate shall be provided at the inlet to bye-pass channel in between two grit chambers.
- Design flow = 3 X 0.367/ 2 = 0.55 MLD = 550 m^3/day
- Surface loading = 1100 m^3/m^2/day
- To account for turbulence and short circuiting, reduce the surface loading to about 800m^3/m^2/day
- Area required = 550 / 800 = 0.6875 m^2
- Provide 1.70m dia. chamber (if circular), or 1.70 X 1.70 m square chamber (if square).
- Detention time = 60sec
- Volume = (550 X 60) / (24 X 3600) = 0.3819 m^3
- Depth = .3819m^3 / 0.6875m^2 = 0.555 m
- Size of the Grit chamber = 1.70m X 1.70m (dia. or side) X 1.2m (i.e. 0.554 + 0.6 F.B. = 1.2m)
- Check for Horizontal Velocity

Velocity = 550 / (1.7 X 0.554 X 24 X 3600) = 0.006759 = 0.67 cm / sec < 18cm / sec.

Hence, O.K.

- Grit generation = 0.05 m3 per 1000m^3 of sewage flow (Assume)
- Even though Grit is continuously raked, still 8 hours of grit storage is provided for average flow.
- Storage Volume required = (550 X 8 / 24) X (0.05 / 1000) =0.009167 m^3
- Grit Storage area = (π/4) X 1.72 = 2.27 m^2
- Grit Storage depth = 0.028 / 2.27 = 0.012 m^2
- Total liquid depth = 0.554 + 0.012 = 0.566 ; say 0.6m
- Provide grit chamber of size : 1.7 X 1.7 X 1.2(depth) ;{ depth = 0.60+0.60 (F.B.)}
- Or 1.7 X 1.7 X 1.2 m size
- Outflow from grit chamber shall be carried to aeration tank through a 600mm wide R.C.C channel provided with fine bar screen (manually operated). The clear spacing between the bars shall be 10mm.
- Note: Parshall Flume and measuring arrangement has not been proposed for two reasons viz:

a) The measuring instruments are rarely working satisfactorily at any plant.

b) The plant is very small, to economize the cost.

F. Design of Primary Sedimentation Tank

- Assume surface settling rate = 40 m^3/m^2.d

Therefore, the surface area of the tank = 25 x 10 = 250 m^2

- Check for peak flow condition: The SOR at peak flow = 22.5 x 103 /250 = 90 m^3/m^2.d

This is less than the recommended value of peak flow.

- Assume width = 6.0 m
- Therefore theoretical length = 250/6 = 41.66 > 40 m Hence, provide two tanks in parallel
- Total length of each tank = 41.66/2 + 2 (inlet) + 2 (outlet) = 24.83 say 24.85 m
  Now,
- Flow rate x detention time = depth x surface area = volume of tank Or Flow / Surface area = depth / detention time = Surface settling rate Provide detention time of 1.5 h
  Therefore, liquid depth required = 40 x 1.5 / 24 = 2.5 m

Therefore, flow through velocity = (0.116 m^3/sec) / (2 x 2.5 x 6) = 0.0039 m/sec < 1 cm/sec hence O.K.

- At peak flow, the flow through velocity = 22.5 x 103 / (2 x 6 x 2.5) = 750 m/d = 0.0087 m/sec.
- (Horizontal velocity should be checked for non-scouring velocity i.e. less than 0.06 m/sec.)
  Provide total depth = 2.5 + 0.5 (free board) + 0.25 (space for sludge) = 3.25 m
- Weir loading rate = 10 x 103 / 12 = 833.33 m^3/m.day > 185 m^3/m.day
- Length of weir required = 10 x 103 / 185 = 54.05 m
- Hence, provide about 27.1 m of weir length for each tank. This can be provide by two effluent collection channel across the width at outlet end offering total 24.0 m and side weir of total 1.55 m on each side.

G. Design of Circular Trickling filter unit

- The BOD values obtained from tests are 210 and 212 mg/l.
- Taking the average value of BOD to be 211 mg/l
- For design consideration the BOD value may be taken = 220 mg/l
- Total BOD present in sewage to be treated per day = 1.1 x 242 = 242 kg
- Assuming the value of organic loading, say as, 1000 kg/hectare metre/day (i.e. between 900 to 2200 kg/ha-m/day),
- The volume of filtering media required = 242/1000 = 0.242 ha-m = 2420 m^3
- Assuming the effective depth of filter to be 2m; we have the surface area of the filter required = 2420/2 m^2 = 1210 m^2
- Using a circular trickling filter of dia 28 m, we have the no. of units required
- = ($Total\ area\ required$ / $Area\ of\ one\ unit$) = (1210 / 0.785x28x28) $^{1/2}$ = 1.966 = 2 no.

H. Check for hydraulic loading –

- The surface area of the filter bed required can also be worked out by assuming the value of hydraulic loading, say as, 10 million liters per hectare per day (i.e. between 5 to 16 ML/ha/ day)
- Surface area required = ($Total\ sewage\ to\ be\ treated\ per\ day$ / $Hydraulic\ loading\ per\ day$) = (1.1/10) hectares = (1.1/10) x10,000 m^2 = 1100 m^2
- The surface area chosen is 1200 m^2 which are greater than 1000 m^2 and hence safe.
- Hence, 2 units each of 28m dia and 2 m effective depth (i.e. 2.6m overall depth), can be adopted. An extra third unit as stand-by may also be constructed.

I. Design of Rotary Distributors –

- Rotary distributors, as said earlier, are to be designed for peak flow, which may be considered as 2.25 times the average flow.
- Peak sewage flow per day = 2.25 x 1.1 M.L./day = 2.475 M.L/day= 2.475 x 106(1000000 x 1/1000 x 24 x 60 x 60) = cu-m/sec = 0.028645 m^3/sec
- This flow is divided into two filter units; and, therefore, Flow through each unit at peak flow = 0.0143225 m^3/sec
- Assuming the velocity of peak flow to be 2 m/sec through the central column of the distributor, we have the dia of the central column = 0.0143225 x 1/2 x (π/4) = 0.0955 m
- Provide a central column of 0.1 m in dia , but check the velocity through the column at average flow, as it should not be less than 1 m/sec or so.

J. Check for velocity at average flow –

- Discharge through each unit at average flow =1.1/2 M.L.D. = 0.55 M.L.D. =0.55 x (1000000/1000) x (1/24 x 3600) = 0.0063657 m3/sec
- Velocity at average flow = 0.00635357/ (π/4)(0.1x0.1).= 08109 m/sec
- Strictly speaking, since the velocity at average flow becomes slightly less than the minimum permissible of 1 m/sec, we should reduce the adopted dia slightly. Say, let us use 0.09 m dia, then The velocity at average flow = (0.00635357 / (π/4) x (0.09 x 0.09) = 1.01 > 1m/sec.

- The velocity at peak flow will then be 0.0143225/(π/4)(0.09x0.09) = 2.25 m/sec
- Hence, we may use a central column of 0.09m dia. If, however, the central column of 0.09m dia is not available, we may permit 0.1 or 0.2 m dia central column, as the velocity of average flow is quite near the allowable minimum value.

K. Design of Arms –

- Now, let us use rotary reaction spray type distributor with 4 arms Then, the discharge per arm = 0.0143225/4 m^3/sec = 0.003580625 m^3/sec
- Dia of filter used = 28 m
- Arm length = 28-2/2 = 13 m
- We can use each arm of length 13m with its size reducing from near the central column towards the end. The first two sections, each of 4m length and third section of 5m length can be used.
- The flow in the arms has to be adjusted in the proportion of the filter area covered by the different lengths of arm calculated first.

L. Design of Secondary Sedimentation Tank –

Data Available:

- Peak flow = 1100 m^3/day
- Avg. flow = 366.67 m^3/day
- Adopting a surface loading rate of 8 $m^3/day/m^2$ at average flow of 1000 m^3/day we have, surface area reqd. =500 / 8m^2= 62.5 m^2
- Adopting a solids loading of 80 kg/ day/ m^2 for MLSS of 1500 mg/l
- We have, the surface area required = (1000 x 1500/1000) x (1/80) m^2 = 18.75 m^2

The higher surface area of 25 m^2 is adopted

- Adopting a circular tank,
- Dia of tank = $(25\ x\ 4/\pi)^{1/2}$ = 5.64 m = 6 m
- Weir loading for a circular weir placed along the periphery of the tank having length 6π will be = (1000/6π) m^3/day/m = 53.05 <150 ; O.K.

Note: If weir loading exceeds the permissible value, we may provide a trough instead of a single weir at the periphery.

Hence, provide 6 m dia secondary settling tank

CONCLUSION

The ultimate goal of wastewater treatment is the protection of the environment in a manner commensurate with public health and socio-economic concerns. Based on the nature of wastewater, it is suggested whether primary, secondary and tertiary treatment will be carried out before final disposal.

The project work has been carried out revolves around the analysis of the available waste-water treatment plant and the sewage characteristics at influent and effluent, comparing the values obtained from testing's against the standard values of treated waste-water to keep a check over the disposal of effluent and sludge. After comparing the values, the waste-water treatment plant failed to fulfill the desired outlet quality of water, so the STP is redesigned to meet the present and future wastewater treatment requirements of the college. Taking into consideration the Indian Standards codes for the designing of various parts of the treatment unit the plant is redesigned for peak flow capacity of 1.1 MLD (Million Liters per Day) for the total population of college around 4K.

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