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Review Article

STP design calculation for 100 KLD SBR (Sequential batch reactor)

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ABSTRACT

Sewage treatment aims to remove the contaminants from different municipal sources in order to prevent pollution of aquatic bodies. There are numerous sewage treatment systems available in the market, including ASP (Activated Sludge Process), MBBR (Moving Bed Bioreactor), MBR (Membrane Bioreactor), etc. One of them, the SBR (Sequential Batch Reactor), is a remarkable technology that may be used in large-scale treatment plants due to its simple maintenance. Sequential batch reactors (SBR) are reactors or basins in which the biological treatment of waste water is carried out in a series of four steps, namely filling, aeration, settling (clarification) and decanting. One of the newest solutions for treating municipal sewage is the sequential batch reactor (SBR). In this research designing study, a thorough design computation for a sewage treatment system with a 100 KLD capacity was elucidated. In this study, two important aspects of design calculation such as units available in the SBR scheme and Equipment's available in the SBR scheme. Thus, the simple calculation makes it easier for any design engineers to construct their sewage treatment plant or system.

1. Introduction

Sewage treatment systems aid in the removal of impurities or pollutants coming from various sources. Physical, chemical, and biological processes are three crucial techniques or approaches used to remove or degrade pollutants. The primary, secondary, and tertiary treatment units are the three stages in the sewage treatment process.[1–3] In response to diverse circumstances brought on by waste water discharge into water bodies that raised concerns for public health,[4] methods of waste water treatment were developed. Waste water treatment uses a variety of physical and chemical qualities, such as turbidity, total dissolved solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen, nitrates, and total phosphates. Utilising percentages of specific indicators, the effectiveness of the sewage treatment plant is assessed.[5] The parameters BOD, COD, and TSS are frequently utilised. The primary goals of traditional waste water treatment planning processes are to minimise capital and operating expenditures.[6]

2. Discussion

STP Design Basis

1. Design Capacity: 100 KLD
2. Operating Hours: 20 Hrs
3. Sewage Source: Residential Apartments
4. Design Technology: SBR (Sequential Batch Reactor)
5. Designed by: M/s. Green Enviro Polestar, Pondicherry

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Table 1: Influent and effluent sewage parameter

Description	Influent Parameter	Effluent Parameter
pH	6.0 – 8.5	6.5 – 7.5
BOD_5 (Biochemical Oxygen Demand)	250 mg/L	< 10 mg/L
COD (Chemical Oxygen Demand)	450 mg/L	< 50.0 mg/L
TSS (Total Suspended Solids)	320 mg/L	< 10.0 mg/L
TKN (Total Kjeldal's Nitrogen)	22 mg/L	< 5.0 mg/L
Temperature	25^0C	-

Table 2: Sewage treatment plant units and equipment

Units available in SBR Scheme	Equipment available in SBR Scheme
Bar Screen Chamber	Raw Sewage Transfer Pumps
Oil & Grease Chamber	Air Blowers
Equalization Tank	Air Diffusers
Anoxic Tank	Decanter System
SBR Tank	Filter Feed Pumps
Decant Tank	Sludge Transfer Pumps
Disinfection & Filtration	Chlorine Dosing system
Treated Water Tank	Pressure Sand Filter
Sludge Holding Tank	Activated Carbon Filter

3. Designing Each Units

3.1. *Design a bar screen chamber*

The raw sewage must first be screened via a manual bar screen to remove any particles larger than 5 mm in diameter as well as floating suspended debris like rags and other materials. These devices are intended to guard against damage and blockage by rags and other big debris in downstream equipment such as pumps, pipes, valves, etc. Gravity transports the clean effluent after screening to the equalization tank.

3.2. *Rectangular or Square horizontal – flow Bar Screen Chamber is provided*

This is designed with a design velocity of 0.3048 m/sec.[7,8]

1. Average flow rate
   (a) (215000 /24)
   (b) 8958 Litres / hour
2. Peak Factor: Peak flow rate shall be thrice the average flow rate
3. So peak flow rate anticipated
   (a) 26875 Litres/hour
   (b) 7.4 Litres/sec
4. Detention time assumed shall be: 60 sec (Advisable is 45 to 90 Sec)
5. Chamber Volume
   (a) 1.7 Litres*60 Sec
   (b) 448 Litres
   (c) 0.448 m^3 (Hence provide a volume of 0.5 m^3)
6. Provide a chamber of size
   (a) Length: 1.00 m
   (b) Breadth: 1.00 m
   (c) Depth: 0.5 M below the Invert Level
   (d) Volume Provided
      i. 1.00 m * 1.00 m * 0.50 m
      ii. 0.50 m^3

3.2.1. *Equalization tank*

The raw wastewater collected in the equalization tank, where it is equalized with respect to its characteristics, homogeneity, flow and uniform pollution load as well as to make bacteria acclimatized. The equalization tank is designed for hydraulic retention time of around 6 hours.[9] Proper equalization process minimizes the shock loadings and stabilizes the pH to improve the biological oxidation reaction in the next downstream units.[7]

1. Plant flow rate: 100 m^3/d
2. HRT (Hydraulic Retention Time): 6 hours to 12 hours (Metcalf Eddy 2004)
3. HRT Considered: 8 hours
4. Provided Tank Volume
   (a) Flow Rate * HRT Considered/24 hours
   (b) 100 m^3/d * 8/24
   (c) 33.33 m^3
5. Designed Tank Volume : 34 m^3

3.3. *SBR tank (Secondary-treatment)*

The process of Oxidation, synthesis and endogenous respiration happens in the SBR tank or aeration tank. Eco-friendly available in the sewage facilitates the above process; hence the complex organic compound gets converted to simpler organic substance. Bacteria or bio augmenter staying in the SBR zone and does the job utilizing the supplied oxygen through Air blowers.[10,11]

1. Plant flow rate: 100 m^3/d
2. BOD Load: 200 mg/l to 350 mg/l (Metcalf Eddy, 2004)
3. BOD Load Considered: 250 mg/l
4. Total BOD Load enters the system
   (a) Flow Rate * BOD/1000
   (b) (100 m^3/d * 250 mg/l) /1000
   (c) 25 Kg/d (BOD considered to be the food for microorganisms)

5. MLSS: 2500 mg/l to 4000 mg/l (Metcalf Eddy, 2004)
6. MLSS Considered: 3500 mg/l
7. MLVSS: 60% to 65% value of the MLSS (6)
    (a) MLSS * 65%
    (b) 3500 mg/l * 65%
8. MLVSS Calculated: 2275 mg/l
9. F/M Ratio Standard: 0.07 to 0.2 (Metcalf Eddy 2004)
10. F/M Ratio: BOD/MLVSS
11. F/M Ratio Calculated: 0.11

3.4. Decant tank

The flow from the SBR tank i.e., the supernatant liquid is let into the decant water tank, which has a minimum 4 hours detention capacity. The decanted water would meet the pressure sand and activated carbon filter units' prerequisites.

1. Flow Capacity : 100 m^3/d
2. HRT Provided : 10 hours
3. Decant Tank Volume
    (a) Flow capacity * HRT Provided/24 hours
    (b) 100 m^3/d * 10 hours/24 hours
    (c) 41.66 m^3
4. Designed Decant Tank Volume : 42 m^3

3.5. Treated water tank

The treated water tank capacity must be provided for no more than 24 hours, as longer treated water retention times make it impossible to maintain the FRC (Free Residual Chlorine) level of 0.5 ppm (parts per million). Foul odour would result from organic growth in the treated water if the FRC level could not be maintained, which is more likely to happen. The standard retention time provided would be 12 hours to 24 hours.[12]

1. Flow Capacity: 100 m^3/d
2. HRT Provided: 12 hours
3. Decant Tank Volume
    (a) Flow capacity * HRT Provided/24 hours
    (b) 100 m^3/d * 12 hours/24 hours
4. Designed Tank Volume: 50 m^3

3.6. Sludge holding tank

The sludge holding tank volume can be provided depending upon the WAS (Waste Activated Sludge) rate.[13] The waste activated sludge can be calculated considering the value of MLSS (Mixed Liquor Suspended Solid) available in the treatment system.

1. Waste Activated Sludge (WAS)
    (a) (Flow * MLSS) / (1% Consistency of MLSS - MLSS)
    (b) (100 m^3/d * 3500 mg/l) / (10000 mg/l – 3500 mg/l)
    (c) 53.84 m^3/d
2. Slurry to be Wasted
    (a) WAS Rate * 10% (10% of slurry volume should be wasted/day)
    (b) 53.84 m^3/d * 10%
    (c) 5.38 m^3/d

4. Designing Electromechanical Equipment

4.1. Raw sewage transfer pumps[8]

The raw sewage transfer pumps could be used to transfer the incoming waste water from the equalisation tank to the SBR zone. These pumps are designed in accordance with the sewage inflow capacity and the size of the solids present in the sewage water.

1. Flow Capacity: 100 m^3/d
2. SBR Number of Batch: 3 Batch (8 hours / batch)
3. Flow per batch
    (a) (100 m^3/d) / 3 batch
    (b) 33.33 m^3/ batch
4. Filling hours
    (a) 1.5 hours (1.15 hours to 2 hours)
5. Raw water Feed Pump Capacity
    (a) Flow per batch / Filling hours
    (b) 33.33 m^3/ 1.5 hours
    (c) 22.22 m^3/hr
6. Designed Pump Capacity
    (a) 24 m^3/hr

4.2. Air blower capacity

The procedure of aerating wastewater is done in order to promote the bio-degradation of the polluting components. Bacteria used in wastewater treatment and stabilisation are given oxygen through aeration. The bacteria require oxygen for biodegradation to take place. In a sewage treatment facility, an air blower's job is to provide high pressure and effective airflow to supply air for the aeration process. Airflow is also known as flow rate. The naturally occurring aerobic bacteria or microorganisms must have access to air in order to treat sewage and wastewater. The BOD (Biochemical Oxygen Demand) load entering the system and the amount of oxygen needed to meet the oxidation needs could be used to design the air blower capacity. The amount of oxygen needed could be twice as much as the system's BOD load. In designing the air blower capacity, additional variables such as the atmosphere's percentage of oxygen, OTE (Oxygen Transfer Efficiency) in waste water, air density, alpha and beta factors, etc., are crucial.[10]

1. Flow Capacity: 100 m^3/d
2. BOD: 250 mg/l
3. Total BOD load
   (a) Flow Capacity * BOD Load
   (b) 100 m^3/d * 250 mg/l
   (c) 25 Kg/d
4. Twice the amount of Oxygen would be required to remove the BOD Load.
5. Hence, the Oxygen required
   (a) Total BOD Load *2
   (b) 25 Kg/d * 2
   (c) 50 Kg/d
6. % of Oxygen in Atmosphere: 21%
7. Oxygen Transfer Efficiency (OTE): 25% (Considered)
8. Density of air: 1.2 Kg/m^3
9. Air required for SBR zone
   (a) (50 Kg/ day) / {(1.2 Kg/m^3) * 0.21 * 0.25 * 0.65 * 0.75 * 24}
   (b) 67.83 m^3/hr.
   (c) 68 m^3/hr.

(Whereas, 1.2 Kg/m^3 is the density of air, 21% will be percentage of oxygen in atmosphere, 25% will be considered as OTE (Oxygen transfer efficiency), 65% is the Alfa factor and 75% was considered as Beta factor).

1. Air required for Equalization:
   (a) Volume * 85%
   (b) 35 m^3 * 85%
   (c) 28.9 m^3/hr
   (d) 30 m^3/hr.
2. Air required for Treated water tank
   (a) Volume * 85%
   (b) 50 m^3 * 85%
   (c) 42.5 m^3/hr.
   (d) 44 m3/hr.
3. Total Air requirement
   (a) SBR Zone + Equalization Tank + Treated Water Tank
   (b) 68 m^3/hr + 30 m^3/hr + 44 m^3/hr
   (c) 142 m^3/hr
4. Designed Air Blower Capacity: 150 m^3/hr

4.3. Filter feed pumps

The waste water that has been cleared or decanted is pumped into the pressure sand and activated carbon filter using feed pumps. Based on the sewage flow rate and the filtration pressure, this might be designed. Between 2 Kg/Cm^2 and 3.5 Kg/Cm^2 may be the filtration pressure.[10]

1. Flow Capacity: 100 m^3/d
2. Hours of Operation: 16 hours (12 hours to 24 hours)
3. Feed flow/hour
   (a) 100 m^3/d / 16 hours
   (b) 6.25 m^3/hr
4. Designed Pump Capacity: 7 m^3/hr

4.4. Sludge transfer pumps

For sludge recirculation and wasting, sludge transfer pumps are used to pump sewage sludge from the decant tank to the equalisation tank and sludge holding tank. Sludge pumps are designed based on the rate of recirculation activated sludge, the rate of waste activated sludge, and the consistency of the sludge. The majority of sludge pumping in treatment plants comprises sludge of varying consistency.

1. Slurry production rate considered
   (a) Flow Capacity * 10%
   (b) 100 m^3/d* 10%
   (c) 10 m^3/d
2. Designed Pump Capacity
   (a) Slurry Production Rate/Operating hours
   (b) 10 m^3/d / 2 hours (Considered)r
   (c) 5 m3/hr

Fig. 1: SBR zone

4.5. Disinfection System

Chlorine disinfection system installed to oxidize the pathogenic bacteria from the treated sewage water and then allowed to pass through the filtration units like PSF and

Fig. 2: PSF & ACF

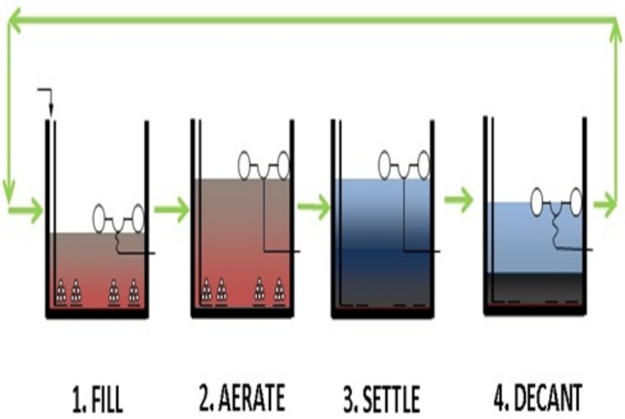

Fig. 3: SBR process stages

ACF. The oxidation process could be carried out with the dosage ranging from 2 mg/l to 3 mg/l online downstream to the decanted water. After the process oxidation the suspended solids or the dead sludge would be filtered through the PSF (Pressure Sand Filter) and excess chlorine will be removed through the ACF (Activated Carbon Filter) to maintain the FRC (Free Residual Chlorine) level at 0.5 mg/l.

4.6. *Pressure sand filter (PSF)*

From the filter feed tank, the clear water is pumped to the pressure sand filter. The filtration takes place in the downward mode. The filter is filled with a layer of graded sand media supported by a layer of graded gravel. The

Fig. 4: STP treated water

suspended matters from the effluent get filtered. The process of filtration can also be improved through dosing chemical coagulants [14] and natural coagulants. Some the natural coagulants such as seed extracts of Moringa olefeira Lam which can help in turbidity and hardness reduction in waste water [15,16] and Strychnos Potatorum Linn which can help in turbidity reduction. [17]

1. Feed Pump Flow Rate: 7 m^3/hr
2. Filtration Velocity: 12 m/hr
3. Filtration Area
   (a) Feed Flow Rate/ Filtration Velocity
   (b) 7 m^3/hr / 12 m//h
   (c) 0.583 m^2
4. Diameter: 0.676 m
5. Filter Diameter provided: 0.8 m (800 mm)

4.7. *Activated Carbon Filter (ACF)*

In this unit the feed flow is downward through a layer of granular activated carbon filter in which dissolved organics of the effluent are absorbed. It is necessary to backwash the carbon filter every eight hours.

1. Feed Pump Flow Rate: 7 m^3/hr
2. Filtration Velocity: 14 m/hr
3. Filtration Area:
   (a) Feed Flow Rate/ Filtration Velocity
   (b) 7 m^3/hr / 14 m//h2
   (c) 0.50 m2
4. Diameter: 0.626 m
5. Filter Diameter provided: 0.8 m (800 mm)

5. Conclusion

The suggested SBR calculations can be used to construct the ideal sewage treatment facility with a 100 KLD capacity. The four-stage SBR system is a batch-operated treatment process. The four steps filling, aeration, settling, and decanting are carried out in three batches of eight hours each. Sequential batch reactor is the finest technology for our communities and corporations in our burgeoning population, since it is a batch process with a suspended growth treatment. SBR systems have minimal operating and maintenance costs, can withstand shock loads, and reduce odour using aerobic microorganisms. The best possible aeration and digestion of organic matter also makes it possible to significantly reduce BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solids), Oil and Grease. The treated water would adhere to the discharge regulations and be suitable for use in gardening or for safe disposal.

6. Source of Funding

None

7. Conflict of Interest

The authors declare no conflict of interest

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