Design of Sewage Treatment Plant with Sequential Batch Reactor for Public Buildings Complex

Shubham M. Dongre[1], Dr. Maya R. Ray[2]

[1] Student, Dept. of Civil Engineering, G.H. Raisoni College of Engineering, Nagpur, Maharashtra, India
[2] Professor, Dept. of Civil Engineering, G.H. Raisoni College of Engineering, Nagpur, Maharashtra, India

---***---

Abstract - *Sequential batch reactor (SBR) is one of the most budding options in the treatment of municipal sewage. SBR operating is in a single tank which operates in time rather than in space. It requires less area to operate easy to function and is economical even in small scales. This research focuses on designing of sewage treatment plant with sequential batch reactor for public building Complex in Shantivan, Chicholi, Nagpur area. The total sewage generated in one-day was estimated to be 100 KLD. The various components of sewage treatment plant are bar screen chamber, equalization tank, SBR tank and treated wastewater collecting tank. By considering the various permissibility limits and various standards of treated sewage water it is proposed to design the many components of wastewater treatment facilities. The treated wastewater will be used for gardening proposes, sludge product which are produced by the treatment procedure can be suggested to be used as fertilizers to increase the fertility of the land this reduces the ground water utilization.*

Key words: *Sequential batch reactor (SBR), municipal sewage, sewage treatment plant, permissibility limits*

1. INTRODUCTION

Sewage treatment plant (STP) assumes a significant job for the humankind. The primary capacity of these plants is to make the water of the sewage clean that originates from home.

Sequential batch reactor (SBR) has acquired a worldwide attention as it can treat various types of effluents such as domestic, Municipal, saline, tannery, brewery, and Dairy wastewater, landfill leachates under various circumstances. Is it require less area to operate easy to function and is economical even in small scales. The extensive working of SBR is based on five steps that is Fill, React, Settle, Decent, and Ideal. The modification process is very simple because of flexible character of the SBR. Dislodge retention time SRT, hydraulic retention time HRT, cycles can be altered and for this reason it provides wide scope for treatment for a single reactor which is the most prominent factor along with the other treatment facilities SBR can be used successfully.

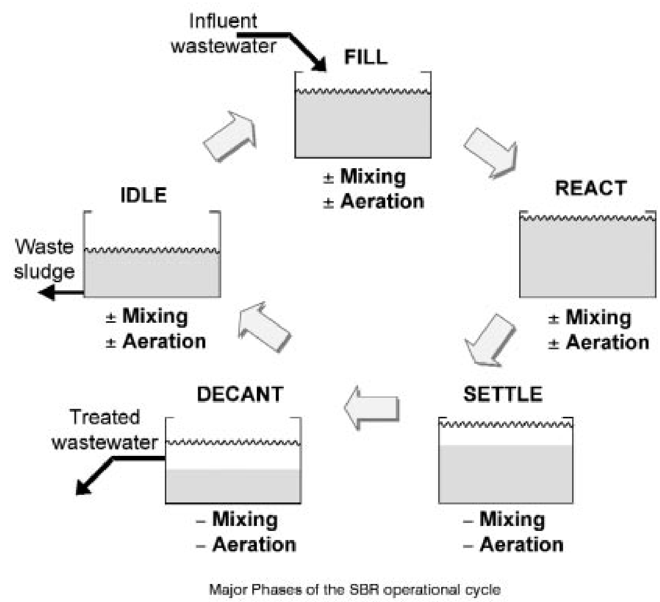

Fig-1: SBR operational cycle with its major phases.

More established wastewater treatment facilities can be retrofitted to a SBR on the grounds that the basins are as of now present. Sewage disposal permits are getting more and much tougher and SBR presents a practical method which accomplishes lower effluent limits. Discharge limits which need more noteworthy level of treatment may require the expansion of a tertiary unit after the SBR treatment stage. This thought ought to be an significant piece of the plan procedure. So it is decided to design a Sewage Treatment Plant(STP) with Sequencing Batch Reactor so that the treated water can be used for gardening purpose and reduce the ground water usage.

2. LITERATURE REVIEW

Lamine (2007) completed investigation of treatment of grey water with the help of SBR.HRTs which was noted was 0.6 no. of days what's more, load variety was for 2.5 no. of days. 90% of organic issue with COD removal can be accomplished by a viably SBR and can expel nutrients and do the biodegradation. The SVI noted was 100 ml/g and that is exceptionally good. The execution of phosphorus removal was diminished. Concentration of ammonium noted was greater in 0.6 days system of HRT while it was smaller influenced in 2.5 days system of HRT. The matter is of concentrate as advancement is essential for HRT which is to be received by a load variety.

Moawada et. al. (2009) researched the ability to treat municipal sewage with a combined method of aerobic and anaerobic treatment forms for example Upflow Anaerobic Sludge Blanket (UASB) trailed by aerobic SBR discharge sewage reasonable for irrigation system. 3 trials was tested, which comprises of 4-3 hours variety to HRT of UASB, 6-12 hours period variation of SBR which comprises of aeration cycle variety from 2 -9 hours. The increment in Hydraulic retention time of a SBR system was useful on Total Nitrogen extraction yet having no impact on Total Phosphorus just as extraction efficiencies of COD and BOD. COD removal efficiency was 84 to 89%, BOD removal efficiency was 90 to 95.9 % and TSS removal efficiency was 85 to 93.9% individually which inferred that utilization of SBR after UASB is a excellent innovation.

3. METHODOLOGY

The target of Sewage treatment plant proposition is to treat sewage and reuse the treated water for Non-basic purposes, along these lines limiting the ground water contamination.

The system is designed dependent on SEQUENCING BATCH REACTOR, (SBR) innovation. A SBR works in a genuine batch reactor with sludge settlement and aeration each happening in a similar tank. A significant contrasts among SBR and traditional activated sludge system with a continuous flow, is that the SBR tank does the elements of aeration, Equalization and sedimentation in a period arrangement except in a conventional space sequence of continuous-flow systems. Subsequently, there is a level of adaptability related to work in a period instead of space succession. Likewise the SBR system gives acceptable outcome even at inflow amount variance. Thus SBR system is proposed for the above venture.

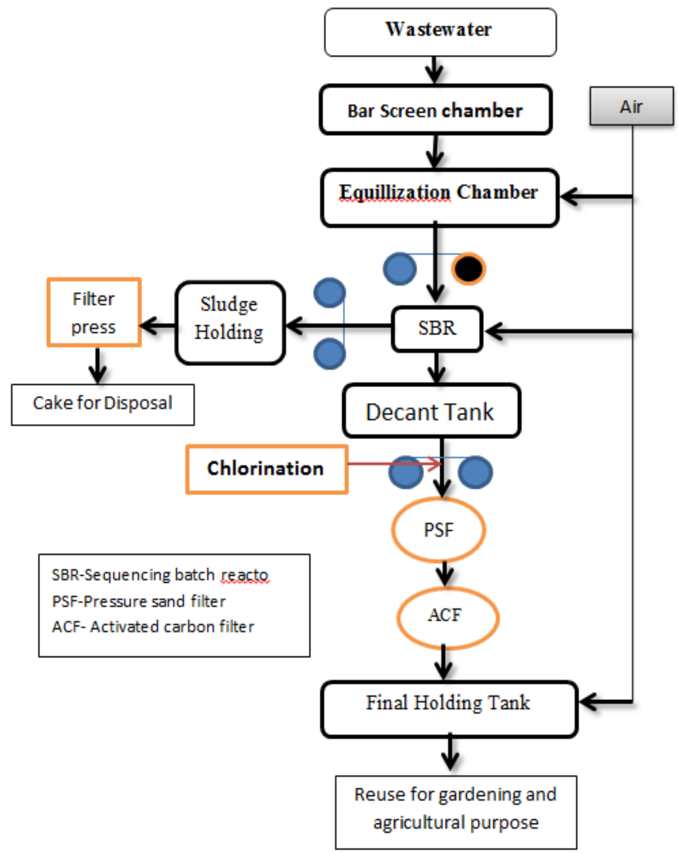

Fig-2: Flow Diagram

4. POINTS TO BE CONSIDERED FOR DESIGN

a) The maximum of generated shall not exceed 100 KLD.
b) The proposed design shall provide sewage treatment plant of 100 KLD capacity which will be consisting of bar screen chamber, equalization tank, SBR tank, treated water holding chamber, tertiary treatment filters and filter press.
c) The wastewater which is shall be utilized for agricultural, flushing, gardening purposes.
d) STP units shall be impervious to prevent underground pollution. It should be constructed in closer kids to avoid odour nuisance.
e) Treated effluent shall be in permissibility limits with inland surface water discharge standards.
f) The treatment unit design should be economical and maintenance easy.

5. DESIGN OF SEWAGE TREATMENT PLANT

5.1. The salient components of the project Layout are as below:

Table-1: Salient features of proposed layout project.

Type of project	Public Buildings
Total land area	56,657.22 sq.m.
Source of Water	Underground water
No of visitors	600-900
Water consumption in KLD	106 KLD
Sewage quantity in KLD	90 KLD
STP proposal With design details	100 LD

5.2. Water consumption details- [3]

Water demand is determined dependent on the rules of NBC. All out quantity of water prerequisite for the proposed project is assessed to be about 106 KLD during the activity stage.
By considering 85 % of the water provided will be changed over in to sewage for example 90 KLD. Wastewater produced from the proposed project will be treated in an STP of 100 KLD.

Amount of water required: 790 X 135 lpcd [3]= 106000 LPD say
= 300 KLD
Amount of wastewater generated: 0.85 X 106 KLD = 90 KLD

5.3. Design wastewater quantity & quality:

The primary & Secondary Treatment units are designed for **100 KLD** flow.

Table-2: The raw effluent & treated effluent quality as per norms.[3]

Expected Parameter	Influent	Treated water
Average BOD	250 to 300 mg/lit	<10 mg/lit
Average COD	400-650 mg/lit	<250 mg/lit
Total suspended solids	250 to 300 mg/lit	<20 mg/lit

5.4. Design of Receiving Bar screen chamber

Design flow = 0.0015 m^3/sec
Assume the detention time = 6 min
Volume of receiving chamber V = 0.0015 (6 x 60)= 0.54 m^3
Chamber size = 1m x 0.6m x 1m
Design of coarse screen :
Velocity through the screen at maximum flow = 0.54 m/s
Bar spacing (clear)= 2.5 cm [6]
Average discharge of wastewater = 0.0015 m/s
Peak discharge of sewage = $Q_{average}$ x peak factor = 0.0015 x3 = 0.0045 m/s
The velocity at average flow not allowed to exceed 0.54 m/s
Vertical projected area of screen, A = Q/V = 0.0045/0.54 = 0.008 m^3
Gross area of screen
Thickness=10mm width= 25mm Clear spacing= 25 mm [6]
Therefore, A= 0.008((25+10)/25) = 0.0112 m^2
The screen is inclined @60^0
Horizontal gross sectional area of the screen = area/ sin(60^0) = 0.0112/ sin(60) = 0.0182
Width of screen = 0.6
Width of screen = (no. of bars x thickness) + (no. of openings x spacing)
0.6 = (n x 0.01) + ((n+1) x 0.025)
n = no. of bars = 16.42 = 17, no. of openings = 18
Assuming depth as 0.9m including free board
Coarse screen is designed for the size of 0.6m x 0.9m
The bar receiving chamber along with screen additionally serves to catch grit and other inorganic materials attributable to its reduced speed which can be cleaned/rejected physically once in a month.

5.5. Equalization tank design.

Equalization tank volume calculation.
Hydraulic retention time(HRT) is general taken as 6 to 8 hours. [4]
Providing Equalization tank of 6 hours of hydraulic retention time
Q maximum = 100 m^3/day
flow rate per hr= 4.167 m^3/hr
Required chamber volume=4.167 x 6 = 25 m^3
effective depth to be provided of 2.5 m
Size of the chamber = 3.5m x 3m x2.5 m SWD+0.5m FB

Equalization chamber air required = 0.5 $m^3$of air/ $m^3$of chamber volume when more than 2 hrs of retention time is to be provided. [5]
= 0.5 x 25 = 12.5 Cu.m /Hr

5.6. Design of SBR Reactor.

1. Organic Load : 100 Cu.m x (300 – 10) x 10^{-3} = 29.0 Kg/Day

2. Calculation of Aeration time
F/M ratio range: 0.1 – 0.18 [4]
Adopt F/M = 0.125

For a SBR F/M ratio shifts from as high as 0.3 to as low as 0.10. Anyway we think about an estimation of 0.20 for design calculations)
Assuming the Total oxygen requirement as 29.0 Kg of O_2/kg of BOD extracted : 29 x 2 = 58 Kg/day
MLSS in the reactor = 4000 mg/L
Hydraulic retention time = BOD (mg/l)/ (MLSS x F/M)
= 58 / (0.2 x 4000) (Assuming 50% decantation)
= 1.74 Hours (Say 2 Hours)
So the cycle time = 1.74(Aeration) + 0.5(Decantation) + 0.5 (Settling) = 2.74 Hours (Say 3 Hours)
Hence designed for 4 batches a day

3. Design of tank [5][7]

- Design Flow = 100 m^3/ day
- BOD = 300 mg / lit
- Volume SBR tank = $\frac{Q \times BOD}{MLSS \times F/M}$
  = (100 x 300) / (0.2 x 4000)
  = 37.5 m^3
- Sludge accumulation provided is 30%
- Total volume of SBR tank provided = 48.75 m^3 (say 50 m^3)
- SWD assumed is 3 m
- plan area = 50/3 = 16.67 m^2

So, provide a Reactor of 50 m^3effective volume + Free board
Size of Tank : 4.2 x 4.0 x 3.0(SWD) + 0.3m F.B.

4. Oxygen Requirement for SBR Reactor
Oxygen requirement = 1.5 x BOD Load = 1.5 x 29/4 = 10.875 Kg/Batch = 11/ 3 = **3.660 Kg/Hr**
[4]
So, Oxygen to be supplied = 3.66 Kg/Hour
Assuming Oxygen transfer efficiency of 3.5 % per meter depth of water column [12]
Total SWD of the reactor = 3.0 m
Overall Efficiency = 3.0 x 3.5 = 10.50 %
Oxygen to be supplied = 3.66 / 0.105 = 34.85 Kg /Hour
Air to be supplied = Oxy. Required /(Density of air x W/W % of Oxy in air)
= 34.85 / (0.23 x 1.4) = 108.22 Cu.m / Hr

5. Total Air required = Air for equalization tank + Air for SBR reactor = 12.5+ 108 = 120.5 Cu.m / Hr
Assuming 80 % efficiency for blower = 120.5 / 0.8
=150.625 Cu.m .Hr
Assuming compression factor of 1.4,
required volume is 150.625 / 1.4 = 107.58 Cu.m / Hr
Provide Blower with a capacity of 150 Cu.m /Hr considering air to be provided in sludge tank.
Considering the requirement for Sludge digestion and efficiency factor provide 200 Cu.m /Hr capacity blower.

5.7. Decant Tank Design.

- Average flow = 4.167 m^3/hr
- Providing holding capacity of 4 hours
- Tank required Volume = 16.67 m^3
- SWD provided is 2.5 m
- **Final collection size of tank is 2.5m x 3m x 2.5m SWD+0.3 m FB**

5.8. Tertiary Treatment

A. Chlorination

There is no filter before chlorination. The supernatant from the SBR Reactor is emptied by gravity and is straightforwardly taken care of into the chlorine contact tank. The tapped treated water will have under 20 mg/L of TSS and this will be taken consideration by the sand filter. Thus we don't give any filter before chlorination.
We don't suggest sand filtration before any disinfection procedure as this permits development of microscopic organisms, parasites and green growth (diverted from Reactor) in the sand filter. Besides giving on the web chlorination after sand filter and before carbon filter doesn't give satisfactory contact time to disinfection.

Dosage required for 3 log reduction for Secondary treated effluent = 3 – 6 mg/L [5]
Adopt 4 mg/L of chlorine
Required Dosage = 4 x 100 = 400 gm / Day
Sodium hypo chlorite to be used as a source of chlorine @ 6.5 % available chlorine.
= 400 / 0.065 = 6.2 Kg of Sod. Hypo chlorite solution / Day
Say 6.516 Lit of Sod hypo chlorite / Batch

B. Pressure Sand Filter

Assuming 20 Hours of operation in a day average flow rate = 5 Cu.m / H
Considering one PSF with the period of filteration of 20 hrs / day
Flow rate = 100/20 = 5 m^3/hour
Filter type = Vertical type sand filter
Rate of Filtrations = 120 lit/m^2.min[5]
=0.120 x 60 m^3/m^2.hr =7.2 m^3/m^2.hour
Cross section area of Filter = 5/7.2 = 0.694 m^2
Filter dia. = 0.9 m
Provide Filter size= 0.9 m dia. x 1.5 m ht – 1 nos

C. Activated Sand Filter

Considering one ACF with the period of filteration of 20 hrs / day
Flow rate = 100/20 = 5 m^3/hr
Filter type = Vertical type

Rate of Filtrations = 120 lit/m^2.min[5]
=0.120 x 60 m^3/m^2.hr =7.2 m^3/m^2.hr
Cross section area of Filter = 5/7.2 = 0.694 m^2
Filter dia. = 0.9 m
Provide Filter size= 0.9 m dia. x 1.5 m ht – 1 nos

5.9. Sludge Calculation for design of filter press.

Reduction of BOD in aeration tank = 300 – 10= 290 mg/L
Net yield considering average age of sludge of 20 days 25%
Therefore, sludge production = 0.280 kg/Cum x1000 cu.m/Day x 0.25 =7 Kg/day of secondary sludge
Contribution of Sludge by TSS = 0.5 x 350 g/Cu.m x 100 Cu.m/Day = 17.5 Kg / day on dry basis
Total Produced sludge = 7+17.5 = 24.5 Kg , Say 25 Kg.
Sludge is drawn from the SBR reactor at the end of settling at 1% concentration. So the volume of produced sludge
= 25/0.01 = 2500 Lit or 2.5 Cum./ Day
The excess sludge generated is dried from the above treatment, filter press is used for sludge de-watering. The filtrate will be connected with the screen chamber.

Assuming the type of sludge	: Organic
Designed sludge flow	: 2500 ltrs/day
Solids concentration	: 1%
Solids specific gravity	: 1.2
Dry solids minimum to be allowed in the cake of sludge	: 25-30 %

Sludge solids generated on daily basis
Generation rate : 2500 x 1.2 x 0.01 =30 kgs/ day
Quantity of Sludge load on filter : 30 x 3 (three days of operation per week) = 90 kgs/day
Assuming sludge holding capacity as 40 kgs/m^2
The size of the filter press required = 90/40 =2.25 m^2
Size of each plate taken will be (0.6 x 0.6 m) = 0.36 sq.m.
No. of chambers required = 2.25/0.36 = 6.25 nos
However**, provide 8 chambers with 30mm of spacing and filter press of 0.6m x 0.6m.**
Consider 50 kg sludge production per day, and at 30 % solids in sludge cake the volume of sludge cake = 25/0.3 = 83 Lit
Henceforth the filter press given is satisfactory.

5.10. FINAL COLLECTION TANK

- Average flow = 4.167 m^3/hr
- Provide 6 hour of capacity of holding
- Tank vol. required= 25 m^3
- Providing SWD 2.5 m
- **Size of Final collection tank is 3.5m X 3m X 2.5m SWD+0.3 m FB**

5.11. Pumps

A. Providing 2 Nos. sewage transfer pumps (one working and one standby)
Capacity : 5.0 KLH @ 15 m head
Type : Centrifugal pumps
Solid handling capacity : Up to 10 mm
Purpose : To pump the sewage from the Equalization tank to SBR tank.

B. Provide 1 No. Sludge Transfer pump
Capacity : 3 KLH/hr @ 15 m head
Type : Centrifugal pumps
Solid handling capacity : Up to 25 mm
Purpose: To pump the sludge from the SBR tank to the Sludge holding tank

C. Provide 2 Nos Filter feed pumps
Capacity : 5.0 KLH @ 30 m head
Type : Centrifugal pumps,
Solid handling capacity : Up to 5 mm
Purpose : To pump the treated effluent from the Pre-filtration tank through both the tertiary treatment filters.

6. CONCLUSION

Wastewater generated is proposed to be treated by 100 KLD Sewage Treatment Plant. The treatment is to be carried out by Sequencing Batch Reactor (SBR) technology which is nothing but a modified type of activated sludge treatment process. In a SBR a number of sequencing batch reactors are provided to treat the wastewater in batches. SBR will oxidize the biological oxygen demand (BOD), it will nitrify the ammonia and denitrify the reduced total nitrogen to a permissible limit. The water treated from the Sequencing Batch Reactor tank is first disinfected with chlorine as this would not permit the development of microscopic organisms, parasites and green growth (diverted from reactor) in the sand filter. Then it is pumped through both the tertiary filters which removes the suspended solids and colour. The treated water can be used for gardening and flushing proposes. Excess of sludge from SBR is sent to filter press for dewatering and can be used as manure.

Table-3: Treatment units and its sizes

S. No	Name of the unit	Size in m
1	Bar screen chamber	1.0m×0.6m×1m
2	Equalization tank	3.5m×3m×2.5m
3	Sequencing Batch Reactor (SBR)	4.2m×4.0m×3.0m
4	Decant tank	2.5m×3.0m×2.5m
5	Final Collection tank	3.5m×3.0m×2.5m
6	Sand bed filters	0.9m dia. and 1.5mm height
7	Activated carbon filter	0.9m dia. and 1.5m height
8	Filter Press	8 chambers with 30mm spacing, plate size of 0.6m x 0.6m

7. REFERENCES

[1] Lamine M., Bousselmi L., Ghrabi A., Biological treatment of grey water using sequencing batch reactor. Desalination 215-127–132, (2007).

[2] Moawada A., Mahmouda U.F., El-Khateebb M.A. , El-Mollaa E., Coupling of sequencing batch reactor and UASB reactor for domestic wastewater treatment, Desalination Vol. 242 pp. 325–335, (2009).

[3] Indian Standard- CODE OF BASIC REQUIREMENT FOR WATER SUPPLY DRAINAGE AND SANITATION (4th revision), 1172: 1993

[4] Ministry of Housing and Urban Affairs, Government of India, CPHEEO manual on "Sewerage and Sewage Treatment Systems"- 2013

[5] Metcalf & Eddy, 'Wastewater Engineering: Treatment and Reuse', Tata McGraw Hill: 4th edition; 2012.

[6] Department Of Environmental Protection Bureau Of Point And Nonpoint Source Management, 'Design Standards for Sequencing Batch Reactors', pp. 385-2188-003.

[7] New England Interstate Water Pollution Control Commission, 'Sequencing Batch Reactor Design And Operational Considerations', 2005.

[8] Keller, J., Watts, S., Battye-Smith, W., and Chong. R., "Full-Scale Demonstration Of Biological Nutrient Removal In A Single Tank SBR Process" Proceedings of the 2nd International symposium of International Water Association (IWA) on Sequencing Batch Reactor Technology, 10-12, July, Narbonne, France, pp 380-388, 2000.

[9] Lin S.H., Cheng K.W., "A New Sequencing Batch Reactor For Treatment Of Municipal Sewage Wastewater For Agricultural Reuse". Desalination Vol.133, pp. 41-51, 2001.

[10] Klimiuk E., Kulikowska D., "The Influence of Hydraulic Retention Time and Sludge Age on the Kinetics of Nitrogen Removal from Leachate in SBR". Polish J. Environ. Stud. Vol. 15(2), pp. 283-289, 2006.

[11] Ng, W. J. and Chin, K. K., "Biological Treatment for Pig Farm Wastewater". Proceedings of the Regional Symposium on Management of Industrial wastes in the Asia & Pacific, ENSEARCH, Kualalumpur, Malaysia, 17-18 November, pp 123-127. 1986.

[12] Kulikowska Dorota , Klimiuk Ewa , Drzewicki A., "BOD5 and COD Removal And Sludge Production In SBR Working With Or Without Anoxic Phase". Bioresource Technology Vol. 98, pp. 1426–1432,2007.

[13] Source:http://www.mmaqua.com/airmax-diffuser.htm