Design of MBBR Based Sewage Treatment Plant for an Educational Campus

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Abstract: ***Waste water reclamation is the treatment or processing of waste water to make it reusable. In educational campuses where the demand for water is huge, it is highly feasible to adopt a system of waste water recycling for purposes like toilet flushing, gardening/agriculture and for maintenance of landscape, since these are usages with low physical contact. Among the available technologies for waste water treatment, MBBR based sewage treatment is most suitable. This paper demonstrates the detailed procedure for the design of a MBBR based sewage treatment plant of 530 KLD capacity for an educational campus.***

Keywords: Sewage treatment, MBBR, Educational campus

1. Introduction

In many locations where the available supply of fresh water has become inadequate to meet water needs, it is clear that the once-used water collected from communities and municipalities must be viewed not as a waste to be disposed of but as a resource that must be reused [1]. Waste water reclamation is the treatment or processing of waste water to make it reusable, and water reuse is the use of treated waste water for beneficial purposes such as agricultural irrigation and industrial cooling [2]. The cost of treating 1 KLD (Kilo-Litre per Day) of sewage is about 18 to 20 INR (Indian Rupees), while the cost of treated water lies between 40 – 60 INR, thereby posing a profitable option for most citizens prospectively treating their own water, and fostering a positive response from a possibly participatory public [3]. Therefore, we must establish technology to recover or remediate contaminated water for reuse in energy and food production as well as to become more efficient in its use. [4]

2. Waste Water Treatment Technologies

One of the most challenging aspects of a sustainable sewage treatment system design (either centralized or decentralized) is the analysis and selection of the treatment processes and technologies capable of meeting the requirements. The process is to be selected based on required quality of treated water. While treatment costs are important, other factors should also be given due consideration. For instance, effluent quality, process complexity, process reliability, environmental issues and land requirements should be evaluated and weighted against cost considerations [5]. The following are the technologies used in sewage treatment.

- Activated Sludge Process (ASP)
- Moving Bed Bio-film Reactor (MBBR)
- Sequencing Batch Reactor (SBR)
- Up-flow Anaerobic Sludge Blanket (UASB)
- Membrane Bio Reactor (MBR)

Among these, MBBR technology is found suitable where the availability of land area, capital investment and skilled manpower for operation and maintenance are scarce [6].

3. MBBR – An Overview

Moving Bed Bio-film Reactor (MBBR) is gaining importance around the world. It is a leading technology in waste water treatment as this system can operate at smaller footprints and give higher removal efficiency [7]. It is compact, efficient and effective option for domestic waste water treatment [8]. In properly designed MBBR, the whole reactor volume is active, with no dead space or short circuiting [9].

MBBR is an aerobic attached biological growth process. It does not require primary clarifier and sludge recirculation. Raw sewage, after screening and degritting, is fed to the biological reactor. In the reactor, floating plastic media is provided which remains in suspension. Biological mass is generated on the surface of the media. Attached biological mass consumes organic matter for their metabolism. Excess biological mass leaves the surface of media and it is settled in clarifier. Usually a detention time of 5 to 12 h is provided in the reactors [5]. The following are the merits and demerits of the process.

Merits

- Moving Bed Bio-film Reactor needs less space since there is no primary clarifier and detention period in reactor is generally 4 to 5 h.
- Ability to maintain a continuous flow since the backwash requirements is eliminated
- Ability to withstand shock load with equalization tank option
- Demand less operator intervention
- It is versatile, since it is suitable to retrofit into the existing tanks

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Demerits

- High operating cost due to large power requirements
- Not much experience available with larger capacity plants (>1.5 MLD)
- No energy production

A Schematic Diagram showing various components of MBBR based STP is shown in Fig.1

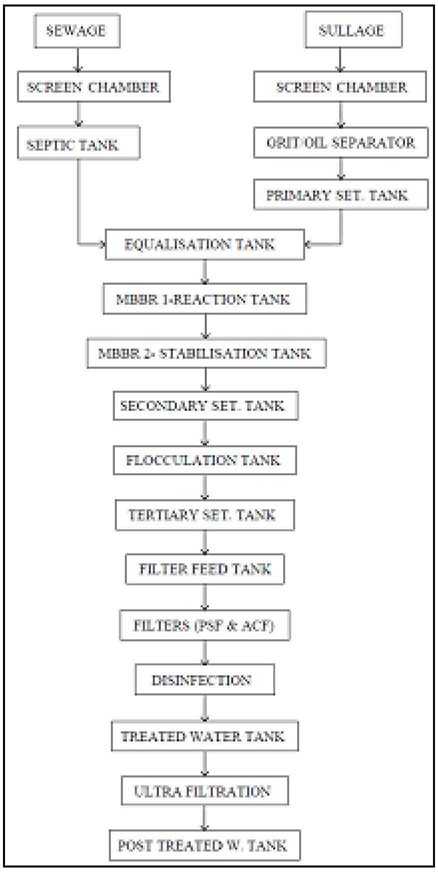

Figure 1: Schematic diagram of MBBR

4. Study Area

The study was conducted in an educational campus situated in the district of Kozhikode in Kerala, India. 'Jamiyyat Da'wa Tablighul Islam, better known as JDT Islam is a charitable, cosmopolitan educational campus established in the year 1922 spreads over an area of 20 Acres. The campus houses 26 institutions from primary school to professional colleges with a total population (including 1000 residents) of 12000. The recent past has seen the campus facing water scarcity especially during the summer months. Because of the shortage of ground water, the campus is heavily depended on the municipal water supply. The campus has a floating population of 11000 (daily commuters) which is more than 90% of the total population. The per capita demand of water for the floating population is 45 lpcd, while that of the residents is 135 lpcd [10] . Of the total water demand, the water usage for toilet flushing, gardening/agriculture and for maintenance of landscape constitute more than 65% of the total water demand. It is possible to recycle or reuse the waste water for these purposes, since there is low physical contact. In the case of JDT Campus, it is highly feasible to have such a system of recycling or reusing the waste water.

5. Design Data

For various requirements in the campus (institutional and residential), the total quantity of water is estimated to be 613 KLD. Assuming that 85 % of the water supplied would be converted into sewage and sullage , the quantity of waste water was estimated as 530 KLD. It was proposed to have a STP adopting MBBR technology in which, the sewage generated during the operation phase would be treated up to the tertiary level and the entire treated waste water (100%) from STP would be recycled/ reused for toilet flushing, agricultural and gardening purposes in the entire Campus. The following parameters were considered for the design:
i) Average Hourly Flow Rate (AHF),
ii) Peaking Factor (PF) and iii) Retention Time (RT).

Total waste Water Generated = 530 KLD
Quantity of sewage (40%) = 212 KLD
Quantity of sullage (60%) = 318 KLD

6. Design of MBBR Based STP

The design of MBBR STP of capacity 530 KLD with its components was executed as given below [1,11].

6.1 Screen Chamber

The Screen Chamber is the first unit to screen the solid particles above a certain size; such as plastic cups, paper dishes, polythene bags, sanitary napkins etc.

6.1.1 Screen Chamber for Sewage

(i) AHF of sewage=212/20hrs=10.6 m^3/hr
(ii) PF (Peaking Factor) = 2.5, RT = 7.5 min.
Max flow or peak flow through screen = AHF x PF
= 10.6 m^3 /hr x 2.5 = 26.5 m^3 /hr = 0.44 m^3 /min.
(iii) RT = Volume of the chamber /Flow Rate in minutes
Hence, Volume of Chamber = RT x Flow rate in minute
= 7.5 x 0.44 = 3.3 m^3
Assuming depth of wall as 0.75 and L/B ratio of 2:1,
Size of sewage screen chamber = 1.50 x 3.00 x 0.75 m

6.1.2 Screen Chamber for Sullage

(i) AHF of sullage=318/20 hrs = 15.9m^3/hr
(ii) PF = 2.5, RT = 7.5 min.
Max flow or peak flow through screen = 0.66 m^3 /min
(iii) Volume of Chamber = 7.5 x 0.66 = 4.95 m^3
Assuming depth of wall 0.75m and L/B ratio of 2:1,
Size of sullage screen chamber = 1.85 x 3.65 x 0.75 m.

6.2 Septic Tank

The septic tank is a large-volume, watertight tank provided for the initial treatment of waste water by intercepting solids and settleable organic matter. This cause reduction and decomposition of accumulated solids, provide storage for the separated solids (sludge and scum) and allow the clarified waste water to flow out of the chamber.

(i) AHF rate of Septic Tank = 212 /20 hr = 10.6 m^3 / hr
(ii) RT of 1 day (Take 20 hrs.)
(iii) Volume of Septic Tank = 10.6 x 20 = 212 m^3
Assume depth 3 m and L/B ratio of 3:4,
Size of Septic tank = 9.70 x 7.30 x 3.00 m

6.3 Oil Separator

The Oil Separator is used to separate solid and fatty matter at source from the waste water before it is taken to the equalization tank.

(i) AHF of OS = 318 / 20 hr = 15.9 m^3 /hr
(ii) RT = 30 min., PF = 2.5,
Peak flow = 15.9 x 2.5 = 39.75 m^3/hr = 0.66 m^3 /min.
(iii) Volume of OS= 30 x 0.66 = 19.875 m^3
Assuming a depth of 1.25 m and L/B Ratio as 2 : 1,
Size of OS Tank = 5.65 x 2.85 x 1.25 m

6.4 Primary Settling Tank

After grit removal in grit chamber, the wastewater containing mainly floating and settleable materials found in waste water is settled in the primary settling tank (PST).

(i) Surface Loading for PST = 0.3 m^3/ m^2 / hr
(ii) AHF for sullage = 15.9 m^3 /hr
Area = AHF / Surface loading **=** 15.9/0.3 = 53 m^2
(iii) Assuming a L/B Ratio of 2 : 1,
base dimension of the tank = 10.3 m x 5.2 m
Required depth of the tank is to be computed based on the following conditions:
Tank to be designed with a cone at the bottom to facilitate settling, with angle of inclination of the slope between 30^0 - 60^0; max. height of cone as 2m;
height of rectangular portion at the top as 1m.
With trial and error method, it was found that two tanks would be required instead of one.
With height of cone as 2m, and angle of inclination of 35^0, Size of one conical chamber was computed as 5.5 x 5.5 x 2
Volume of conical chamber = 5.5 x 5.5 x 2/3
= 20.17m^3
Volume of Rectangular portion = 5.5 x 5.5 x 1.0
= 30.25 m^3
Total volume available = 2 (20.17+30.25) = 100.1 m^3
Considering 4 hrs retention period,
Volume required = (530/ 20) x 4 = 106 m^3
Volume available approx equal to volume required.
Dimension of PST = 11.00 x 5.50 x 3.00 m

6.5 Equalization Tank

The equalization tank is the first collection tank in an STP. Its main function is to act as a buffer to collect raw sewage that is coming at widely fluctuating rates, before it is passed on to the rest of the STP at a steady flow rate.

(i) AHF = 530 / 20 hrs = 26.5 m^3 / hr
(ii) RT of 12 hours,
(iii) Volume for ET = 26.5 x 12 hr = 318 m^3
Assuming Square section and 3m height
Dimension for ET = 10.30 x 10.30 x 3.00 m.

6.6 Aeration tank

Aeration tank is the heart of aerobic treatment system. The main function of the aeration tank is to maintain a high population level of microbes. The mixed liquor is passed to the clarifier tank, where the microbes are allowed to settle at the bottom.

(i) Organic Loading rate = 1.2 kg/ m^3 / day
Assuming a BOD of 350 mg/litre = 350 x 10^{-6} kg/litre
BOD in 530 KLD = 530 x 1000 x 350 x 10^{-6}
= 185.5 kg/m^3/day
(ii) Volume of AT = 185.5 / 1.2 = 155 m^3
Assuming the Media Filling Factor = 0.5,
Media Volume = 155 x 0.5 = 77.5 m^3
Required Number of Tanks = 2 Nos
(MBBR 1- Reaction Tank, MBBR 2- Stabilization Tank)
Assuming Square section and 3m height
Dimension of AT = 7.20 x 7.20 x 3.00 m

6.7 Secondary Settling Tank

The function of the secondary clarifier is threefold:
To allow settling of biomass solids in the Mixed Liquor coming out of the aeration tank, to thicken the settled biomass in order to produce a thick underflow and to produce clear supernatant water in the overflow from the clarifier. All the above actions occur due to gravity.

(i) Surface Loading Rate for SST = 0.5 m^3 /m^2 /hr
(ii) AHF for total waste water = 530 / 20 = 26.5 m^3 /hr
Area = AHF / Surface Loading = 26.5 / 0.5 = 53.5 m^2
(iii) Assuming a L/B Ratio 2:1 and height = 3 m with 1m rectangular portion at the top and 2 m, conical portion at bottom with 35^0 inclination.
The design procedure is similar to the one presented in Section 6.4
Dimension of SST = 11.00 x 5.50 x 3.00 m

6.8 Flocculation Tank

Flocculation refers to the process by which fine particulates are caused to clump together into a floc. The floc may then float to the top of the liquid (creaming), settle to the bottom of the liquid (sedimentation), or be readily filtered from the liquid.

(i) AHF = 26.5 m^3 /hr = 0.44 m^3/min
(ii) RT = 5 Minutes
Length of Flocculation Tank = Width of Settling Tank
Length of Flocculation Tank = 5.2 m
Assuming the height of Flocculation tank to be 0.75 m
(iii) Volume of FT = 0.44 m^3 /min x 5 min = 2.2 m^3
Dimension of FT =5.50 x 0.60 x 0.75 m

6.9 Tertiary Settling Tank

When the intended receiving water is highly vulnerable to pollution, secondary effluent should be treated further by tertiary process. The design procedure is similar to the one presented in Section 6.7.

Dimension of TST = 11.00 x 5.50 x 3.00 m

6.10 Chlorine Dosage

The filtered water from the tertiary settling tank should be chlorinated before it is fed into the filter feed tank. Assuming a chlorine dosage of 30 ppm,
Amount of chlorine required to disinfect 26500 litre/hr
= 26500 x 30 = 795000 mg /hr
Amount of chlorine solution required = 795000 mg /hr
= 795000/150000 = 5.3 litres/hr

Chlorine dosage per day = 5.3 x 20 = 106 litres/day

6.11 Filter Feed Tank

Filter Feed Tank is required to collect the water from the tertiary settling tank before it is fed to PSF and ACF.

(i) AHF = 26.5 m^3 /hr
(ii) RT = 8 hrs
(iii) Volume of filter feed tank = 26.5 x 8= 212 m^3

Assuming a height of 3m and a square plan,

Dimension of FFT = 8.50 x 8.50 x 3.00 m

6.12 Pressure Sand Filter

The pressure sand filter (PSF) is used as a tertiary treatment unit to trap the trace amounts of solids which escape the clarifier, and can typically handle up to 50 mg/l of solids in an economical manner. This is essentially a pressure vessel filled with graded media (sand and gravel).
1) AHF = 530/20 = 26.5 m^3 /hr
2) Specific flow rate of the filter = 12.50 m^3/hr /m^2
3) Area = 26.5 m^3/hr /(12.5 m^3/hr /m^2) = 2.12 m^2
Considering Circular dimension for the tank
Diameter of the tank = 1.6 m
Assuming total depth of PSF = 2.25
(Filter media depth of 1.5m + 0.75 m for expansion)

Dimension of PSF = 2.25 m Height with 1.6 m ϕ

6.13 Activated Carbon Filter

An activated carbon filter (ACF), like the pressure sand filter, is a tertiary treatment unit. It receives the water from the Pressure Sand Filter and improves multiple quality parameters of the water like BOD, COD, clarity (turbidity), color and odor. Ref 6.12

Dimension of ACF = 2.25 m Height with 1.6 m ϕ

6.14 Treated water Tank

Treated Water Tank is used to collect the treated water after ultra filtration. The design procedure is similar to the one presented in Section 6.11.

Dimension of TWT = 8.50 m x 8.50 m x 3.00 m

6.15 Ultra filtration

Ultra filtration (UF) is a pressure-driven barrier to suspended solids, bacteria, viruses, endotoxins and other pathogens in order to produce water with very high purity and low silt density. Ultra filtration (UF) is a variety of membrane filtration in which hydrostatic pressure forces a liquid against a semi permeable membrane. Ultra filtration process is done with respect to membrane specification. Based on the efficiency of removal, low-pressure difference and lesser area requirement, a membrane of PENTAIR of size 8" diameter x 54 cm was selected as module.

Assuming the operating pressure of membrane as
2 kg/cm^2 and back wash of 3 kg /cm^2,
AHF = 26.5 m^3/hr
Taking the efficiency of module as 2m^3/hr,
Number of Membrane Module required for filtration
= 26.5/2 = 13.35 = 14

Number of Membrane Module required = 14

6.16 Post Treated Water Tank / Roof Top Tank

Post Treated Water Tank (PTWT) is required to collect the post-treated water. The volume of Post Treated water tank and the Roof Top Tank (RTT) are same. The design procedure is similar to the one presented in Section 6.11.

Dimension of PTWT & RTT = 8.50 m x 8.50 m x 3.00 m

6.17 Blower air Requirement

BOD loading = 185.5 kg / day
Oxygen Uptake Ratio = 1.25 kg of oxygen /kg of BOD
Oxygen required for 185.5 kg of BOD = 185.5 x 1.25 = 231.875 kg
Percentage of oxygen in air = 22.5 % = 0.225
Weight of oxygen required = 231.875 / 0.225 = 1030 kg
i.e., 1030 Kg of air is required to treat BOD of 185.5 kg
Density of air = 1.225 kg /m^3
Volume of air = 1030 /1.225 = 840 m^3 /day
Air transfuse efficiency of diffuser = 7.5 %= 0.075
Quantity of air required = 840 / 0.075 =11200 m^3/day
Factor of safety 50% =11200m^3/day x 1.5 =16800m^3/day
Volume of air required /hr = 16800/20 hr = 840 m^3 /hr
Volume of Equalization Tank = 318.00 m^3
Volume of Flocculation Tank = 2.20 m^3
Total Volume = 320.20 m^3
Air required for Equalization = 1.5 m^3 / m^3 / hr
Volume of air required = 320 x 1.5 = 480 m^3 /hr
Total Air required = Air required for BOD digestion + Air required for Equalization= 840 + 480 = 1320 m^3 /hr
Therefore,

Capacity of blower = 1320 m^3 /hr

7. Design Dimensions

The following table (Table 1) gives the summary of all the components of the MBBR based Sewage Treatment Plant and their respective dimension for ready reference.

Table 1: Summary of Designed Components

Important Units of Sewage Treatment Plant		
Sl No	Name of Unit	Size in Metres
1(a)	Sewage Screen Chamber	1.50 x 3.00 x 0.75
1(b)	Sullage Screen Chamber	1.85 x 0.65 x 0.75
2	Septic Tank	9.70 x 7.30 x 3.00
3	Oil Separator	5.65 x 2.85 x 1.25
4	Primary Settling Tank	11.00 x 5.50 x 3.00
5	Equalization Tank	10.30 x 10.30 x 3.00
6	Aeration Tank (MBBR)	7.20 x 7.20 x 3.00
7	Secondary Settling Tank	11.00 x 5.50 x 3.00
8	Flocculation Tank	5.50 x 0.60 x 0.75
9	Tertiary Settling Tank	11.00 x 5.50 x 3.00
10	Chlorine Dosage	106 Liter / Day
11	Filter Feed Tank	8.50 x 8.50 x 3.00
12	Pressure Sand Filter	1.6 Dia x 2.25 Ht.
13	Activated Carbon Filter	1.6 Dia x 2.25 Ht.
14	Treated Water Tank	8.50 x 8.50 x 3.00
15	Ultra Filtration	14 Modules
16	PTWT & RTT	8.50 x 8.50 x 3.00
17	Blower Requirement	Discharge 1320 m^3/hr

8. Conclusion

In the present scenario, where the availability of fresh water is becoming increasingly scarce, it is essential that waste water treatment technologies are to be resorted to. Waste water should be effectively reused for non-potable purposes like toilet flushing, landscaping, gardening etc. The educational campuses, where the future citizens are moulded, should come forward to adopt these technologies so that this would become a model for the future generation and for the society as a whole.

Through this paper, the detailed procedure for the design of a MBBR based sewage treatment plant of 530 KLD capacity for an educational campus is demonstrated. It is hoped that this would act as a reference for the designers as well as the stakeholders in educational campuses to adopt this or similar technologies.

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