Design of Waste Water Treatment Plant Based on Bio-Filtration Recirculation Reactor (BRR) Technology

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Abstract: This study includes design of waste water treatment plant based on BRR technology for setting up at college campus i.e. Samrat Ashok Technological Institute (SATI), Vidisha (M.P.). As we know, waste water generation is a serious issue at present time in India. There are no proper disposal or treatment facilities for waste water. The treatment plant for the college campus will be designed for 4000 users. After collecting data and conducting a field survey, the water demand of the college campus is calculated to be 0.54 MLD @ 135 LPCD. According to CPHEEO norms and guidelines, approximately 80 % of it will generate wastewater i.e. 0.43 MLD (430 KLD). And add 10 % infiltration of rainwater so demand will come to about 0.475 MLD Hence, a treatment plant is proposed so that generated wastewater can safely be used in the maintenance of lawns & plantation in the campus. Various treatment technologies have been reviewed and studied thoroughly before finalizing the Bio-Filtration with Recirculating Reactor (BRR) Technology-based treatment plant for the campus. This technology is economical for small waste water treatment plants.

***Keywords* – Bio-Filtration Recirculation, BRR, Design of WTP with BRR.**

I. Introduction

Waste water generation is a serious problem that is increasing day-by-day due to lack of awareness and responsibility among people. Water sources are getting polluted due to rapid increase in urbanization and industrialization. Waste water generation leads to water pollution which is the most significant environmental problem and threat to public health in both rural and urban India is inadequate access to clean drinking water and sanitation facilities. Almost all the surface water sources are contaminated to some extent by organic pollutants and bacterial contamination which makes them unfit for human consumption. There are various diseases such as typhoid, cholera, bacterial dysentery, amoebic dysentery, hepatitis etc. that are caused due to consumption of contaminated water. In India, waste water is generated from three main sources i.e. domestic sewage, industrial effluents and run-off from agriculture.

It is estimated that 22,900 million litres per day (MLD) of domestic wastewater is generated from urban centres against 13,500 MLD industrial wastewater. The treatment capacity available for domestic wastewater is only for 5,900 MLD, against 8,000 MLD of industrial wastewater. Thus, there is a big gap in treatment of domestic wastewater. Govt. of India is assisting the local bodies to establish sewage treatment plants. It is estimated that the total cost for establishing treatment system for the entire domestic wastewater would be around Rs. 7,560 crores. Operation & maintenance cost would be in addition to this cost. Similarly, there is a gap in treatment of about 5,500 MLD of industrial wastewater, mainly generated from small-scale industries. Establishing effluent treatment systems in small-scale industries is a problem, since a large number Domestic human waste includes human excreta, urine and the associated sludge (collectively known as black water), and wastewater generated through bathing and kitchen (collectively known as grey water). In 1950, the average daily output of human waste (i.e. excrement and urine) was estimated to be 3.2 million tonnes; in the year 2000, the estimated daily output was 8.5 million tonnes. 2 of them are located in residential areas, where space is a constraint.

II. METHODOLOGY

The study conducted at Samrat Ashok Technological Institute, Vidisha (M.P.). The coordinate of the site are 23° 31' 15.4704" N, 77° 49' 12.6336" E. The proposed treatment plant is of 0.43 MLD capacity. The recommended treatment scheme for sewage is primarily based on Biological-Filtration with Re-circulating Reactors (BRR) Technology. This technology utilizes the living material to size and biologically degrade the polluting agents. The solution is also called an Air Intermittent Re-circulating Reactor owing to its highly scientific process that is carefully managed to achieve the desired results. The patented and low cost-highly efficient technology is biological treatment of effluent by controlling biological/bacterial activities in three process (Aerobic, Anaerobic and Anoxic Process). The design of the system eliminates the need of chemicals while minimizing odour from the treatment process. The technology is best suited for open drain sewage and mixed sewage from habitats. It can also be connected directly to the septic tank or embrace the overflow.

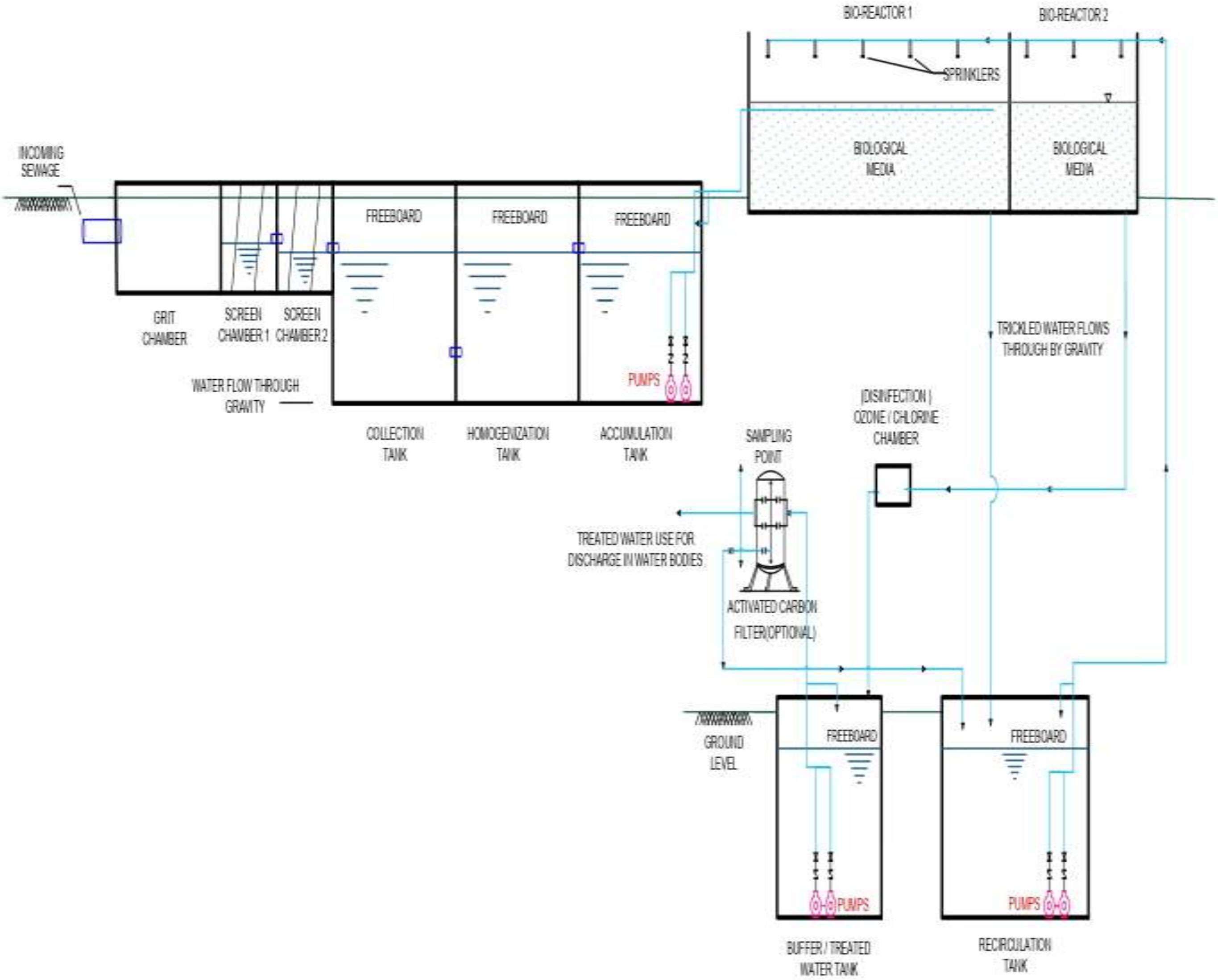
The treated water from the system and process meets all international standards and requirements. BRR Technology does not require lagoons and no sludge is generated from the core process; hence completely eliminating the odour causing sludge from the process. The added advantage of BRR Technology is scalability and modularity; scaling up as per requirement, it can size up and can treat sewage from 100 KLD up to 10 MLD of wastewater per day. It is ideal for treating mixed sewage from open drains with peaks and lows. It can be scaled up and integrated into any project within the constraints of the space available. It is designed

for specific applications with the necessary features and functionalities. The pre and post treatment can also be tailored to meet specific targets for the effluent water.
Another important aspect of the above technology is the flexibility; it can be constructed above ground, below ground or partly above and below. The exterior of the structure can blend with the local architecture hence, providing aesthetics according to the community. Also, it can be built solely by using locally sourced material, which makes the technology a cost-effective and eco-friendly alternative.

The key components of the system are:

1. Dosing tank with secondary treatment bed.
2. Recirculation tank.
3. Tertiary treatment bed and disinfection chamber or a specially designed post treatment solution as explained in the further sections.

PROCESS OF SEWAGE TREATMENT PLANT BASED ON BRR (BIO-FILTRATION WITH RECIRCULATION REACTOR)



KEY COMPONENTS OF THE SYSTEM

i. Inlet of raw sewage: Dosing Tank

The dosing tank receives water directly from drains or septic tanks, eliminating the need for an additional solid separator. Pumps in the dosing tank deliver wastewater into the secondary treatment bed via a sprinkling distribution system.
A control system activates the pumps to deliver a specific quantity of wastewater or partially treated water, through a sprinkler network. This network distributes the wastewater or partially treated water evenly over the treatment beds (secondary and tertiary treatment beds) as shown in Figure. The dosing and recirculation tanks can be built underground while treatment beds are built in covered areas for zero exposure to the atmosphere.

ii. **Secondary treatment of waste-water: Treatment Bed**

The wastewater from the dosing tank is sprayed over the secondary treatment bed using sprinklers, consisting of a fixed bed of specially selected gravel-based filter media. After activation of the treatment bed, a layer of mixed culture microbes form on the surface of the filter media. This is known as attached growth microbes or biofilm, when wastewater flows through the filter media via gravity, the filter media filters the wastewater and some wastewater also get adsorbed on the biofilm.

Microbes in the biofilm then digest and degrade the organics and remove nutrients while partially treated or clean water gravity gradually trickles to the bottom of the treatment beds (secondary or tertiary treatment beds).

iii. **Re-treatment of secondary treated water: Re-circulation Bed**

The partially treated water out of the secondary treatment bed flows into the recirculation tank, which is sprayed over the treatment sections via overhead spray nozzles, brings oxygen and moisture into the treatment media, naturally aerating the system. A control system activates the pumps in the recirculation tank and reticulates partially treated water back into the secondary and tertiary treatment beds. Recirculation of partially treated water introduces conditions into the treatment beds that enable nitrification and de-nitrification to occur, removing nitrogen from the wastewater.

iv. **Tertiary Treatment Bed**

Similar to the secondary treatment bed, the tertiary treatment bed uses a mixed population of attached growth micro-organisms to further remove organics and nutrients. The partially treated water from the recirculation tank that is sprayed over the treatment sections via overhead spray nozzles brings oxygen and moisture into the treatment media, naturally aerating the system. This brings optimum conditions for microbial activity on the bio film.

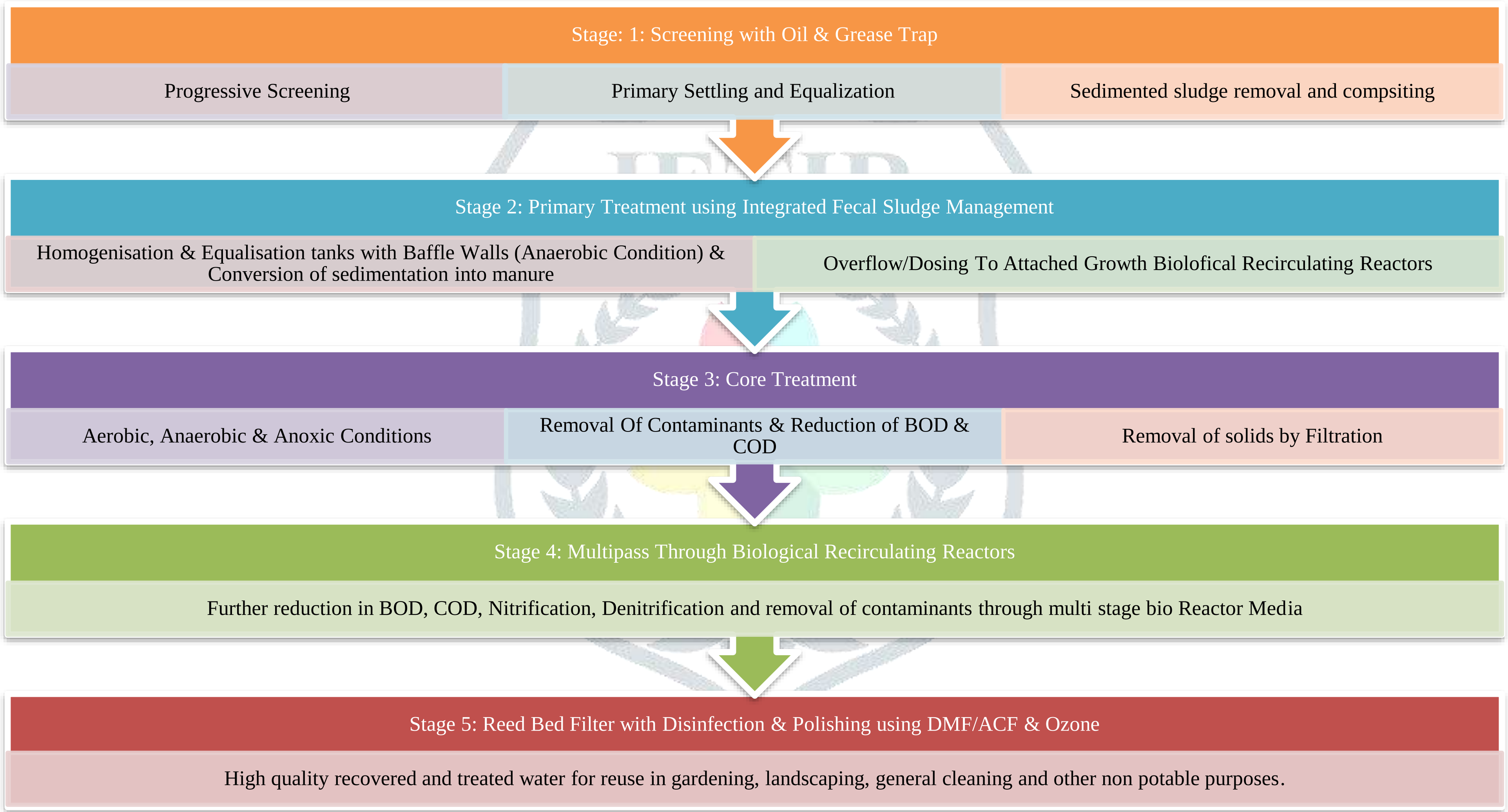
The treated water after the constituent’s removal, that falls on the tertiary treatment section flows through a drainpipe to discharge or post-treatment.

v. **Advanced Post-treatment System: Dis-infection System**

The type of post-treatment required depends on the use of treated water. Typically, UV disinfection, natural ozone or chlorination can be used. Recycled water is of good quality (meets all norms) and ready to use for landscaping, agriculture, non-potable purposes, discharge into ground or surface water bodies, and recharging ground water sources.

The Attached Growth Biological Recirculating Reactors system is superior to any other technology owing to its unique design using aerobic, anaerobic and anoxic processes (as shown in process flow diagram below), it achieves high level of removal of carbon, nitrogen and phosphorous in single treatment unit. This reduces the hydraulic retention time of wastewater in the system, and thus savings in the footprint required. At the same time, it generates a high quality of treated water ready for non-potable reuse. The system is can also be connected to the overflow of a septic tank and will be designed with modular features and can treat varying volumes and load. It is a unique innovation in wastewater treatment technologies and is inspired by mother-nature. The design is driven by optimizing biological processes using the least amount of space or foot-print, no chemical, high efficiency rate and meets all international standards.

PROCESS OVERVIEW



Stage 1: Screening of Incoming Used Water (Wastewater/Sewage) with Oil & Grease Separator

This stage allows for removal of unwanted large and non-biodegradable solids through screening chambers using the established bar screening process and further an oil & grease trap for the
Benefits: Easy to clean, maintains and prevents clogging of pumps, valves and aeration systems in subsequent stages.

☑ **Energy:** Gravity flow
☑ **Ease of Maintenance:** Easy
☑ **Additives:** No
☑ **Skills Required:** Low
☑ **Cleaning Frequency:** Weekly

Stage 2: Anaerobic Baffle Tanks for Equalisation & Homogenization

The system is designed based upon peak and low flows including any condition for power outages and unlikely breakdowns. The tanks are specially designed in concrete for long life and has baffle walls. The tanks are further divided into chambers that are connected to maintain the hydraulic retention time under aerobic or anaerobic conditions. These tanks are generally below ground level. Two pumps are connected to the controller to transfer the sewage further.

Benefits: Optimises capacity and flow rates to allow for peak and low seasons. No addition of chemicals/additives unless specific goals are required.
☑ **Energy:** Low
☑ **Ease of Maintenance:** Easy
☑ **Additives:** No
☑ **Skills Required:** Low
☑ **Cleaning Frequency:** Monthly or Quarterly

Stage 3: Aerobic Biofilter Without Sludge (ABWS)

It supports an aerobic biological process that digests organic matter naturally. Wastewater is sprayed through specialized sprinklers over layers of natural filter media such as sawdust and gravel media. Suspended solids are filtered by the filter media. Earthworms and attached growth micro-organisms digest organics and nutrients to produce useful by-products such as natural fertilizer and earthworm castings. This system has the ability to take in raw sewage, thus eliminating the need for septic tanks.
Benefits: No generation of sludge and odour, eliminates the need for septic tanks and produces useful by-products. Very low noise. Sustains itself for periods with low or no influent.
☑ **Energy:** Low
☑ **Ease of Maintenance:** Easy
☑ **Additives:** No
☑ **Skills Required:** Low
☑ **Cleaning Frequency:** Weekly

Stage 4: Anaerobic, Aerobic & Anoxic Multi-Stage Biological Recirculating Reactors
This process utilizes naturally available material to trap and biologically degrade pollutants in wastewater. Using specially configured media, microorganisms attach and grow to form a biological layer called biofilm. Through the attached growth process on the bio-filter media layers, organics and nutrients are digested and degraded while partially treated water trickles to the bottom of the treatment beds. It supports an aerobic biological process that digests organic matter naturally. Wastewater is sprayed through specialized sprinklers over layers of natural filter media such as sawdust and gravel media. Suspended solids are filtered by the filter media. Earthworms and attached growth micro-organisms digest organics and nutrients to produce useful by-products such as natural fertilizer and earthworm castings. Effluent from the secondary treatment bed is collected in the recirculation tank. A control system activates the pumps in the recirculation tank and recirculates partially treated water back into the secondary and tertiary treatment beds. Recirculation of partially treated water introduces conditions into the treatment beds that enable nitrification and de-nitrification to occur, removing nitrogen from the wastewater.

Benefits: No sludge and odour generated through the endogenous growth process. Low noise. Small footprint allows for various installation locations and integration with surrounding environment.
☑ **Energy:** Low
☑ **Skills Required:** Low
☑ **Ease of Maintenance:** Easy
☑ **Additives:** Activation, Stabilisation & Optimisation
☑ **Cleaning Frequency:** Quarterly or Annual

Stage 5: Planted Reed Bed Filter with Final Treatment, Disinfection & Polishing

The tertiary treatment for the proposed technology consists of two staged treatment using Planted Reed Bed filter, followed by disinfection. An added with an ozone chamber and removal of color and odor at the end of the bioreactors. Further type of post-treatment required depends on the use of treated water. Typically, UV disinfection, chlorine dosing and/or membrane filtration can be used. Recycled water is of good quality (meets all norms) and ready to use for landscaping, agriculture, non-potable purposes, discharge into ground or surface water bodies, and recharging ground water sources.

We have designed 2 stage polishing.

1. Active Carbon & Ozone: Built into each module: Good for Gardening & Landscaping
2. Multi Media: Water Features, General Cleaning and Reuse

Stage 6: Discharge, Reuse, Recharge

The treated water is good for gardening, landscaping, irrigation and related non-potable purposes. It meets all standards for discharge into ground and surface water. As a back-up chlorine can be used in prescribed limits

III. CALCULATIONS

DESIGN SPECIFICATION OF SEWAGE TREATMENT PLANT

1. Design data and calculation of STP of 430 KLD

S.NO.	DATA	CALCULATION
1.	Proposed STP Design for Current Flow	0.475 MLD (475 KLD)

Design of Sewerage Treatment Plant Based on Bio-Filtration with Recirculating Reactor, it is best suited for small and large volume of flow.

The details of STP are as follows –

S.NO.	DESIGN DATA	CALCULATION
1.	Capacity of the Sewage Treatment Plant	0.475 MLD
2.	Average Flow per hour	19800 L/Hr.
3.	Peak Flow	19800 x 3 = 59400 L/Hr.
4.	STP Design for Normal Flow / Average Flow	19800 L/Hr.
5.	Sewage Profile	Mixed Sewage
6.	Drain	Open Drain (RCC Drain)
7.	Sewage Flow	Institutional/Residential Flow
8.	Free Board of tanks	0.3 – 0.5 m
9.	Type of STP	Aerobic, Anaerobic, Anoxic Process
10.	Area Required	30m x 30m = 900 sqm
11.	Reuse of Recycle Water	Discharge in Water Bodies
12.	STP Run Time	24 Hr.
13.	STP Run time per Cycle	30 min
14.	Per Cycle Discharge	9900 L/Hr.

DETAILS OF THE MAIN COMPONENTS OF THE STP PLANT

SNO	STP COMPONENT	SIZE	VOLUME
1.	Screen Chamber	1.0 m x 1.0 m x1.0 m	1.0 Cum
2.	Grit Chamber	1.0m x 2.0 m x1.0 m	2.0 Cum
3.	Collection Tank	5.0m x 4.0 m x 3.0 m	60.0 Cum
4.	Accumulation Tank	5.0m x 4.0 m x 3.0 m	60.0 Cum
5.	Homogenization Tank	5.0m x 4.0 m x 3.0 m	60.0 Cum
6.	Recirculation Tank	6.0m x 5.0 m x 3.0 m	89.10 Cum
7.	Buffer Tank	3.3 m x 3.0 m x 3.0 m	29.70 Cum
8.	Biological Reactor 1	10.0 m x 17.0 m x 3.0 m	171 Sqm
9.	Biological Reactor 2	5.0 m x 17.0 m x 3.0 m	86 Sqm

DESIGN OF SEWER TREATMENT PLANT

SNO	DESIGN DATA	VALUE
1.	Dry weather flow in the year 2020	0.475 Mld
2.	Average flow	475.20 cum/d

DESIGN PARAMETERS OF INCOMING SEWAGE

SNO	PARAMETERS	DESIGN PARAMETER IN %	DESIGN PARAMETER IN VALUE
1.	Expected efficiency for removal of suspended solids	100%	**150 – 200 Mg/L**
2.	Expected efficiency for removal of BOD5	Over 95% or (25-30 mg/l)	**150 – 200 Mg/L**
3.	Expected efficiency for removal of COD	Range 50-120	**500 – 1000 Mg/L**
4.	Expected for removal of total coliform	Over 90%	**>10000 No./100ml**
5.	Total Nitrogen		**20 – 100 Mg/L**

DESIGN PARAMETERS OF TREATED SEWAGE

SNO	PARAMETERS	DESIGN PARAMETER IN %	DESIGN PARAMETER IN VALUE
1.	Expected efficiency for removal of suspended solids	>95%	**<10 Mg/L**
2.	Expected efficiency for removal of BOD5	Over 95% or (25-30 mg/l)	**<10 Mg/L**
3.	Expected efficiency for removal of COD	Over 98% < 20 mg/l	**<30 Mg/L**
4.	Expected for removal of total coliform	Over 90%	**<1000 No./100 ml**
5.	Total Nitrogen	Range 50-120	**<10 Mg/L**

DETAILS OF DESIGN

S.No.	Description of Component	Proposed Component	Design Criteria	Size
1.	Bar Screening	Screen Chamber	15 Sec Retention Time	1.0 Cum
2.	Grit Settling	Grit Chamber	60 Sec Retention Time	2.0 Cum
3.	Raw water Collection Tank	Collection Tank	60 Min Retention Time	60 Cum
4.	Aerobic Tank	Accumulation Tank	60 Min Retention Time	60 Cum
5.	Secondary Treatment	Homogenization Tank	60 Min Retention Time	60 Cum
6.	Tertiary Treatment	Recirculation Tank	90 Min Retention Time	80 Cum
7.	Ozonation with Aeration	Buffer Tank	30 Min Retention Time	27 Cum
8.	Aerobic, Anaerobic and Anoxic treatment	Biological Reactor 1	2.7m3/Sqm	160 Sqm
9.	Aerobic, Anaerobic and Anoxic treatment	Biological Reactor 2	2.7m3/Sqm	80 Sqm

DETAIL DESIGN OF SEWERAGE TREATMENT PLANT COMPONENT OF 475.20 KLD CAPACITY.

1. **Design of Screen Chamber**

- Total flow per day – 475.20 m3/day
- Average flow per sec – 0.0055 m3/sec
- Peak factor – 3.0 times of Average flow
- Peak Flow / Max Flow – 3.0 x 0.0052m3/sec = 0.0165m3/sec

Horizontal velocity as 0.2 m/sec & detention time as 15 Sec (as per Manual of Sewerage and Sewerage Treatment)

Volume of Grit Chamber = Discharge x Detention time
- 0.0165 x 15= 0.247 m3 (250 ltr.)
- Provide 1.0 m3 (1000 ltr.)

- Chamber size – 1.0m x 1.0m x 1.0m
- Free board – 0.5m
- No. Screen Chamber 2 Unit

2. **Design of Grit Chamber**

- Total flow per day –450 m3/day
- Average flow per sec – 0.0052 m3/sec
- Peak factor – 3.0 times of Average flow
- Peak Flow / Max Flow – 3.0 x 0.0052 m3/sec = 0.015 m3/sec

Horizontal velocity as 0.2 m/sec & detention time as 1 minute (60 Sec) (as per Manual of Sewerage and Sewerage Treatment)

Volume of Grit Chamber = Discharge x Detention time
- 0.0165x 60 = 0.99 m3 (990 ltr.)
- Provide 2 m3 (2000 ltr.)

- Chamber size – 1m x 2.0m x 1.0m
- Free board – 0.5m

3. **Design of Bar for Screen Chamber**

- Total flow per day – 475.20 m3/day
- Average flow per sec – 0.0055 m3/sec
- Peak factor – 3.0 times of Average flow
- Peak Flow / Max Flow – 3.0 x 0.0052 m3/sec = 0.0165 m3/sec
- Bar Size – 9mm x 50mm (9mm face to flow)
- Spacing – 30mm
- Angle – 30^o
- Velocity of flow – 0.3 m/sec at average flow
- Net submerged area of screen opening

$$\frac{0.0165\ m3/sec}{0.3\ m/sec} = 0.55\ m2$$

- Average velocity of flow normal to screen 0.75 m/sec at max flow
- Hence net submerged area of screen

$$\frac{0.0165\ m3/sec}{0.75\ m/sec} = 0.022m2$$

- Provide net submerged area – 0.77 m2

4. **Design of Collection Tank /Accumulation Tank/Homogenization Tank**

- Total flow per day –475.20 m3/day
- Average flow per sec – 0.0055 m3/sec
- Peak factor – 3.0 times of Average flow
- Peak Flow / Max Flow – 3.0 x 0.0055 m3/sec = 0.0165 m3/sec

Detention time as 60 minute (as per technology)

Volume of Tanks = Discharge x Detention time
- 0.0165x 60 = 59.4 m3 (60000 ltr.)
- Provide 60cum Each Tank
- Peak Flow 3 Hour (60x 3 times = 180 kl)

- Tank size –5.0m x 4.0m x 3.0m
- Free board – 0.5m

5. **Design of Recirculation Tank**

- Total flow per day –475.20 m3/day
- Average flow per sec – 0.0055 m3/sec

- Peak factor – 3.0 times of Average flow
- Peak Flow / Max Flow – 3.0 x 0.0055 m3/sec = 0.0165 m3/sec

Detention time as 90 minute (as per technology)

Volume of Tanks = Discharge x Detention time
- 0.0165 x 90= 89.1 m3 (89100 ltr.)
- Provide 89.1m3

- Chamber size – 6.0m x 5.0m x 3.0m
- Free board – 0.5m

6. **Design of Buffer Tank**

- Total flow per day –475.20 m3/day
- Average flow per sec – 0.0055 m3/sec

Detention time as 60 minute (as per technology) of Average Flow or 30 min of Peak Flow

Volume of Tanks - Peak Flow x Detention time
- 0.0165 x 60 x 30= 29.7 m3 (29700 ltr.)
- Provide 29.7cum

- Chamber size – 3.3m x 3.0m x 3.0m
- Free board – 0.5m

7. **Design of Biological Reactor 1 & 2**

- Total flow per day –475.20 m3/day
- Average flow per sec – 0.0055 m3/sec

Surface area required for filtration is about 2.78m3/sqm/Day (Filtration Rate)

Volume of Tanks - Total Volume (m3) / Surface Area
- 475.20 /2.78= 170.94 m2
- Provide 172 m2 for Reactor 1 & 86 m2 for Reactor 2

- Reactor size – 17m x 10 x 2.5m & 17m x 5m x 2.5m
- Free board – 0.5m

IV. RESULT

The research is been carried out to the design of a wastewater treatment plant based on BRR technology for setting up at college campus i.e, which is fairly significant. Samrat Ashok Technological Institute (SATI), Vidisha (M.P.), which kind of is fairly significant. And the pretty overall execution of the Sewage Treatment Plant particularly is up to the mark in a major way. 90% of the wastewater transpires as the treated water and the rest 10% particularly comes out in the form of sludge, which specifically is fairly significant. The Sewage Treatment Plant meets the MPPCB guidelines to reuse the water, which for the most part is quite significant. So we can safely basically say that the design is working and this concludes the study, demonstrating that and the kind of overall execution of the Sewage Treatment Plant specifically is up to the mark in a particularly big way..

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