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STUDY AND DESIGN THE SEWAGE TREATMENT PLANT OF BHOPAL CITY BY USING SEQUENCING BATCH REACTOR (SBR) TECHNOLOGY OVER MBBR AND CONVENTIONAL ACTIVATED SLUDGE PROCESS

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A B S T R A C T :

The Sequential Batch Reactor (SBR) is an effective and flexible method for treating industrial wastewater containing complex pollutants. It operates in five stages-fill, react, settle, decant, and idle-and allows easy modifications in process parameters. SBRs show high efficiency in removing COD, BOD, nutrients, and solids compared to traditional systems. This paper also discusses the design of a sewage treatment plant in Bhopal to handle 10 MLD sewage over the next 30 years, driven by population growth. The plant includes components like screens, grit chambers, sedimentation tanks, and sludge drying beds. Treated water will be reused for irrigation, and sludge will serve as fertilizer, reducing groundwater use.

1. Introduction

The sewage treatment plant (STP) for Bhopal City is designed to treat wastewater and reduce environmental pollution using Sequential Batch Reactor (SBR) technology, an advanced and flexible form of the activated sludge process. SBR operates through phases like filling, aeration, settling, and decanting in a single reactor. The Moving Bed Biofilm Reactor (MBBR) was also considered but SBR offers better efficiency and a smaller footprint. The plant design includes analyzing wastewater flow, selecting suitable technology, and sizing components. The goal is to produce treated water safe for reuse or safe discharge, improving Bhopal's wastewater management and environmental quality.

1.1. Objective of Study

The main objectives of study to design a STP for Bhopal using SBR technology are follows.

- Assess the sewage handling needs for Bhopal City, including the projected residents growth, current and future sewage flow rates and the quality of sewage entering the treatment plant.
- Compare the technical requirements of SBR technology with MBBR and conventional activated sludge process, in terms of efficiency, cost, and effluent quality, to determine the most appropriate technology to use for the sewage treatment plant in Bhopal City.
- To develop an optimal design for the STP using SBR technology, counting the number & size of SBR tanks required, number and size of pumps, the type and dimension of aerators and the dimension or type of sedimentation tanks.
- To evaluate the environmental or social effects of the projected STP develope mitigation measures to minimize any adversative impacts.
- To estimated capital and operating costs of the sewage treatment plant and determine the feasibility of implementing the proposed design.
- To provide recommendations for the implementation and operation of the sewage treatment plant with ongoing maintenance & monitoring to ensure its long-term effectiveness.

By accomplishing these objectives, study provide a comprehensive and thorough proposal for design to implementation of a STP using SBR technology for Bhopal City. The proposed plan will be environmentally and socially sustainable, cost-effective, and capable of meeting the growing sewage treatment needs of the city.

SBR (Sequential Batch Reactor) is an efficient, batch-based wastewater treatment technology used in municipal and industrial applications. It operates in a single tank through five phases: filling, reacting (aeration), settling, decanting, and idle. SBR systems are suitable for various sites like homes, hospitals, malls, airports, and complexes. They offer advantages such as compliance with strict discharge standards, cost-effectiveness, low sludge production, energy efficiency, and protection of aquatic ecosystems by reducing pollution.

1.2. Sewage Treatment by Conventional Activated Sludge Process

This method of cleaning wastewater, called activated sludge, relies on natural biology. It uses microscopic organisms to eat away the muck (organic matter) in sewage, and it does this by blowing air into a treatment tank, where bacteria consume the organic pollutants, producing CO_2, water are new microbial biomass. This process is crucial for reducing biochemical oxygen demand (BOD) and suspended solids in wastewater.

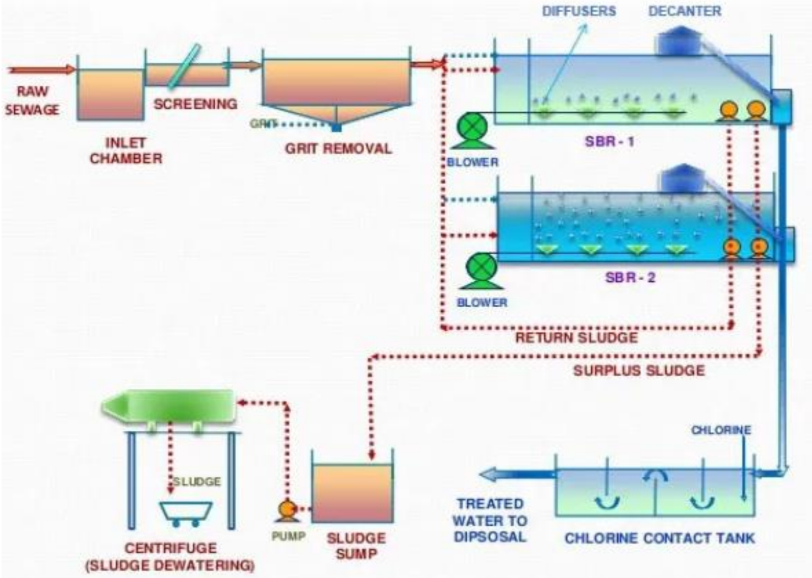


Figure 1.1 SBR- Process Flow Diagram

Initial Blending: Settled wastewater is combined with a concentrated mixture of beneficial microbes, known as activated sludge, within a large aeration vessel.

Oxygen Supply: Air or pure oxygen is continuously introduced into this tank, providing the essential O_2 required by the microorganisms on behalf of their metabolic functions.

Impurity Breakdown: These microorganisms actively consume the biological compounds present the wastewater, transforming them into less harmful substances.

Aggregation: As the microbial population grows and processes the waste, individual cells begin to aggregate, forming visible, settleable particles called flocs

Secondary Clarification: The wastewater activated sludge mixture are transferred to a secondary clarifier, where heavier flocs settle in bottom.

Sludge Recycling Waste:

A percentage of the settled sludge is recycled back to the aeration tank to maintain a high concentration of microorganisms. The outstanding sludge is removed from system are surplus activated sludge (SAS) for disposal.

Effluent Discharge: The clarified effluent (the treated water) is discharged from the clarifier.

1.3. Waste Water Management

Effective water and wastewater management is crucial for public health and environmental protection. Untreated wastewater can contaminate water sources, especially with increasing population, urbanization, and industrial activities. This has led to higher volumes of wastewater and degradation of water quality due to excess pollutants. Traditional treatment methods, though effective, are energy-intensive and costly. To ensure sustainability, there is a growing need for advanced, energy-efficient treatment technologies that lower operational costs while meeting environmental discharge standards.

1.4. Energy Demand of Wastewater Treatment

Wastewater treatment has improved significantly over the past 20 years, with approximately 75% of India surface waters now being in good biological and chemical quality. However, the energy required to treat wastewater to this standard is high; with energy being used to collect, treat and discharge wastewater and manage sewage sludge. Insufficient data were available to assess accurately the actual energy intensity of each step of the water treatment.

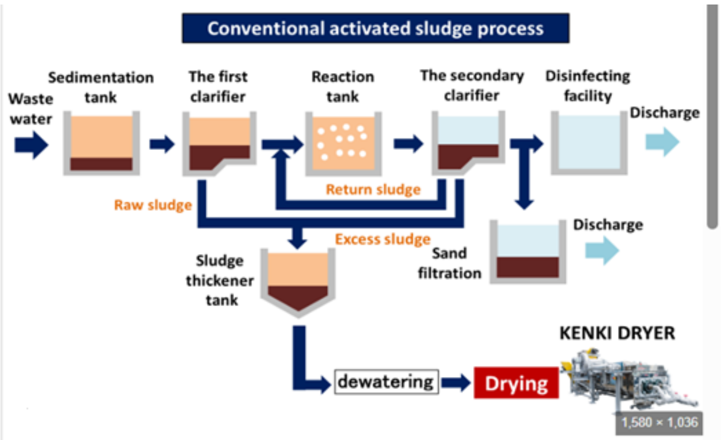


Figure 1.2 Conventional Activated Sludge Process

Table 1.1 Typical energy demands for a wastewater treatment facility

S. No.	Stage	Energy Demand (%)
1	Inlet pumping and headworks	4.9
2	Primary clarifier and sludge pumps	10.3
3	Activated Sludge aeration	55.6
4	Secondary clarifier and Ras	3.7
5	Thickener and sludge pump	1.6
6	Effluent filters and process water	4.5
7	Solids Dewatering	7
8	Tertiary treatment	3.1
9	Heating	7.1
10	Lighting	2.2
Total		**100**

To take a step to towards wastewater treatment facilities that have zero to negative net energy demands (Energy produced during treatment is greater than the energy required for their operation), all potential energy saving and energy production steps in a typical treatment facility should be identified. illustrates how and where within the train system of wastewater treatment, the greatest potential for energy saving and recovery can be achieved.

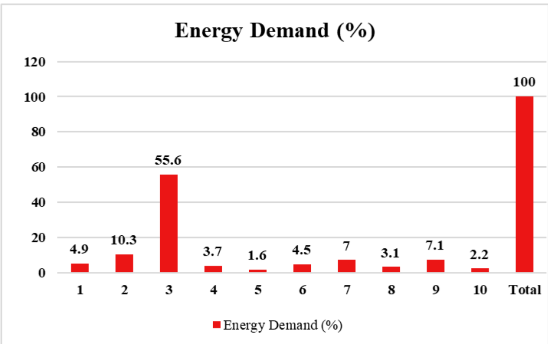


Figure 1.3 Energy Demand for Wastewater Facility

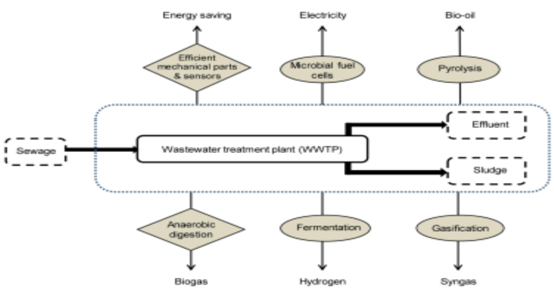


Figure 1.4 Processes of wastewater treatment facility

2. Literature Review

The reviewed literature highlights the versatility and efficiency of Sequencing Batch Reactor (SBR) technology for wastewater treatment across various applications, including domestic, industrial, and high-strength waste. SBR operates in cycles—filling, reacting, settling, decanting, and idle—making it adaptable to varying influent loads.

Membrane-based SBRs face fouling issues such as biofouling and scaling. Effective solutions include chemical cleaning, anti-fouling coatings, and advanced control systems (Al-Ashesh et al., 2021).

Design-based studies (e.g., Aswathy et al., 2017; Chakarbhushan et al., 2017; Murthy Polasa et al., 2014) emphasized efficient STP layouts to handle urban sewage and reuse treated water.

Granulation studies (B.K. Bindu et al., 2014) proved aerobic granules effective for high-strength organic waste, achieving up to 98% COD removal.

Industrial effluents (Chauhan, 2008; Vigan et al., 2009; Xiangwen et al., 2008) show SBR adaptability to treat complex pollutants from tanneries, dyes, and breweries, with COD removal consistently above 90%.

Hybrid and modified systems such as anaerobic-SBR (Moawad et al., 2009; Nardi et al., 2011) and membrane-SBR (Gao et al., 2021) demonstrated enhanced nutrient removal and potential for energy recovery.

Optimization techniques (Kargi & Uygur; Subbaramaiah & Mall) employed statistical models to fine-tune parameters like COD/N/P ratios and aeration time for maximum removal efficiency.

Advanced treatment integrations like coagulation and UV disinfection (Lin & Cheng, 2001; Nardi et al., 2011) further improved effluent quality.

3. Methodology for Water and Wastewater Analysis

pH Measurement: Best done immediately after sample collection using a pH meter or test strips to prevent changes due to gas exchange.
Alkalinity: Measured via titration with sulfuric acid using phenolphthalein and mixed indicators to detect pH endpoints of 8.3 and 4.5.
Turbidity: Measured using a turbidimeter after calibrating with known standards. Samples with >40 NTU are diluted before measurement.
Acidity: Determined by titration using methyl orange and phenolphthalein indicators or potentiometric method with NaOH until pH reaches 3.7 and 8.3.
Chloride: Measured by titration with mercuric nitrate after adjusting pH and adding indicator-acidifier reagent, observing a color change at endpoint.
Residual Chlorine: Detected using O-Toluidine reagent; the resulting color is compared using a comparator to find chlorine concentration (1–2 mg/L typical).
Total Solids: Measured by evaporating a known volume of sample in a pre-weighed dish, then drying it to constant weight at ~103–105°C.
Dissolved Oxygen (DO): Measured at three depths (bottom, middle, top) using a DO meter with sample stirred by magnetic stirrer; the average is recorded.
Biochemical Oxygen Demand (BOD): Measured using airtight bottles with NaOH and a magnetic stirrer; BOD values recorded daily (e.g., BOD3 or BOD5).
Hardness: Determined by titration with EDTA using Eriochrome Black T indicator at pH 10. Pre-treatment with nitric acid is required for polluted samples.
This comprehensive methodology ensures accurate water quality analysis critical for environmental monitoring and wastewater treatment.

3.1. Design of Sewage Treatment Plant

BAR SCREEN CHAMBER

Bar screen chamber are design to remove large debris from wastewater flows, protecting downstream treatment processes. Key design thoughts include bar spacing, screen angle, flow velocity, and the method for cleaning the screen.

COLLECTION SUMP

In Sequencing Batch Reactor (SBR) systems, a collection sump (also known as an equalization tank or collection tank) is a crucial component that receives influent wastewater after screening, prior to the SBR process. It serves to equalize flow variations, homogenize wastewater quality, and provide a buffer for the SBR tank. This ensures a more consistent and manageable flow for the subsequent treatment stages.

FINE BAR SCREEN CHAMBER

A fine bar screen is a wastewater treatment device that removes smaller solid particles and debris using closely spaced bars or other filtering media with openings typically less than 20 mm. These screens act as a primary filtration stage, taking materials like plastics, fibres and other trash that could clog before harm downstream equipment. Fine bar shelter are essential design for maintaining efficient wastewater treatment plant operations and avoiding operational issues.

Figure 4.1 Coarse Bar Screen Chamber

Figure 4.2 Collection Sump Tank

Figure 4.3 Fine Bar Screen (mechanical)

DEGRIT CHAMBER

Component Description
Inlet System-Controls flow into the tank during the fill phase.

A grit removal chamber, similarly, known as a grit chamber & detritus tank, is a waste water treatment component designed to remove inorganic solids like sand, gravel, and other gritty materials that can damage downstream equipment or clog channels. These chambers are typically placed at the beginning of a wastewater treatment plant, before finer screen processes.

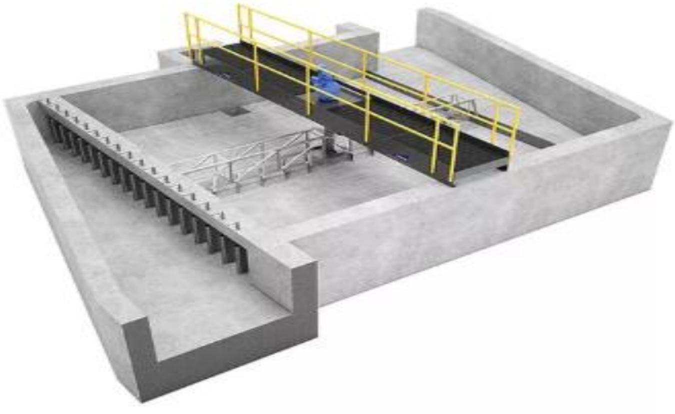


Figure 4.4 DeGrit Mechanism

SBR INLET BASIN

An SBR inlet basin is the initial chamber a SBR wastewater treatment system, where wastewater is first received then temporarily held before the treatment process begins. It serves equally a buffer, equalizing flow and pollutant concentrations, and often includes a preliminary screening step. The inlet basin helps to dampen the effects of fluctuating influent flow rates and pollutant concentrations by providing a holding volume.

SBR TANK-I& II

An SBR (Sequencing Batch Reactor) tank is a biological wastewater treatment unit that operates in batch mode rather than continuous flow, treat wastewater using activated sludge principles. It's typically used to municipal, industrial, and regionalized treatment systems.
Decanter-Draws off treated water from the top after settling.
Aeration -Supplies oxygen during the react phase (blower + diffusers).
Sludge Return-Waste sludge removed or resumed to maintain biomass.
Control Panel/PLC-Automates and sequences the phases.

Figure 4.5 SBR TANK **Figure 4.6 Centrifuge machine for Dewatering Sludge** **Figure 4.7 Sludge Sump**

CENTRIFUGE

Centrifuges are a vital component in modern Sewage Treatment Plants (STP), primarily for the critical processes of sludge thickening and dewatering. They utilize outward force to effectively detached solid components (sludge) from the fluid phase of wastewater. This parting helps reduce the volume of sludge, making it to easier & more cost-effective to handle, transport & dispose of sludge.

SLUDGE SUMP

A Sludge sump in an SBR system is a low-point collection area used to store or concentrate settled sludge before it is removed from the reactor or pumped to further treatment (e.g., sludge thickening or dewatering units).

CHLORINE CONTACT TANK (CCT)

A Chlorine Contact Tank is a post-treatment unit designed to provide sufficient contact time between chlorine disinfectant & effluent water, to inactivate harmful pathogens before release or reuse.
It's used in:

- Municipal STP
- Treated Sewage Recycle Systems
- Drinking Aquatic Systems
- Effluent Polishing Stages (after SBR, MBBR, etc.)

Figure 4.8 Chlorine Contact Tank

Figure 4.9 Chlorine Dosing Area

DISINFECTION AREA

Disinfection Area refers to the final stage of wastewater treatment where the treated effluent is disinfected to remove any remaining pathogens before discharge or reuse. This area typically follows the SBR five main phases: fill, react, settle, decant, and idle. Disinfection methods can include UV radiation, chlorination, or ozonation, depending on the specific necessities and regulations.

BLOWER ROOM

Blower Room is dangerous component of an SBR (Sequencing Batch Reactor) system in a wastewater treatment plant. Air blowers that are supplied oxygen to the aeration phase of SBR cycle, which essential for biological treatment of biological pollutants & nutrients (BOD, COD, ammonia, etc.) A Blower House is dedicated building & attachment where roots blowers, centrifugal blower, and screw blower are installed to offer aeration air to SBR tank.
It includes:

- Air blowers
- Control panel/MCC/PLC
- Air distribution manifolds
- Vibration/temperature monitoring
- Sound insulation (optional)

PLC CUM MCC ROOM

A PLC cum MCC Room is a centralized control and power distribution hub in a wastewater treatment plant (like an SBR system). It combines the functions of:

- PLC Room (Programmable Logic Controller): for process automation and logic control.
- MCC Room (Motor Control Centre): for controlling and powering motors, pumps, blowers, etc.

DG YARD & TRANSFOMER

A Genset (Diesel Generator Set) is a combination of a diesel engine, Generator used to produce electrical power. It is primarily used to provide backup power during power outages, or in areas where grid power is unavailable or unreliable. the Genset (Diesel Generator) and Transformer used in an SBR-based Sewage Treatment Plant (STP) focusing on design, sizing, integration, and safety.

3.2. DESIGN CALCULATIONS

Design Data
Flow = 3000 m^3/day = 125 m^3/hr.
Peak Factor = 2.5
Peak Flow = 7500 m3/day = 312.5m^3/hr.
COD = 250-1000 mg/l
BOD5d = 110-400 mg/l
TSS = 100-350 mg/l
Free Ammonia = 12-50 mg/l
Total Nitrogen = 20-85 mg/l
Total Phosphorus = 4-15 mg/l
Treated Sewage Characteristics
pH = 6.5-9.0
BOD5 @ 20 = ≤ 10 mg/l
COD = ≤ 50 mg/l
TSS = ≤ 20 mg/l
Ammoniacal Nitrogen = ≤ 5 mg/l
Total Nitrogen = ≤ 10 mg/l
Total Phosphorus = ≤ 1 mg/l

3.3. DESIGN OF TREATMENT UNIT

1.RECEIVINGCHAMBER

Flow	3000 $m^{3/}$day
Average flow	125m^3/hr

Peak flow (Peak Factor: 2.5)	312.5 m^3/hr
Velocity at peak flow	1.2 m/s
Detention time provided	30 Sec
Volume of Receiving chamber	2.6 m^3
let the SWD of the chamber	1.0 m
Area of the chamber	2.6 m2
Width of the chamber Provided	1.6 m
Length of the chamber Required	1.62 m

2. COARSE SCREEN CHAMBERS

Peak flow Factor = 2.5
Average Flow = 125 m^3/hr. = 0.0347 m^3/s
Peak Flow = 312.5 m^3/hr = 0.0868 m^3/s
Velocity Range = 0.6 -1.2 m/sec (As per CPHEEO Chapter 5 Page No. 5-30)
Velocity at Average Flow = 0.6 m/sec
Velocity at Peak flow = 1.2 m/sec
Angle Of Inclination of bar screen = 45°
Assume Thickness of Bar = 10 mm
Clear Spacing Bar = 20 mm
Net Submerged Area of Bar Screen
required Av. Flow = 0.0347 /0.6= 0.0578 m^2
Net Submerged Area of Bar Screen
required at Peak Flow = 0.0868 /1.2= 0.0723 m^2
Hence, provide Net submerged Area = 0.0723 m^2
For Gross Submerged Area of screen,
When “n” no. of bars is provided and quantity of bars are between 20-30, formula is applicable,
$[(n+1)20] / [(n+1)20 + 8 \times n] \approx 0.72$
Hence,
Gross Submerged area of screen
At peak flow= 0.0723/0.72= 0.100 m^2
The submerged Vertical Cross
Sectional Area at peak flow= 0.100 X sin 45°= 0.0855 m^2
Which is equal to cross sectional area of bar screen chamber
Provide 21 clear spacing of 20 mm each
No. of Bars = 20 of 10 mm each
Total width of the screen chamber = Bar Thickness x No. of Bar + Space
Between Two Bar No. of openings= 10 X 20 + 21 X 20 = 620 mm
Provide total width of the screen
Chamber = 700 mm = 0.7 m
Hence SWD of screen chamber
At peak flow= 0.0855/0.7 m = 0.122m
Provide Free Board = 0.5 m
Hence Total Required Height of
Chamber = 0.122 + 0.5 = 0.622 mtr
Provided Height of Chamber = 0.7 m
Let the Length of chamber = 4 m
Quantity of chamber = 2 Nos
Provide 2 nos. of Coarse Screen Chamber of 4 m Length X 0.7 M Width X 0.7 m Ht (1W Mechanical Screen + 1SB Manual Screen)

3. COLLECTION SUMP

Flow 3000 m^3/day
Average flow 125 m^3/hr
Peak flow (Peak Factor: 2.5) 312.5 m^3/hr
Velocity at peak flow 1.2 m/s
Detention time provided 5 Mins
Therefore, volume of Sewage Sump 26 m^3
let the SWD of the chamber 1.5 M
Area of the chamber 17.33 M^2
Dia of the chamber required 4.69 M
Raw sewage Transfer Pump Capacity 156.25 M^3/hr

4. INLET CHAMBER

Flow 3000 m^3/day
Average flow 125 m^3/hr
Peak flow (Peak Factor: 2.5) 312.5 m^3/hr
Velocity at peak flow 1.2 m/s
Detention time provided - 30 Sec
Therefore, volume of Receiving chamber 2.6 m^3
let the SWD of the chamber 1.0 m
Area of the chamber m2 2.6
Width of the chamber Provided m 1.6
Length of the chamber Required m 1.62
provide 1 Nos. of Inlet Chamber of 1.65 m Length X 1.6 M Width X 1 m Ht SWD + 0.5 M FB

5. FINE SCREEN CHAMBERS

Peak flow Factor = 2.5
Average Flow = 125 m^3/hr. = 0.0347 m^3/s
Peak Flow = 312.5m^3/hr = 0.0868 m^3/s
Velocity Range = 0.6 -1.2 m/sec (As per CPHEEO Chapter 5 Page No. 5-30)
Velocity through Screen at Average Flow = 0.6 m/sec
Velocity through Screen at peak flow = 1.2 m/sec
Angle Of Inclination of bar screen = 45°
Assume Thickness of Bar = 3 mm
Clear Spacing between Bar = 6 mm
Net Submerged Area of Bar Screen
required at Ave Flow = 0.0347 /0.6= 0.0578 m^2
Net Submerged Area of Bar Screen
required at Peak Flow = 0.0868/1.2= 0.0723 m^2
Hence, provide Net submerged Area = 0.0723 m^2

6. DEGRITCHAMBER

Peak flow Factor = 2.5
Average Flow Peak Flow = 3000 m^3/day =125 m^3/hr.
7500 m^3/day = 312.5 m^3/hr= 0.0868 m^3/sec for 100% removal of 0.15 mm and above, having specific gravity 2.65, As per CPHEEO Manual, chapter No. 5 Table No. 5.6
Surface Overflow Rate= 960 m^3/m^2/day
Settling velocity =0.025 m/sec

Therefore, plan area of grit chamber (Required)	7500/960
7.8125 m^2 7.84 m^2 0.9 m 2.8 m	Considered Area for Grit Chamber Side Water Depth of Grit Chamber Let Length of Chamber Hence, Width of chamber

Settling Velocity of above-mentioned Particle size = 0.201m/sec Peak Flow Rate = 0.0868 m^3/sec
Hence,

Cross sectional area of grit chamber (Required)	0.0868/0.201 = 0.432 m^2

Cross sectional area of grit chamber (Provided)	2.8 X 2.8	= 7.84 M^2	>7.8125 m^2

Dimension of Grit Chamber – 2.8 m x 2.8 m x 0.9m SWD + 0.1 SWD for Grit + 0.5 m FB

7. CHLORINE CONTACT TANK

Flow = 3000 m^3/day = 125 m^3/hr.
Detention time provided =30 minutes
volume of bar screen chamber = 125 x 30/ /60 =62.5 m^3
Let the SWD of chamber be = 3.1 metre
Therefore, plan area of the unit = 65/3.1 = 20.16 m^2
Length and Width Required = 4.49 m
Provide Chlorine Contact Tank 4.6 m L x 3.4 m W + 4.0 m SWD + 0.5 m FB

8. SLUDGE DEWATERING UNIT (CENTRIFUGE)

Volume of thickened sludge = 19.9 m^3
Max Operating Hours = 18
Required Centrifuge Feed Pump Flow = 1.10 m^3/Hr
Provided Centrifuge Feed Pump Flow = 3 m^3/Hr
Centrifuge Feed Flow will be = 2 m^3/Hr

Table 0.1 Design Sheet for SBR Basin

Sequencing batch reactor basins	**Capacity**	**unit**
Design Flow		
Design Average flow for SBR Basins	3.00	MLD
	125	m^3/h
Peak flow for SBR Basins	3.00	MLD
	125.00	m^3/h
Recycle Flow	0.001	m^3/s
Total Design Flow - Average	3086	m^3/day
Total Design flow	0.04	m^3/s
Total Design Flow – Peak	3086	m^3/day
Treatment Sequence		
Sewage to be treated in a day	3086	m^3/day
Time for "Fill and Aerate" Phase provided	2	hrs
Time for "Settle" Phase provided	1	hrs
Time for "Decant" Phase provided	1.00	hrs

Total cycle time provided	4.0	hrs
No. of cycle provided per basin per day	6.0	hrs
Aeration time provided per basin per day	12.0	hrs
No. of basins under settling simultaneously.	1.0	nos.
Flow rate to each basin	129	m^3/hr
Basin Sizing		
Volume of sewage to be treated in a day	3100.00	m^3/day
Inlet BOD	200.0	mg/l
MLSS Considered	4000.0	mg/l
MLVSS = 0.7 x MLSS	2800	mg/l
F/M considered	0.150	day-1
Total volume of Aeration basin required	1500	m3
No. of basins provided	2.0	nos.
Volume required per basin	750	m^3

Table 0.2 Area Requirements for SBR Basin

Fill Volume and Area Requirement			
Flowrate		129	m^3/hr
No. of basins receiving flow simultaneously		1	no's
Flowrate per basin		129	m^3/hr
Fill aeration time		2.0	hrs
Fill volume per basin		257	m^3
Design decant depth considered		2.0	m
Basin surface area required per basin for provided decant depth		129	m^2
Length provided		12.0	m
Width required		11.0	m

Table 0.3 Calculation of Sewer Water Depth

Calculation of SWD			
Volume of basin required		750	m^3
Area of basin provided		132	m^2
Side Water Depth provided	=	5.7	m
Length of each Basin	=	12.0	m
Width of each Basin	=	11.0	m
Freeboard provided	=	0.5	m
Total Depth Provided	=	6.2	m
Hydraulic Retention time provided (HRT)	=	11.7	hrs
Size of each basin	=	12 m L x 11 m W x 5.7 m SWD + 0.5 m FB	

Results & Discussion

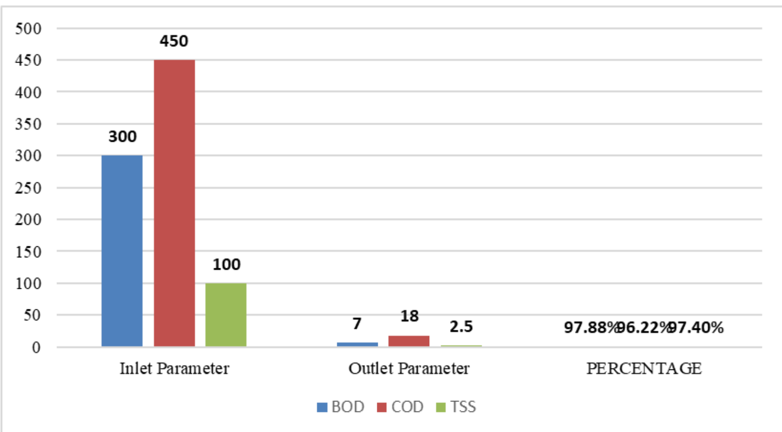
HIGH REMOVAL EFFICIENCES

SBR systems consistently demonstrate high removal rates for BOD, COD, TSS, and nutrients like Nitrogen and Phosphorus. For instance, study showed removal efficiencies of 97.88% for **BOD, 96.22% for COD, and 97.40% for TSS.**

Table 5.1 Treated water sample Report

S. No.	Description	Inlet Parameter	Outlet Parameter	PERCENTAGE
1	BOD	300	7	97.88%
2	COD	450	18	96.22%
3	TSS	100	2.5	97.40%

Figure 5.1 Treated water sample Report



The consistent high performance of SBR technology can be attributed to several inherent design and operational advantages:

PROCESS FLEXIBILITY & CONTROL

This is most significant factor. ability to precisely control duration of each phase aeration intensity and mixing allows operators to optimize conditions for specific biological reactions. This means SBR can be tailored to varying influent characteristics (flow, load, composition) and stringent effluent requirements (specific nutrient limits), which is difficult to achieve in continuous flow systems without multiple dedicated tanks.

ADAPTABILITY TO FLOW/LOAD FLUCTUATIONS

SBR effectively act as their own equalization basins. They can "hold" influent during the settle or decant phase, preventing hydraulic or organic shock loads to the biological process. This makes them ideal for small to medium communities, official facilities, industry with intermittent highly variable wastewater flows.

EXCELLENT SOLIDS SEPARATION

The completely quiescent settling phase is a more advantage. Without any incoming flow mechanical disturbances, activated sludge flocs settle exceptionally well, leading to a very clear supernatant and minimal TSS carryover in the effluent. This contributes significantly to overall effluent quality for BOD and COD as well.

ENHANCED NUTRIENT ELIMINATION CAPABILITY

The sequential nature of SBR operation naturally facilitates biological nitrogen & phosphorus removal. The facility create distinct anaerobic, anoxic & aerobic zones within the same reactor permits for the necessary situations for nitrification, denitrification, biological phosphorus uptake. This often eliminates the need for chemical addition for nutrient removal, leading cost savings & reduced chemical sludge production.

COMPACT FOOTPRINT

By combining multiple procedures (equalization, aeration, clarification) into a single few tanks, SBR systems typically need a smaller physical footprint compared to conventional activated sludge plants need detached tank for each unit operation. This is beneficial for sites with limited land availability, a common constraint in urban or industrial areas.

SIMPLIFIED INFRASTRUCTURE AND REDUCED CAPITAL COSTS

Eliminating the need for separate clarifiers, (RAS) pumping potentially primary clarifiers (for certain wastewater types) lead to important capital cost savings.

AUTOMATION & EASY OPERATION

While requiring sophisticated controller systems, SBRs are highly amenable to automation. Programmable Logic Controller (PLC) and controlling of SCADA system can manage entire cycle, minimizing need for endless manual intervention and reducing operator labour.
Sludge Management: Ability to control SRT and MLSS within reactor lead to better sludge settleability and potentially reduce sludge production depending on operational strategy. SBRs can also manage filamentous bulking more effectively due to their "feast-famine" conditions.

CHALLENGES AND CONSIDERATIONS

Despite their numerous advantages, some points need discussion:

- **Complexity of Controls:** While automated, the control systems for SBRs are more sophisticated than for continuous flow systems, requiring skilled personnel for programming, maintenance, and troubleshooting.
- **Intermittent Discharge:** As a batch process, SBR discharge effluent intermittently. Downstream processes (e.g., filtration, disinfection) or receiving water bodies might require a post-SBR equalization tank to manage this intermittent flow.
- **Larger Aeration System Capacity:** Batch nature, aeration system may want to deliver a higher peak air current rate during aerobic phase compared to continuous system, although the overall energy consumption might be lower due to irregular operation.

Potential for Floating / Settled Sludge Discharge: Decanting is not properly controlled or sludge bulking occurs, there is a risk of discharging some solids with the treated effluent. Modern decanter designs and robust control strategies minimize this risk.

Conclusion and Future Demand

In Bhopal, SBR (Sequencing Batch Reactor) technology presents a capable solution for wastewater treatment due to its efficiency, flexibility, and potential for resource recovery. Its ability to handle fluctuating wastewater characteristics and produce high-quality effluent makes it well-suited for the city's needs, particularly in densely populated areas where space is limited.

SBR vs MBBR:

- **Process Flexibility:** SBR batch cycles, which can provide better flexibility handling adjustable influent qualities & flow rates. Operator can adjust parameters like aeration period, settling period, and decanting period to optimize treatment.
- **Working Complexity:** MBBR system tend to have a simpler operation, with continuous flow treatment, while SBR require careful sequence of cycles. MBBR are less prone shock loading than SBR.
- **Planetary Efficiency:** MBBR typically required less space than an SBR due in the direction of the biofilm support medium, which provide to high surface area for microbial growth. This allows MBBR to achieve higher treatment capacities in smaller volumes.
- **Sludge Production:** MBBR typically produce less sludge compared to SBR, the biofilm grows on media, which is a more effective form of microbial growth of suspended biomass in SBR.

SBR vs Conventional Activated Sludge

Performance & Efficiency: SBR generally provide better regulator over treatment process, with aeration & settling phases, allowing for improve effluent quality. CAS is a continuous-flow process. while effective, is less flexible cutting-edge handling fluctuating loads.

Space & Footprint: SBRs usually have a higher footprint than CAS because they operate into batch mode & require separate tanks for aeration, settling. However, CAS can require more planetary for clarification tank & aeration basins comparison.

Cost & Maintenance: SBRs tend have higher capital costs due to need for multiple reactors, but operational costs can be lower because of more efficient control over the aeration and settling phases. CAS, on the other hand, may have lower initial costs but could involve more complex management and control, especially with varying loads.

Sludge Settling: The SBR process generally has better sludge settling characteristics, which can lead to improved effluent quality. In contrast, conventional activated sludge systems can suffer from poor settling and require secondary clarification units.

SBR technology is suitable when flexibility & better effluent excellence are required, especially for wastewater with mutable loads. It offers a better solution for small to medium-sized treatment plant or when space & efficiency in treatment load variation are important.

Table 0.1 STP Inlet Parameter

S.No.	Description	unit	Inlet Parameter
1	FLOW	M^3/DAY	3000
2	PH	Mg/L	6.5-7.5
3	O&G	Mg/L	15
4	BOD	Mg/L	300
5	COD	Mg/L	450
6	TSS	Mg/L	50-100

Table 0.2 STP Outlet Parameter

S.No.	Description	unit	Outlet Parameter
1	FLOW	M^3/DAY	3000
2	PH	Mg/L	7-7.1
3	O&G	Mg/L	Nil
4	BOD	Mg/L	<10
5	COD	Mg/L	<50
6	TSS	Mg/L	<10

FUTURE DEMAND

Automation and Smart Control Systems-Energy Recovery & Sustainability, Energy Efficiency Wastewater Treatment for Circular Economy

Sludge Management-Reduction Sludge Production, Sludge Valorisation

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