Case-study: Batchflow® SBR Wastewater Treatment Plant

Introduction

Project at Glance

Location: Gobranawapara, Dist. Raipur, C.G.

Town Area: 418.21 Ha.

Design Population: 85536

STP Capacity: 7.6 MLD

Photo: 7.6 MLD STP on Mahanadi River

Raw Water Characteristics:

Parameters	Raw Water
Average Flow	7.6 MLD
Peak Flow	17.10 MLD
BOD 5 @ 20°C	250
COD	450
TSS	375
TKN	40
TN	—
TP	7

Background

The town, Gobranawapara, situated on the left bank of Mahanadi River lacked system for proper disposal and treatment of sewage.

The town had a network of open drains through which the sewage was disposed into the river. This network of nallas due to increased disposal of sewage and solid waste in them lead to overflow and pollution of the Mahanadi river violating the norms of National Green Tribunal (NGT) and Chattisgarh Environmental Conservation Board, Raipur (C.G.).

Photo: Sewage disposal in Mahanadi River

Gobranawapara is also on the the opposite bank of Rajim town where Rajim Kumbh, the annual hindu pilgrimage is held where devotees flock in to bathe en masse in sacred Mahanadi River.

Photo: Rajim Kumbh Mela

The absence of proper treatment and disposal of sewage created high risk problems of health and environmental contamination for devotees and inhabitants of the town.

Objective & Scope

The primary objective of the project was to prevent contamination of Mahanadi River with untreated sewage and utilise the treated effluent for non-potable purposes. The overall objective of the project was to improve existing service level of disposal of drain system.

The scope of this project comprised of construction of 7.6 MLD Capacity Sewage Treatment Plant on the right bank of Mahanadi River at Gobranawapara, Raipur. The scope also included sewer networking and connecting open streams through RCC pipelines and collecting the wastewater at main pumping station in the STP campus.

Technology Adopted

Photo: SBR Basin, 7.6 MLD STP

Batchflow® sequencing batch reactor (SBR) is a wastewater treatment system that operates on a fill-and-draw principle within a single reactor. In this method, wastewater is introduced in a single batch, undergoes treatment to eliminate undesirable elements, and is subsequently discharged. All processes of equalisation, aeration, and clarification are conducted within the confines of this singular batch reactor. To enhance system performance, multiple batch reactors are employed in a predefined sequence of operations. SBR systems have proven effective in treating both municipal and industrial wastewater, particularly in situations with low or intermittent flow conditions.

Batch processes characterised by the fill-and-draw method, akin to the Sequencing Batch Reactor (SBR), have been in existence for a longer period than commonly perceived. In the time span between 1914 and 1920, multiple full-scale fill-and-draw systems were actively functioning. While there was a decline in interest, a resurgence occurred in the late 1950s and early 1960s, driven by advancements in equipment and technology. Progress in aeration devices and controls has enabled SBRs to effectively rival traditional activated sludge systems.

The operational steps in both the Sequencing Batch Reactor (SBR) and the conventional activated sludge systems share similarities. A 1983 report from the U.S. EPA succinctly expressed this by indicating that the SBR essentially functions as an activated sludge system but operates over time rather than space. While both technologies involve equalisation, biological treatment, and secondary clarification, the key distinction lies in the SBR's ability to carry out these processes within a single tank through a timed control sequence. It is worth noting that, in certain instances, the SBR may also handle primary clarification. In contrast, the conventional activated sludge system achieves these unit processes by utilising separate tanks.

The Batchflow®, developed by Adroit, is a variation of the Sequencing Batch Reactor (SBR). In the Batchflow® system, incoming wastewater enters the reactor continuously but with extended batch periods. To accommodate this constant inflow, a baffle wall is employed to establish a pre-reactor zone. Despite this distinction, the design configurations of Batchflow® closely resemble those of the traditional SBR.

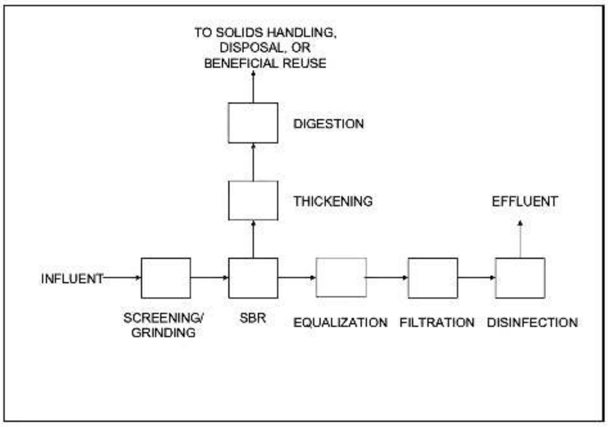


Figure 1: Process flow diagram for SBR

Figure 1 displays a common schematic outlining the operational sequence of a municipal wastewater treatment plant that employs a Sequential Batch Reactor (SBR). Typically, the incoming wastewater goes through screening and grit removal processes before entering the SBR. Inside the partially filled reactor, which contains acclimated biomass from previous cycles, the wastewater undergoes treatment. Once the reactor reaches its capacity, it functions similarly to a traditional activated sludge system, but without a continuous flow of influent or effluent. Aeration and mixing are halted after the completion of biological reactions, allowing the biomass to settle, and the treated supernatant is extracted. Excess biomass can be removed at any point during the cycle, and regular removal helps in maintaining a consistent mass ratio of influent substrate to biomass across cycles. In contrast, continuous flow systems achieve this stability by continuously adjusting return activated sludge flow rates based on variations in influent flow rates, characteristics, and settling tank underflow concentrations. Following the SBR treatment, the wastewater batch may be directed to an equalisation basin, where the flow rate to subsequent processing units is regulated. In some scenarios, the wastewater undergoes filtration to eliminate additional solids before being subjected to disinfection.

As depicted in Figure 1, the system for managing solids could include a thickener and an aerobic digester. Unlike traditional activated sludge systems, Sequencing Batch Reactors (SBRs) eliminate the requirement for pumps handling return activated sludge (RAS) and primary sludge (PS). In SBRs, usually, there is only one type of sludge to manage. The decision to incorporate gravity thickeners before digestion depends on the specific attributes of the sludge and is assessed on a case-by-case basis.

Advantage

- **Integrated Treatment:** Equalisation, primary clarification (in most cases), biological treatment, and secondary clarification can all be accomplished within a single reactor vessel.
- **Operating Flexibility:** SBRs offer operational flexibility and control.
- **Space Efficiency:** Minimal footprint, potentially leading to space savings.
- **Cost Savings:** Potential capital cost savings by eliminating the need for clarifiers and other equipment.

Design Criteria

The initial stage in designing the wastewater treatment plant involved identifying the expected characteristics of the incoming wastewater and the desired quality of the treated effluent for the proposed system. The influent parameters usually encompass design flow, maximum daily flow BOD5, TSS, pH, alkalinity, wastewater temperature, total Kjeldahl nitrogen (TKN), ammonia-nitrogen (NH3-N), and total phosphorus (TP).

Effluent requirements for the proposed plant were determined from the norms outlined by the Hon'ble National Green Tribunal (NGT). Establishing effluent requirements is critical because they significantly influence the operational sequence of the Sequential Batch Reactor (SBR). For instance, if there is a nutrient requirement with NH3-N or TKN specifications, nitrification becomes essential. If a TN limit is in place, both nitrification and denitrification are necessary.

Once the influent and effluent characteristics were determined, Based on the parameters and other site-specific conditions such as temperature, the Adroit selected key design parameters for the system. An illustrative set of these parameters is listed as under:

Design Parameters	Consideration
Food to Mass (F:M)	0.1/day
Treatment Cycle Duration	4.0 Hours
MLSS	4195 mg/L
Hydraulic Retention Time	14.29 Hours

Once the key design parameters were determined, the number of cycles per day, number of basins, decant volume, reactor size, and detention times were calculated. Additionally, the aeration equipment, decanter, and associated piping were then sized. Other site-specific information was needed to size the aeration equipment, such as site elevation above mean sea level, wastewater temperature, and total dissolved solids concentration.

The operation of a Sequencing Batch Reactor (SBR) relies on the fill-and-draw principle, encompassing five fundamental steps: Idle, Fill, React, Settle, and Draw. Multiple operational strategies can be applied throughout these steps.

The Idle phase occurs between the Draw and Fill stages. Here, treated effluent is extracted, and influent wastewater is introduced. The duration of the Idle step varies based on influent flow rate and chosen operational tactics. Variable idle times can lead to equalisation during this phase. Depending on the operational approach, mixing for biomass conditioning and sludge wasting may also take place during the Idle step.

60 Minutes	120 Minutes	180 Minutes	240 Minutes	Cycle Time
Fill & React		Settle	Decant	SBR Reactor 1
Decant	Settle	Fill & React		SBR Reactor 2
240 Minutes	180 Minutes	120 Minutes	60 Minutes	Cycle Time

In the Fill step, influent wastewater is introduced into the reactor. Three variations are employed for this step, and any combination of them may be utilised based on the operational strategy: static fill, mixed fill, and aerated fill. Static fill involves adding influent wastewater to the existing biomass in the SBR without mixing or aeration. This results in a high substrate (food) concentration at the start of mixing. The elevated food to microorganisms (F:M) ratio supports the development of floc-forming organisms over filamentous organisms, promoting favourable settling characteristics for the sludge. Moreover, static fill conditions encourage organisms that generate internal storage products during high substrate levels, essential for biological phosphorus removal. Static fill can be likened to using "selector" compartments in a conventional activated sludge system to regulate the F:M ratio.

Mixed fill involves combining influent organics with the biomass, triggering biological reactions where bacteria break down the organics using residual oxygen or alternative electron acceptors like nitrate-nitrogen. Denitrification, the conversion of nitrate-nitrogen to nitrogen gas, may occur in these anoxic conditions, where oxygen is absent, and nitrate-nitrogen serves as the electron acceptor for microorganisms. In a conventional Biological Nutrient Removal (BNR) activated sludge system, mixed fill is akin to the anoxic zone for denitrification. Anaerobic conditions may also be achieved during mixed fill, using sulphate as the electron acceptor after nitrate-nitrogen is utilised.

Aerated fill, on the other hand, involves aerating the reactor contents to initiate aerobic reactions that continue in the React step. This can reduce the aeration time needed in the React step. The React step encompasses mixed react and aerated react modes. In aerated react, aerobic reactions from aerated fill are completed, achieving nitrification—the conversion of ammonia-nitrogen to nitrite-nitrogen and ultimately nitrate-nitrogen. Opting for the mixed react mode allows the attainment of anoxic conditions for denitrification and anaerobic conditions for phosphorus removal.

Settle occurs under quiescent conditions in the SBR, with gentle mixing during initial settling stages potentially resulting in a clearer effluent and more concentrated settled sludge. Unlike conventional activated sludge systems, there are no influent or effluent currents in an SBR to disrupt the settling process.

In the Draw step, Adroit's Batchflow® decanter removes the treated effluent, Floating Batchflow decanters offered by Adroit provides various advantages, as detailed in the Tank and Equipment Description Section.

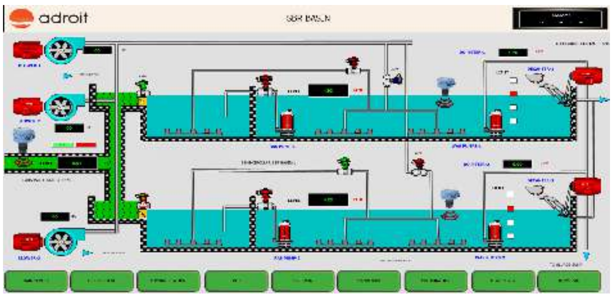
SBR Tank & Equipment

The SBR system comprises a tank, aeration and mixing equipment, a decanter, and a control system. Key components of the SBR system include the control unit and automatic switches and valves that govern the timing and sequence of various operations. Typically, a comprehensive SBR system recommended by a single manufacturer should be employed. Although it is feasible for an engineer to design an SBR system using tanks, equipment, and controls from different manufacturers, this is not the usual practice due to the advanced instrumentation and controls associated with these systems.

Photo: Batchflow decanter under manufacturing at Adroit's manufacturing facility Indore

The Batchflow SBR decanter plays a crucial role in the sequencing batch reactor (SBR) system by extracting clarified effluent from the basin in the decant phase of the operational cycle. This Batchflow process, an advanced SBR technology featuring continuous inflow, operates with defined cycle times adjusted to variable flow conditions. Typically, each cycle comprises four main phases: fill, aerate, settle, and decant. Continuous aeration occurs in the first half of the cycle, followed by a settling phase for liquid/solids separation. The last step involves decanting clear water from the basin.

The decanter is usually positioned on the basin wall, supported by an effluent box on one end and a pedestal on the other. Its electro-mechanical actuator facilitates lowering and raising, moving between top and bottom limit switches during operation. This ensures the decanter travels from the "park" position to the bottom water level (BWL). During the aeration and settling phases, the decanter remains parked above the top water level, eliminating the risk of solids carryover.



Controlled by a variable frequency drive (VFD), the decanter speed remains relatively constant from its entry into the water until it reaches the BWL. This mechanism maintains a consistent discharge rate throughout the entire process.

Performance

The performance of Batchflow® was found superior to conventional activated sludge/SBR systems and depended on system design and site-specific criteria. It could achieve good BOD and nutrient removal. The results after testing were as under:

Left: Inlet from MPS | Right: Effluent Water

Parameter	Raw Sewage (Inlet)	Effluent (Outlet)
BOD_5	210	6
COD	425	30
TSS	315	5
TN	32	7
TP	5.5	1.5

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