



## Article

# Improving Wastewater Treatment Efficiency Using Sequencing Batch Biofilm Reactor technology: A Mini Review

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**Abstract:** Wastewater treatment is an essential part of environmental management because it minimizes the negative effects that wastewater has on the environment and public health. The Sequencing Batch Biofilm Reactor (SBBR) technology is one technology that has become more well-known due to its effectiveness and affordability. The (SBBR) has attracted a lot of attention since it combines the advantages of sequencing batch reactor and the biofilm for effective treatment all type of wastewater. through the past research demonstrated that, Capability of this system to overcome the limitations of conventional treatment processes, such as low removal efficiency of organic pollutants, by leveraging the advantages of aerobic degradation mechanisms by focus on optimizing process parameters, evaluating performance in terms of eliminating organic matter, nutrients, and demonstrating scalability through a pilot scale model. This review demonstrates how efficient and effective this method for eliminating nitrogen phosphorus, and organic matter in a range of environmental conditions.

**Keywords:** SBBR, wastewater treatment, SBR, Review, Sequencing Batch Biofilm Reactor, BNR, BPR, biofilm.

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## Introduction

Wastewater is a mixture of water and water-borne contaminants from residential, commercial, and industrial facilities as well as institutions. High concentrations of organic material, various harmful microbes, nutrients, and hazardous substances are all present in untreated wastewater. Therefore, the wastewater must be properly treated before final disposal in order to protect the environment while addressing socioeconomic and public health concerns. It is a combination of medical facilities, agricultural drainage, manufacturing waste effluents, and sewage water; it is commonly known that household wastewater contains suspended particles, pathogens, and other organic and inorganic contaminants.

These pollutants and impurities must be reduced to allowable levels for wastewater disposal in order to lessen the risks to the environment and human health. As a result, eliminating organic pollutants and pathogens from wastewater is crucial for its subsequent use in many applications. Sewage is the term for the wastewater that flows after being utilized for manufacturing, industry, household, and other uses. The primary component of sewage is water, but it also contains chemicals and organic garbage [1]. Ensuring the disposal of human and industrial effluents without presenting a risk to public health or generating unacceptable environmental harm is the primary goal of wastewater treatment. The most basic and essential resource for all living things—plants, animals, and humans are water. While the water supply is stagnant, the use of water is growing incredibly quickly [2]. One of the most significant environmental issues facing the world now is eutrophication. The two main nutrients in water that cause eutrophication are nitrogen (N) and phosphorus (P). Therefore, before wastewater from homes and businesses enters receiving water bodies, N and P should be eliminated [3].

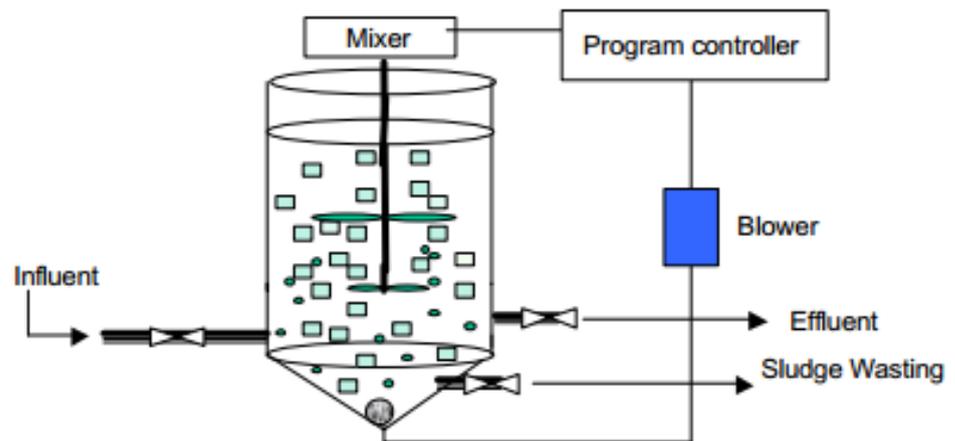
For the removal of biological nutrients, the (SBR) technique has demonstrated promising results. Wastewater is treated by the SBR process occurs in a time sequence, The five stages are fill, react, settle, draw, and idle. of a typical SBR operation. The benefits of the SBR process over continuous flow processes are include [4]; The ability to combine aerobic and anoxic stage in a same reactor, ideal settling conditions, and the lack of separate clarifiers. Furthermore, when compared to traditional activated sludge procedures, the SBR process is beneficial for treating wastewater on a small scale [5]. Suspension-growth activated sludge is used in the standard SBR process. Numerous research has been carried out to investigate the effectiveness of the SBR process in the Biological Nitrogen Removal (BNR)[6], Biological Phosphorus Removal (BPR)[7], and simultaneous biological removal of phosphorus and nitrogen [8]. In wastewater treatment, biofilms hold considerable great for the effective and simultaneous removal of nutrients like N and P as well as organic carbon [9]. For enhanced biological phosphorus removal (EBPR), They can expose anaerobic and aerobic environments alternately, they are well suited for nitrification because the slow-growing nitrifying bacteria's attached growth shields them from washout. Multiple nutrient elimination in the biofilm systems has already been shown in the first instances [10]. For extremely effective EBPR, the (SBBR) was recently developed [11] and attained the pilot size with success [12]. because of the benefits previously described. Recently, the use of fixed-growth bacteria cultivated on biofilm carriers in the SBBR technique has been investigated. Nutrient removal from wastewater has also been accomplished using the SBBR process, and it was discovered that SBBR was more effective overall at removing nutrients than a standard SBR using suspended biomass. However, the thickness of the biofilm has a major role in how SBBR works for nutrient removal since a thinner biofilm promotes phosphorus and nitrification eliminate, while a thicker biofilm increases denitrification and decreases phosphorus removal. For effective phosphorus removal, frequent and vigorous backwashing is thought to be crucial [13]. In order to make removal of nitrogen from wastewater in SBBR easier, an Intermittent ventilation technique has been used throughout time to produce a series of aerobic, anoxic and anaerobic states. One of the primary benefits of intermittent aeration for treating wastewater that contains nitrogen is that it lowers operating costs since less oxygen is used and less carbon is needed for the denitrification phase that follows [14]. Important factors influencing of the processes in nitrogen removal are coupled are the Dissolved oxygen (DO) content and the thicknesses of the biofilm aerobic and anaerobic layers [15].

## Material and Methods

### Basic Treatment Process Of SBBR

The SBR process, also known as sequential suspended growth (active sludge), involves filling, reacting (aeration/mixing), settling, drawing, and idle—all of which take place in the same tank in a sequential manner [16]. The technique is made much more flexible by the ability to alter the duration of each phase separately [17]. There are many options available with water recycling treatment technologies. Membrane processes have become the key to advanced sewage renovation and reuse plans. They are utilized in many globally recognized programs, including those for artificial groundwater replenishment, indirect potable reuse, and industrial process water production [18]. To create the Sequence Batch Biofilm Reactor (SBBR), the SBR can be coupled with biofilm formation on a support material's surface. Regardless of the reactor's hydraulic retention duration and the biological aggregates' sedimentation properties, substantial biomass concentrations can be sustained in SBBR [19]. When the necessary microbial population grows extremely slowly, SBBR reactors are especially well-suited [20]. Sequencing Batch Biofilm Reactors (SBBR) are SBR that use biofilm media. They are typically designed with a fixed bed layout with plastic media (Kaldnes) [12]. Maintaining the ideal biofilm thickness with constant surface renewal is a crucial prerequisite; as a result, the biofilm that grows on the fixed media, which unquestionably raises the SBBR operating costs. The use of floating media in SBBR was investigated using sewage supplemented with acetic acid as well as synthetic wastewater [21]. Anaerobic (An), anoxic (Ax), oxic (Ox), and settling stages are all part of the main working mode of SBBR [22]. To preserve the

health of aquatic systems, organic carbon and nutrients are extracted from water using biological reactors in wastewater treatment. As stricter effluent quality criteria are enforced, a number of new biological reactors and improvements of current technology have been created [23]. Because it can effectively eliminate nutrients and organic matter from wastewater in a one reactor by cycling between aerobic and anaerobic stages, the SBR has drawn a lot of attention in this area [24]. Due to the ease with which individual treatment steps can be added, changed, or omitted, the SBR provides a significant lot of operational flexibility. The (SBBR) can be created by combining the SBR with biofilm formation on a support material's surface. SBBRs are especially useful when the biomass production is minimal or when microbial populations carrying out important functions increase extremely slowly. High biomass concentrations can be sustained in SBBR regardless of the reactor's hydraulic retention time (HRT) and the biological aggregates' sedimentation properties. Furthermore, SBBR systems have shown promise in enhancing the biological aggregates' settling characteristics [25]. Because biofilms can grow on a variety of support materials that can be fixed or hung inside the reactor, SBBR layouts are quite varied [26]. Figure (1) show Schematic of SBBR. The standard SBR has been altered in numerous experiments to give a large surface area for the formation of biofilms. Domestic wastewater, dairy wastewater, Leachate from tanning plants, textile wastewater, and nutrient removal have all already been treated with SBBR. Compared to traditional SBR, the SBBR has a much greater pollutant removal efficiency [27].



Figure(1): Schematic of SBBR[28]

### Kinetics of biofilm

The concentration of the substrate in the treated wastewater has a significant impact on the kinetics of substrate removal in biofilm applications. Figure (2) illustrates the development of kinetic description from a 1<sup>st</sup> order bank of aerators. The expression at low concentration levels to 0<sup>th</sup> order expression at relatively high concentration levels was demonstrated by Odegaard et al. [29]. An phrase of 1/2<sup>nd</sup> order has been used to represent the change from low to very high substrate concentration. As shown in the figure, the substrate concentration is the only factor that limits the rate of substrate removal at low concentration levels, where a slight change in concentration might result in a corresponding difference in degradation. This pace has been constrained by the substrate's diffusion to the biofilm at high substrate concentration levels. This is why kinetics, which have been characterized by 1/2<sup>nd</sup> order kinetics, begin to change from being dependent on concentration to being dependent on diffusion as the concentration increases. Eventually, the kinetics cease to be responsive to the substrate concentration. The rate of elimination is 0<sup>th</sup> order dependent on enzyme efficiency at relatively high substrate concentration levels [30].

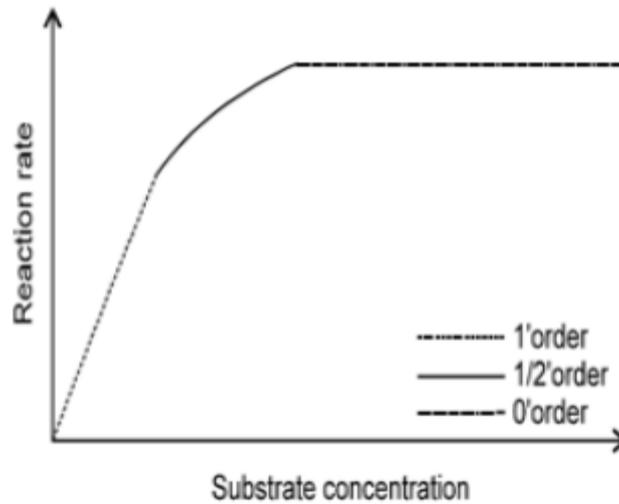


Figure (2): Description of the kinetics utilizing the reaction rate as a function of substrate concentration [30].

### Results and Discussion

Proposed SBR's performance for biofilm reactors in 1997. According to Zou et al. [31], this integrated system is (SBBR). The SBBR was created by combining the SBR with the biofilm on a layer of supporting material to remove phosphorus, nitrogen, and organic matter from household wastewater simultaneously. SBBR techniques can grow bacteria in freely suspended water by using the carriers, which also act as a barrier to protect the biofilm. On carriers with a larger surface area, there may be more places for bacteria to absorb and grow. because it combines the advantages a biofilm and SBR, the (SBBR) concept has attracted a lot of interest. In pure biofilm reactors, biofilm typically forms on carriers; in SBBR, however, suspended activated sludge and biofilm coexist in the same vessel. The reactors are mixed by aeration; in the SBBR, the biomass grows as a biofilm on microscopic plastic carriers that flow freely into the effluent [32]. Plastic biofilm carrier properties are displayed in Table (1). Biomass occurs on the carriers that are free to move about in the reactor tank. In contrast to traditional suspended biomass systems, where cell loss finally occurs due to the inadequate capability for sludge settling, biomass fixed upon support media may result in increased solid retention in biological reactors. Consequently, biofilm-based methods can demonstrate a greater volumetric treatment capacity, meaning they can treat the same volume of wastewater in a smaller volume. [30].

Matos et al. [33], investigated biomass attachment and biofilm formation and found that the hydrodynamic conditions created in the SBBR and the support geometry were important factors in biofilm formation. Biofilms were shielded from erosion and abrasion detachment mechanisms by the supports increased internal surface area, which encouraged biofilm accumulation. In order to remove ammonium, ammonium was first converted to nitrate and then denitrified. The elimination of acetate was facilitated by two primary processes (biomass increase and PHB storage as an internal polymer).

A nitrogen removal of 79% was achieved by Villaverde et al. [34] when they used SBR reactor short-cycled aeration for treating high-nitrogen industrial waste water.

Table (1):Plastic biofilm carrier characteristics [35]

Manufacturer	Name	Bulk Specific Surface Area <sup>1</sup>	Dimensions (Depth; Diameter)	Carrier Photograph
Veolia Inc.	AnoxKaldnes™ K1 or K1 Heavy	500 m <sup>2</sup> /m <sup>3</sup>	7 mm; 10 mm	
	AnoxKaldnes™ K3	500 m <sup>2</sup> /m <sup>3</sup>	12 mm; 25 mm	
	AnoxKaldnes™ Biofilm Chip (M)	1,200 m <sup>2</sup> /m <sup>3</sup>	2 mm; 48 mm	
	AnoxKaldnes™ Biofilm Chip (P)	900 m <sup>2</sup> /m <sup>3</sup>	3 mm; 45 mm	
	AnoxKaldnes™ Matrix™ Sol	800 m <sup>2</sup> /m <sup>3</sup>	4 mm; 25 mm	
Headworks BIO (* Licensed by: Infico Degremont, Inc.)	ActiveCell™ 450 *	402 m <sup>2</sup> /m <sup>3</sup> (450 m <sup>2</sup> /m <sup>3</sup> reported by IDI)	15 mm; 22 mm	
	ActiveCell™ 515 *	485 m <sup>2</sup> /m <sup>3</sup> (515 m <sup>2</sup> /m <sup>3</sup> reported by IDI)	15 mm; 22 mm	
	ActiveCell™ 920	680 m <sup>2</sup> /m <sup>3</sup>	15 × 15 × 10 mm (L × W × D)	
AcqWise	ABC4™	600 m <sup>2</sup> /m <sup>3</sup>	14 mm; 14 mm	
	ABC5™	650 m <sup>2</sup> /m <sup>3</sup>	12 mm; 12 mm	
Entex Technologies, Inc.	Biopartz™	589 m <sup>2</sup> /m <sup>3</sup>	14 mm; 18 mm	
Siemens Water Technologies Corp.	CM-100™	750 m <sup>2</sup> /m <sup>3</sup>	9 mm; 13 mm	
Biowater Technology	BWT15™	828 m <sup>2</sup> /m <sup>3</sup>	15 × 15 × 5 mm (L × W × D)	
	BWTx™	640 m <sup>2</sup> /m <sup>3</sup>	15 × 15 × 10 mm (L × W × D)	

Al-Aboodi et al. [36] constructed an aerobic Sequencing Batch Reactor (SBR) in Basrah City, South Iraq, to find out which one offers the best effectiveness of removal for COD, NH<sup>4</sup>-N, and TN from household wastewater. The average elimination rates of COD, NH<sup>4</sup>-N, and TN under the first cycle mode of the SBR system were 83.33%, 69.23%, and 63.33%, respectively, according to the results. The removal efficiencies were 89.71%, 75.56%, and 67.07% for COD, NH<sup>4</sup>-N, and TN respectively, under the second cycle mode.

Ros and Vrtovsek [37], founded a connection with the P concentration in the original wastewater and the P removal, but that N removal was independent of the initial P concentration. Artificial wastewater was used in each experiment.

According to Åhl et al. [38], the aeration system also provided enough oxygen to make the biofilms' outer layers aerobic and able to demonstrate comparatively quick biodegradation. After growing, the biofilms partially separated from the carrier, and the liquid conveyed the separated segments into the secondary clarifier for separation. This system produced ten times less than biologically-made solid the AS systems.

Due to a steady quantity of residual microbial products from the biological processing inside the reactor, Dulkadiroglu et al. [39] discovered that the effluent COD had been between 20 and 30 mg/l, when SBBR was fed residential sewage at 400 mg/L.

Zhang et al. [40] looked into the possibility of directly adding anammox to the treatment of low strength and low C/N ratio home wastewater using a (SBBR) with sponge carrier. Regular nitrifying activated sludge was used to inoculate the SBBR, which was operated at room temperature.

According to Ødegaard [41], in order for the carriers to be free, the filling ratio should be less than 70%. The capacity regulate the loading rates of surface area inside the bioreactor by adjusting the fill ratio of carrier elements is one of the process's main advantages. This makes it a cost-effective treatment option by enabling high-rate treatment to take place in a compact area.

Pollice et al. [42], demonstrated that, in an SBR process with oxygen limitation, at 30°C, and with a pH controlled at 7.2, a partial nitrification of nitrite was consistently achieved, independent of sludge age.

In an 8-hour cycle, Rodgers et al. [43], ran a laboratory-scale SBBR fed with synthetic wastewater of household strength; the removal of suspended particles and COD was reported to be 93% and 95%, respectively, and the organic load was 1.5 kg COD/m<sup>3</sup>. d and the surface organic load were 3.7 g m<sup>2</sup>/d.

Ozturk et al. [44], In a lab-scale, the suitability of SBR and SBBR packed with K1 carrier media for treating dairy effluent was assessed. When compared to SBR, SBBR performed better in terms of removing COD, ammonium, and phosphate. also, under the same operating conditions, SBBR effluent quality was more stable than SBR.

Loukidou and Zouboulis [45], used two porous supports (granular activated carbon particles and polyurethane) to assess the effectiveness of SBBR for eliminating nitrogen and organic carbon.

González et al. [46], assessed an SBBR efficacy in the treatment of sulfamethoxazole solutions that have been pre oxidized and discovered that it was a successful technique for treating wastewaters containing biorecalcitrant medications like sulfamethoxazole.

Keller et al. [47], examined the impact of pretreatment abattoirs and process modifications on the BNR capability using two bench scale SBR. The reactors' maximum operational volume was roughly five liters, and they were run at room temperature (20±2°C). Overall, the entering carbon was removed with very good efficiency, especially when it came to the BOD, which dropped to extremely low levels at the operation. It must be considered that the residual COD is not biodegradable. This portion is actually pretty tiny, making up only around 2% of the COD that was first found in the wastewater.

For the removal of ammonia -N and p-nitrophenol, Goh et al. [48], found that SBBR performed better than SBR.

### Conclusion

This paper referenced of the published articles that discussed the use the use of sequencing batch biofilm reactor (SBBR) method to treatment various wastewater kinds. The removal rate could be increased by adjusting the SBBR system's configuration and parameters, such as carrier selection, Temp., filling ratio of biofilm, cycle time, and carrier surface. Several researchers have used the (SBBR) system as an alternative to traditional treatment methods in wastewater remediation processes To eliminate contaminants that include organic and inorganic from various wastewater types. The study's findings Demonstrate the efficacy of SBBR for the treatment of different wastewater types as well as its dependability when numerous operating variables with investigated ranges are present. In addition, the SBR with biofilm (SBBR) being a much better than SBR alone for treatment different wastewater.

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