Sequencing Batch Biofilm reactor (SBBR) Performace in Domestic Sewage Treatment: Mini Review

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ABSTRACT

This article seeks to give a general overview of the techniques researchers have employed to enhance the efficiency of Sequencing Batch Biofilm Reactor (SBBR) in domestic sewage treatment. One of the most recent uses of sequencing batch reactor treatment technology is the sequencing batch biofilm reactor (SBBR), which is created when the SBR is paired with biofilm development on the surface of the support material. The assessment of the available literature conducted here demonstrates the effectiveness and adaptability of this technique for the removal of phosphorus, nitrogen, and organic materials under diverse environmental conditions. The review contains pertinent laboratory experiments that were conducted.

Keywords: Biofilm, Wastewater treatment, Nitrogen Removal, Sequencing Batch Biofilm Reactor (SBBR), Support.

Introduction

In order to preserve the quality of aquatic systems, biological reactors are employed in wastewater treatment to decrease nutrients and organic carbon from the water. As more strict effluent quality criteria are implemented, a number of improvements to currently used technology as well as innovative biological reactors have been created (Matos et al. 2011). Because it can efficiently remove nutrients and organic carbon from municipal and industrial wastewater in a single unit while successively trying to maintain the aerobic and anoxic phases, the batch sequencing reactor (SBR) has drawn a lot of interest in this field (Fongsatitkul et al. 2008). In the sequential suspended growth (SBR) process, all important phases—namely, fill, react (aeration/mixing), settle, draw, and idle—occur in the same tank in a predetermined order. Because it is simple to change, replace, add, or delete particular treatment phases, the SBR provides a significant lot of organizational flexibility (Al-Rekabi et al. 2007). The procedure is also more versatile because each step's time can be individually changed.

. Although conventional suspended biomass reactors have many disadvantages, such as low volumetric transformation, for instance, necessitating volumes of the large reactor, low velocity for sludge settling necessitating large tanks for sedimentation, and significantly increasing bio-sludge generation, they are still widely used. In order to address the challenge of the development and maintenance of suspended activated sludge flocs on the surface of support material, Wilderer 1997 proposed the performance of SBR to biofilm reactors. This integrated system is known as a Sequencing Batch Biofilm Reactor (SBBR) (Zou et al. 2012). The Sequencing Batch Biofilm Reactor (SBBR), a more recent application of sequencing batch reactor treatment technology for the simultaneous removal of organic matter, nitrogen, and phosphorus from domestic wastewater, was created by combining the SBR with biofilm structure on the surface of supporting material.

Through utilizing the carriers, SBBR methods can cultivate microorganisms in the water that is suspended freely while also providing a protective barrier for the biofilm. More locations for microbes to absorb and flourish may be available on carriers with a greater surface area.

High biomass concentrations can be maintained in SBBR systems irrespective of the organismal assemblages' sedimentation properties and the hydraulic holding period of the reactor. SBBR reactors are particularly suitable when the required microbial population increases slowly or when biomass production is minimal (Vieira et al. 2009).

The Sequencing Batch Biofilm Reactor (SBBR) approach has drawn a lot of interest since it can combine the benefits of both an SBR and a biofilm reactor. Biofilm usually forms on carriers in pure biofilm reactors; however, in SBBRs, biofilm and suspended activated sludge coexist in the same vessel. Aeration is utilized to mix the reactors; the biomass develops as a biofilm in the SBBRs on tiny plastic carriers that pass freely into the effluent (Aygun et al. 2014).

It has been the subject of numerous investigations to alter the conventional SBR for the purpose of expanding the surface area for biofilm formation. With a greater efficiency than traditional SBR, SBBR is used to treat home wastewater, dairy wastewater, tannery wastewater, textile wastewater, and wastewater for the removal of nutrients. The treatment of home wastewater has been the subject of recent investigations examined in this paper using the SBBR laboratory.

Lab-scale sequencing batch biofilm reactor (SBBR)

Numerous effective biological reactors have been developed, and when compared to conventional plants, they have a high degrading performance, a compact design, and an ecologically friendly operation.

Ding et al. (2010) built a laboratory-scale Sequencing Batch Biofilm Reactor (SBBR) with a smart control design to determine the impact of the C/N ratio on nitrogen removal as well as simultaneous nitrification and denitrification (SND) in the reactor (ICS). Four (C/N) ratios—3.8, 6.8, 12.5, and 22.0—were applied to a biological sponge biofilm carrier with a porosity of 98 percent. The outcomes demonstrated that, as shown in Fig. 1, the 12.5 C/N ratio was optimum for the concurrent reduction in SBBR for the nitrogen and COD, and that the efficiencies of removal for ammonia nitrogen (NH_3-N), total nitrogen (TN), and COD at 7 hours after the HRT were 90%, 87%, and 95%, respectively. Additionally, a C/N ratio of 12.5 had a 98% efficiency for simultaneous SND processes in the SBBR.

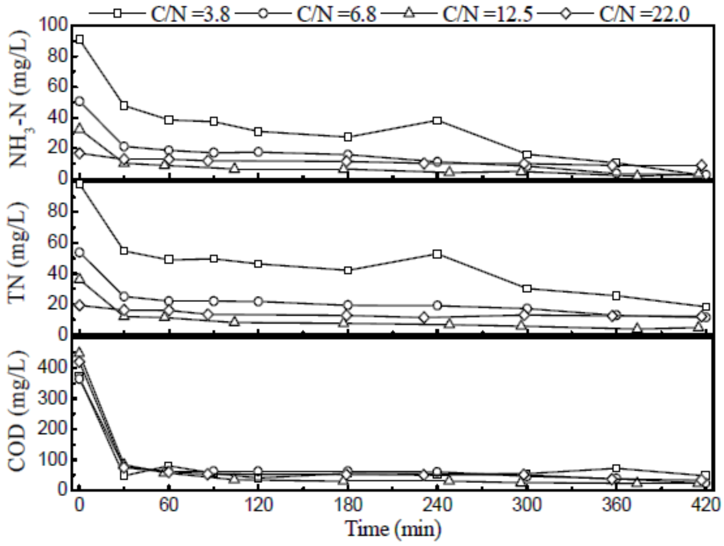

Figure ١ : Profiles of concentrations for NH3-N, TN and COD at the initial C/N ratios of 3.8, 6.8, 12.5 and 22.0 (Ding et al. 2010)

Researchers examined the impact of employing SBBR to treat low-temperature household wastewater (Zou et al. 2012). Bacteria were grown on ceramics as carriers (Fig. 2), and the biofilm thickness measured there ranged from 192 to 450 m, indicating that sludge was present in large quantities in the SBBR. Operation 1 measurements were made at room temperature (16.6 C^0), while Operations 2 and 3 were done at low temperatures (9.6, 8 and 8.8) C^0, respectively.

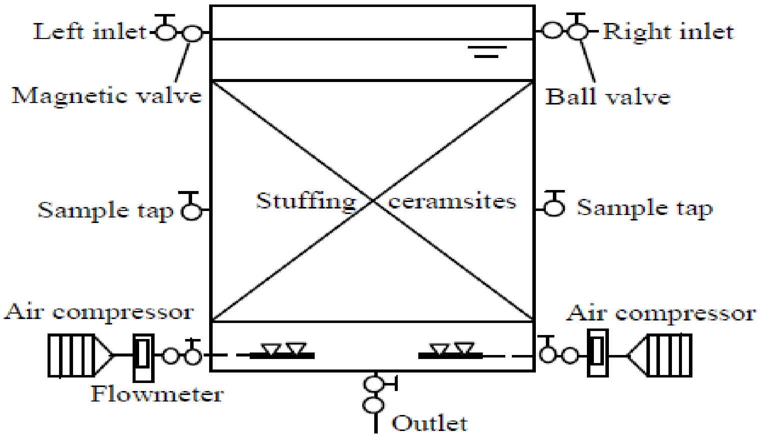

Figure 1: schematic diagram of the experimental SBBR operation equipment (Zou et al. 2012)

The typical removal ratio for COD, NH_4+-N, and turbidity at room temperature were 93%, 98%, and 92%, respectively, achieving high removal efficiencies. However, as demonstrated in Fig. 3, the removal effectiveness of SBBR decreased when the measured temperature dropped to 9.6 C^0 while in use. Microbial activity was reduced at low temperatures as a result. Also, when the temperature dropped, the rate at which NH_4+-N was removed was considerably impacted. According to the study's findings, boosting biomass and extending SBBRR aeration duration could successfully offset the reduction in removal effects brought on by low temperatures.

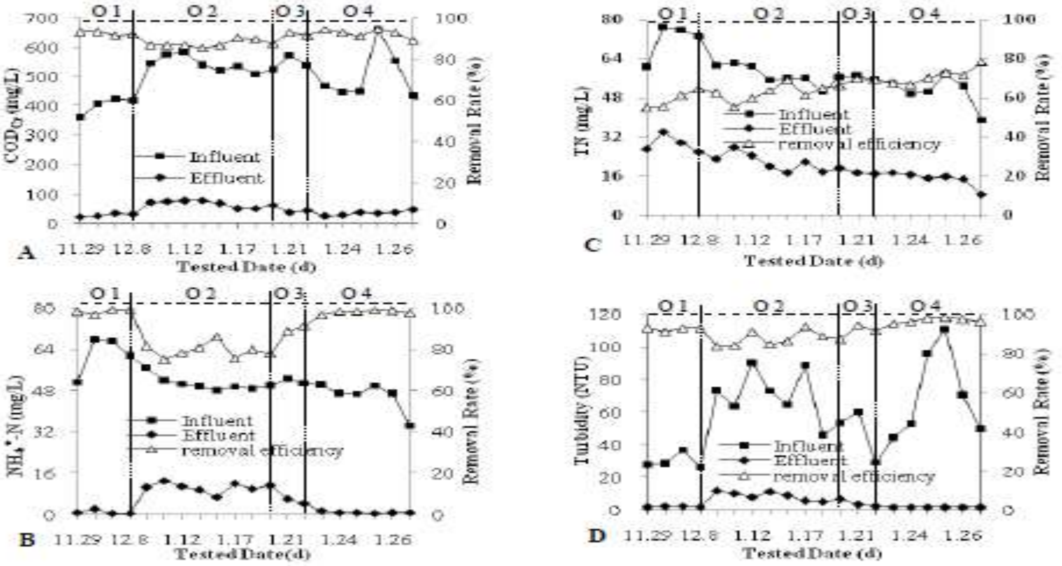

Figure 2: Details of COD, NH4-N and turbidity in various operating patterns at 16.6 C^0, B at 9.6 C^0, C at 8 C^0, and D at 8.8 C^0 (Zou et al. 2012).

Treatment of Chinese home wastewater served as a gauge of the SBBR system's effectiveness (Jin and Yao 2012). They created a sequencing batch biofilm reactor (SBBR) for lab use that uses numerous fiber strands fastened on an acrylic cylinder's surface (70 mm in diameter and 200 mm in height) to transport microorganisms. The particular surface area is bigger in this system than in the usual one, and oxygen partially permeates the biofilm, creating a gradient in the oxygen concentration. Denitrification can proceed because the areas close to the carrier-liquid interface are high in oxygen, where the predominance of aerobic microorganisms and the areas close to the cylinder are devoid of oxygen, where denitrification bacteria are the predominant populations. In other words, nitrification and denitrification can be finished in the same operational plant. Additionally, the container acts as a filter, reducing the number of suspended particulates in the effluent. The outcomes demonstrated that because the reaction was completed in three hours, COD elimination efficiency met or reached the full value, up to 90%. The nitrification phase of NH_3-N required four hours, and as indicated in Fig. 4, the effectiveness of NH_3-N removal reached its highest level. NO_2-N concentration gradually fell until NH_3-N concentration reached zero, after which it slowly climbed until it also eventually reached zero. Before TN concentration decreased gradually to achieve the balancing locate of NO_3-N, NH_3-N concentration reduced rapidly with response time, then increased gradually. As a result, the nitrification and denitrification processes in the SBBR system came to an end when the NH_3-N concentration reached zero or the least value.

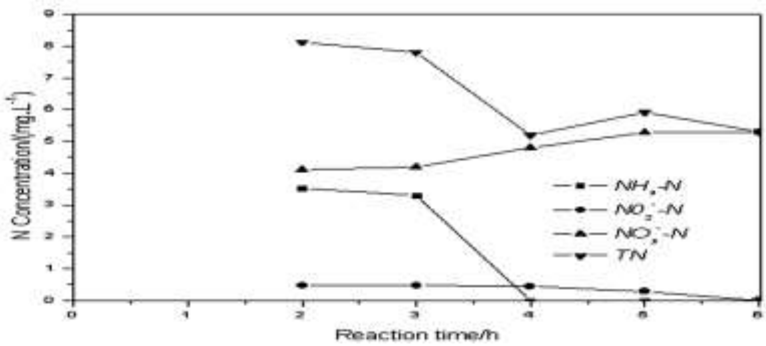

Figure 3: Variation profile of different Nitrogen form (Jin and

With the removal of organic carbon, nitrogen, and phosphorus from residential wastewater, the execution of the sequencing batch reactor (SBR) and sequencing batch biofilm reactor (SBBR) was compared (Gururaj and Kumar 2015). They first worked with SBBR as traditional SBR, which was later transformed into SBBR by combining 10% of the liquid volume of SBR with polyurethane foam cubes from a Porous Biomass Carrier. Both reactors received all of the following: fill, anaerobic phase, aerobic phase, settle, and decant. Following 179 days of operation, SBR initially showed that phosphorus release was 13.7% and COD removal in the anaerobic case was less than 7.5%. On day 74, a 70.4% P absorption was visible in the effluent phosphorus concentration. After day 125, there was an 80% P absorption as measured by the effluent phosphorous concentration. Beginning on day 120, denitrification was observed in the anaerobic case, with effluent ammonia nitrogen concentrations of smaller than 2 mg/l. Beginning on day 26, SBBR demonstrated consistent performance; uptake of COD and release of phosphorus were 99% and 65%, respectively, with effluent concentrations of lower than 4 mg/l and 3.5 mg/l. The ammonia nitrogen concentration in the effluent was less than one milligram per liter, indicating complete denitrification. As shown in Table 1, both reactors (SBR and SBBR) performed well in terms of phosphorus uptake, nitrification, and denitrification. According to Table 1, SBBR outperformed SBR in terms of nitrate nitrogen reduction. While phosphorus removal was greater in SBR than in SBBR.

Table 1:Comparison of Performance of SBR and SBBR (Gururaj and Kumar 2015)

Parameters	SBR	SBBR
	Anaerobic Phase	
P at the end of anaerobic phase, mg/L	23.5	23.2
P release (%)	68.77	56.25
COD at the end of anaerobic phase, mg/L	<6	<4
COD uptake (%)	96.63	99.07
Nitrate nitrogen Reduction, mg/L	7.62	6.16
Denitrification (%)	88	100
	Aerobic Phase	
Phosphorus at the end of aerobic / anoxic phase (mg/L)	2.1	3.5
P Uptake (%)	91.06	65.52
Ammonia-nitrogen removal, mg/L	1.1	13.6
Nitrification (%)	89.93	94.05
Nitrate nitrogen in the treated wastewater, mg/L	15.5	10.8

For the SBBR reactor's nitrification and denitrification processes to be successful, a unique method for selecting an appropriate carrier was proposed by (Sarti et al. 2016). Low-density polyurethane, mineral coal (MC), polyurethane foam, and basaltic gravel are the four biofilm carriers—that were employed for household wastewater with a high ammonium concentration. Among the examined biofilm carriers, the investigations using flow cells and (DO) microsensors allowed for the identification of the optimum biofilm carrier concerning the thickness of the aerobic and anaerobic layers. Due to the greater overall biofilm thickness (aerobic and anaerobic layers) as shown in Fig. 5, the flow cell experiment findings showed the possibilities of MC as a carrier of the biofilm. To treat sewage with a max ammonia concentration, the SBBR's achievement incorporating biomass captured in MC can be regarded as a workable reactor design. containing an influent ammonia concentration of 112 to 392 mg/l, it achieved a 95% average N removal rate (for the nitrification process) and 72% (for the denitrification process).

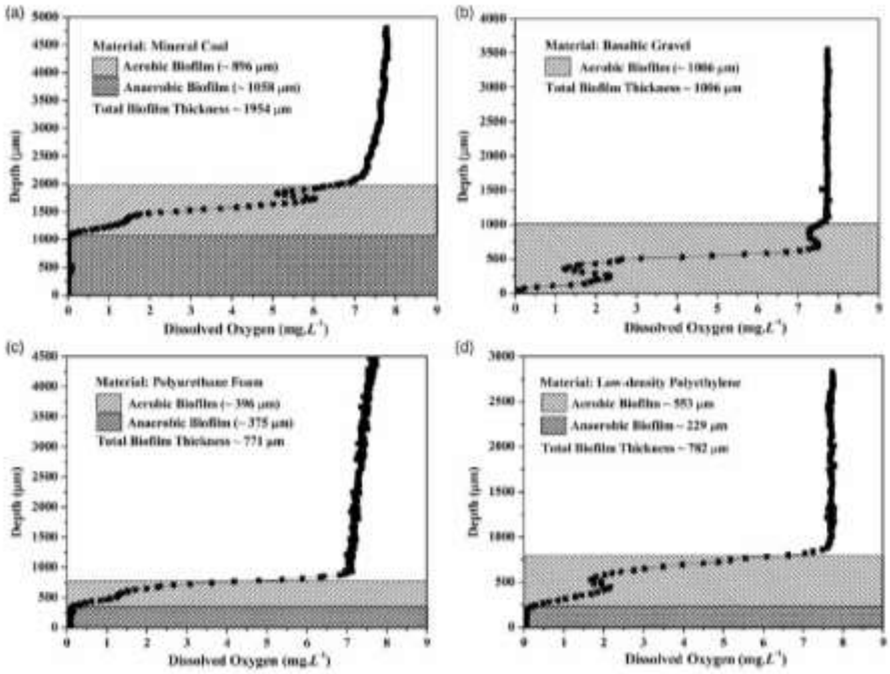

Figure 1 : Profiles of DO in biofilm carriers. (a) Mineral coal; (b) basaltic gravel; (c) polyurethane foam; (d) low-density polyethylene (Sarti et al. 2016)

In order to create a unique algal-bacterial symbiosis (ABS) system, (Tang et al. 2018) offered a viable technique for improving the removal of nutrients from residential sewage by using algae to sequence batch biofilm reactors (SBBR). Algae can utilize CO_2 that bacteria exhale to create O_2, which helps the metabolism of the bacteria. With the algae-assisted SBBR, the removal efficiency of total nitrogen and phosphorus increased, going from 38.5% to 65.8% and from 31.9% to 89.3%, respectively. Both the development of the ABS system and the enhancement of the algae were facilitated by the carriers installed at the reactor's top. At the stable stage, the chlorophyll raised to 3.59 mg/g, that's 4.07 times more than it was suspended. Further evidence that the sludge and algae retention times may be separated came from the fact that the replacement of the bio carrier and the discharge of sludge occurred independently. Overall, compared to other technologies used, Without increasing operation time or aeration need, the ground-breaking A-SBBR system considerably increased both nitrogen and phosphorus removal efficiency. As a result, the A-SBBR system suggested in this investigation demonstrated excellent utilization possibilities in creating sophisticated and efficient methods for treating sewage.

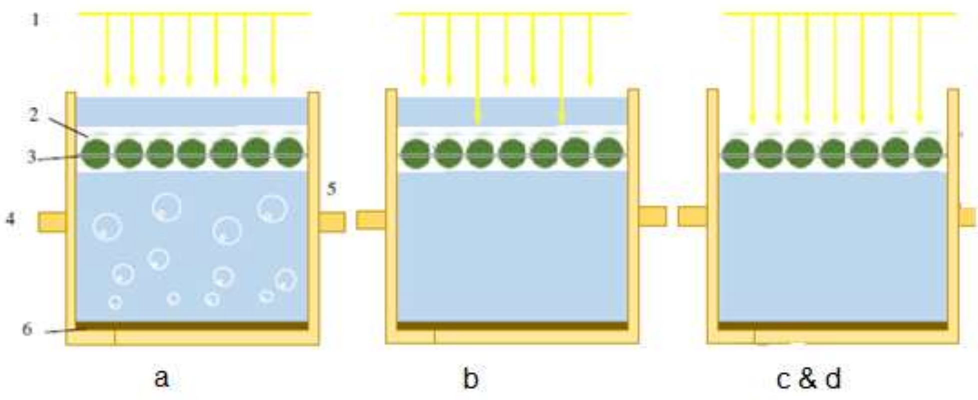

Figure ١ : The whole A-SBBR system and operation process in each phase (Tang et al. 2018)
(a) Aeration, (b) Settling, (c) Decant, (d) Feed.
1. Light source, 2. Algae based carrier, 3. Supporting layer, 4. Inlet, 5. Outlet, 6. Aeration diffusor.

Using a sequencing batch biofilm reactor (SBBR) with sponge carrier, (Zhang et al. 2018) investigated the likelihood of adding anammox directly into the treatment of household wastewater with low strength and low C/N ratio. The SBBR was run at room temperature and inoculated with regular nitrifying activated sludge.

Anammox bacteria were found in greater numbers and were more active throughout the start-up period, according to the data. Achieving the desired nitrogen removal performance took 101 days, and it remained constant in the SBBR even at cold temperatures (15 °C). The anammox reaction may be the main mechanism for nitrogen removal because the average nitrogen removal efficiency was about 88% and the effluent TN was 6.3 mg N/l. The partial nitrification-anammox process benefited from biofilm, restricted aeration, and alternate anaerobic, aerobic, and anoxic patterns. (Elhawary et al. 2019) examined how organic and nutrient removal in sequencing batch biofilm reactor (SBBR) depended on biofilm filling rates, different cycle durations, and organic loading rates Fig.7. The synthetic sample they used had a C: N: P ratio of 100: 10: 1.9, which was extremely comparable to domestic wastewater. The findings suggest that, as shown in Fig. 6, a 25% medium filling rate resulted in greater BOD, COD, TN, and TP removal efficiency than a 50% fill rate. Changes in the (aeration-settling) cyclic time from (8-2) to (6-4) hr also led to an increase in the removal efficiency of TP and TN, which went from 72 and 53% to 76 and 57%, respectively. When organic loading rates were higher, more BOD, COD, and TP were removed.

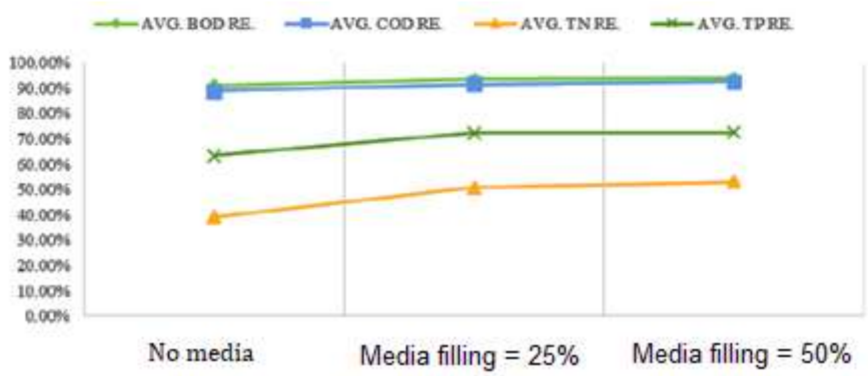

Figure 4: Average removal rates for 0.84 (Kg COD/m3.day) & aeration cycle 2-8 hrs. (Elhawary et al. 2019)

In order to enhance biological nitrogen removal's effectiveness, (Li et al. 2020) treated residential sewage using the sequencing batch biofilm reactor SBBR with a luffa cylindrical sponge carrier. It has also been researched how temperature affects the removal of TN from reactor sewage and how different kinds of nitrogen alter. TN has an 82.25 percent removal rate when the temperature is 30 °C, and 12.46 mg/L of TN is present in the effluent as shown in Fig. 8. The approach produces a strong treatment effect when the controller temperature is between (20 and 30 °C). The change in NH_4+-N influence affects the SBBR system's denitrification process output because the concentration of NH_4+-N influence is not high. While the concentration of NH_4+-N becomes 40-50 mg/L, the treatment effect of the SBBR system is the greatest. Additionally, luffa fillers have high development possibilities as a normal and affordable biological carrier and to hang films more quickly, the impact of enhanced nitrogen removal technology, and other advantages.

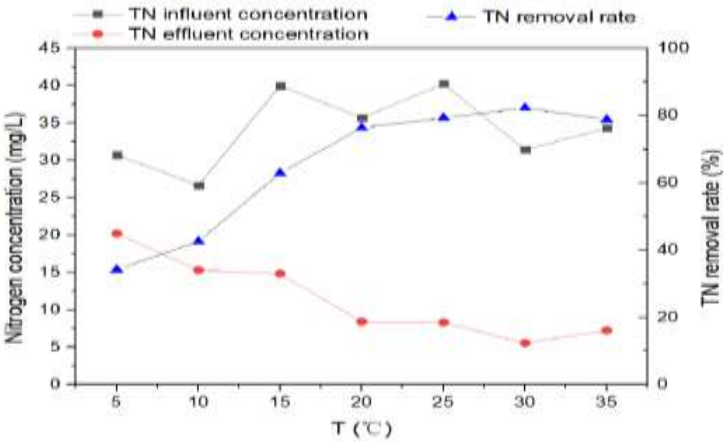

Figure 5: Effect of temperature change on TN removal effect (Li et al., 2020)

The impact of adding magnetic material on N_2O creation and release from a sequencing batch reactor treating residential sewage at low temperatures was investigated (Feng et al. 2020). In contrast to an external magnetic field, a constant, weak, internal magnetic field will be created inside the activated sludge by adding a proper quantity of magnetic powder to the reactor. In varied degrees, the 20–80 Gs fields of magnetism created by adding (1–4 mg/L of powdered magnetism) will enhance treated wastewater. The magnetic powder also improved nutrient removal at a low temperature while reducing N_2O production and emission Fig.9. Additionally, a 76.7% reduction in the N_2O conversion rate has been observed. The field of magnetism controlled the dispersion of microorganisms and modified the dominating denitrifying functional bacteria due to the magnetotactic of microorganisms

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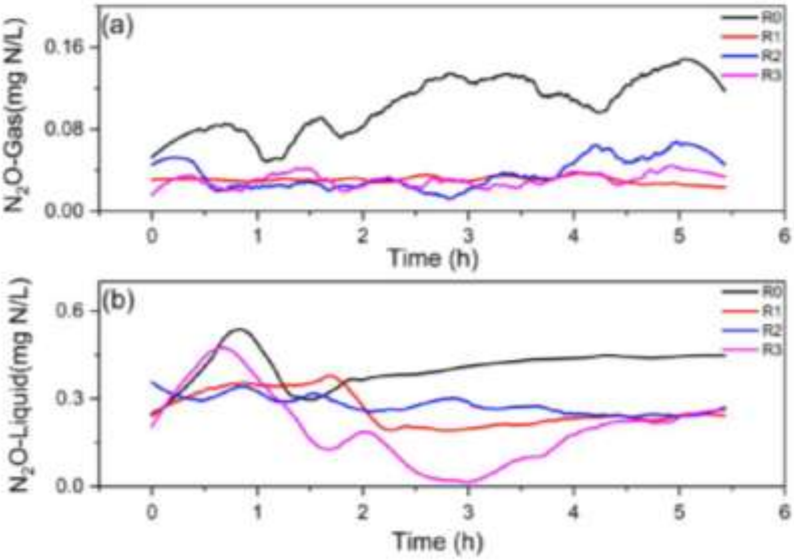

Figure 9: Dissolved and gaseous N2O concentrations in the four different reactors over time. (R0, R1,R2, R3 are : 0, 1, 2, and 4 mg/L) (Feng et al. 2020)

Conclusion

This study's goal was to evaluate various approaches used by researchers to enhance the Sequencing Batch Biofilm Reactor's (SBBR) capability for domestic sewage treatment. The review studies indicated that the removal rate of NH_4, NO_3, and COD from domestic wastewater can be increased by modifying the configuration and conditions of the SBBR system, such as: selecting an appropriate carrier, temperature, biofilm filling rate, hydraulic detention time, the surface of carriers, cycles duration, and organic loading rates. Generally, SBBR shows potential for treating sewage from homes in an efficient manner.

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