

Effectiveness of Sequencing Batch Biofilm Reactor Technology to Treat Domestic Wastewater in Basrah City

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ABSTRACT

The efficiency of a Sequencing Batch Biofilm Reactor (SBBR) for domestic wastewater treatment in Basrah was assessed. The experiments were carried out via a laboratory-scale SBBR cylindrical vessel used for this study, with geometric volume of 26 L, having an internal diameter of 15 cm, a height of 40 cm, and a working volume of 13 L. After a one-month start-up cycle for biofilm growth on the fibrous filler, the SBBR research test period lasted two months. The SBBR was run for three weeks to ensure that the biological treatment systems were mature and those steady-state requirements were reached, throughout the starting-up phase of operation, the removal efficiency for COD, NH₃-N, TN, and TP were 95%, 89%, 85%, and 93% respectively. The impact of aeration time on the SBBR efficiency was also tested by removal of COD, ammonia, total nitrogen TN, and total phosphorous TP under different levels of dissolved oxygen DO (2.0 – 6.8) mg/L. The SBBR method proved to be an effective method for treating domestic wastewater in Basrah city. The COD, NH₃-N, TN, and TP concentrations in the effluent were 42, 6.7, 9.0, and 1.0 mg/L, respectively, with the removal efficiency rates of 90.32 %, 86.24 %, 84.75 %, and 84.38 %. When comparing the SBBR effluent value to the WHO, European, Iraqi, and Chinese discharge standards, it was observed that the COD concentration (42 mg/L) met these standards. while ammonia (6.7 mg/L), TN (9.0 mg/L), and TP (1.0 mg/L) met the WHO, European, and Chinese standard only.

Keywords: SBBR, domestic wastewater, COD, NH₃-N, TN, TP.

INTRODUCTION

In order to comply with the effluent requirements before discharge to water streams, stricter effluent specifications necessitate more efficient wastewater treatment [Güçlü and Dursun, 2010].

SBBR is a biological system for treating wastewater that utilizes microorganisms (usually attached to plastic carriers). It is based on the sequencing batch reactor (SBR). SBBR has been widely studied and applied as a modern biological wastewater treatment method due to its many benefits, including more biomass but less sludge, easy and simple operating, and efficient sewage treatment [Gieseke et al., 2002].

SBBR has a number of advantages over a sequencing batch reactor (SBR), represented by more biomass and higher removal performance,

lesser sludge and sludge conglomeration, higher volumetric loads, and improved process stability against shock loadings [Ding et al., 2011]. SBBR has many advantages over conventional biofilm systems and suspended activated sludge systems. It incorporates the characteristics of activated sludges and biofilm processes, allowing the device to withstand a sudden shock load [Zhang et al., 2006]. Simultaneously, the biofilm carriers create a dissolved oxygen concentration gradient from the surface to the inside, allowing direct denitrification to occur in both anaerobic and anoxic ecosystems [Fu et al., 2010]. Effective removal of many contaminants has been achieved using the SBBR process, and a most essential feature is it can conform to the variation in the village sewage; moreover, it is simple to install and maintain [Di Iaconi et al., 2004].

The sequencing batch biofilm reactor (SBBR), which alternates between anoxic and aerobic environments, is an effective method in removing phosphorus and nitrogen [Fu et al., 2010]. Furthermore, because of dissolved oxygen (DO) gradation throughout the aeration phase, in the internal part of the biofilm, SBBR provides an anoxic microzone [Choi et al., 2008]. There is a possibility to achieve a nitrification on the surface of biofilm and denitrification in the inner layers (simultaneous nitrification and denitrification (SND)) [Cassidy et al., 2000]. Therefore, SBBR has been used to eliminate (Phosphorus and Nitrogen) from different types of wastewaters simultaneously [Di Iaconi et al., 2004].

[Dulkadiroglu et al., 2005] found that the COD effluent had been in the range of 20–30 mg/l when SBBR was fed with domestic sewage at 400 mg/L COD, due to a stable amount of residual microbe products as part of the biological processing within the reactor. High COD removal efficiencies in the treatment of dairy sewage using SBBR at estimated organic loadings were performed [Abdulgader et al., 2009].

In order to obtain good removal efficiency, the reactor was continually aerated during the reaction process, as a result, the oxygen utilization rate (OUR) and consumption of energy are low. The Dissolved Oxygen concentrations and temperature are essential factors that influence the metabolic processes of microorganisms. The dissolved oxygen concentrations and temperature can an effect on the growth of nitrifying bacteria rate and actions [Andrade do Canto et al., 2008].

SBBR is already used in domestic wastewater treatment [Clifford et al., 2008, Sarti et al., 2007], dairy wastewater treatment [Zhan et al., 2006, Abdulgader et al., 2009], textile wastewater treatment [Park et al., 2010], tannery wastewater treatment [Di Iaconi et al., 2003], and for nutrient removal [Jin and Yao, 2012]. SBBR has a much higher pollutant removal performance than a traditional SBR [Singh and Srivastava, 2011]. Moreover, the possibility to enable wastewater denitrification in a (SBBR) by using an organic substrate in the form of acetic were investigated in addition to studying the characteristics of the sludge formed via SVBBR [Mielcarek et al., 2018, Kłodowska et al., 2018].

This study aimed to evaluate the effectiveness of SBBR in removing the pollutants via a laboratory-scale SBBR and compare the effluent with various international discharge standards.

MATERIALS AND METHODS

Figure 1 illustrates the laboratory-scale SBBR cylindrical vessel used in this study, geometric volume is 26 L with an internal diameter of 15 cm, a height of 40 cm, and a volume of working is 13 L. The SBBR was fabricated with transparent plastic, 4 mm thick material in order to observe biofilm and sludge in the reactor easily. In order to improve the mixture in the reaction phase, the feeds were added into the reactor from the bottom. Plastic units of fibrous filler were hung in the reactor, which measures 30 cm in length and has over a thousand fiber strands.

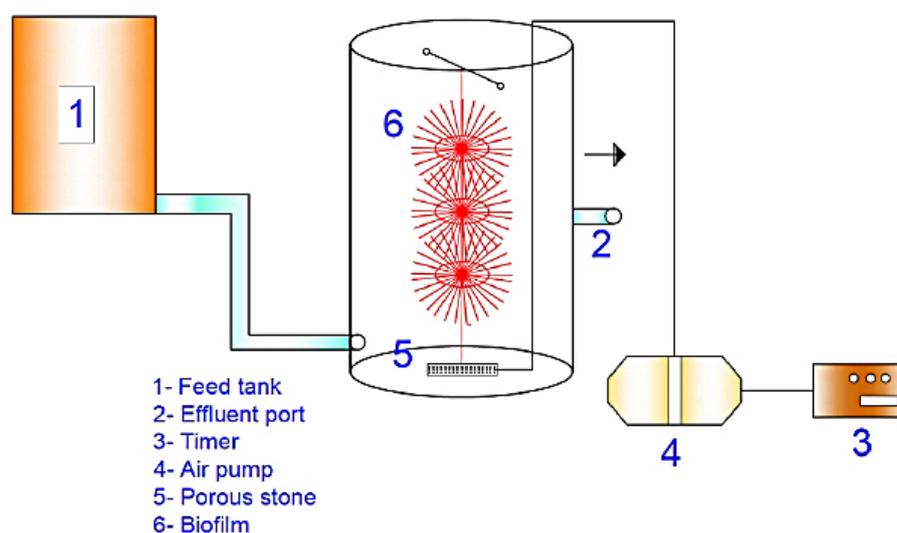


Figure 1. SBBR system schematic

There were many filaments scattered to create a wide surface area, and flexible fibers yarns swing with the wastewater in the SBBR reactor during aeration to boost mass transfer in the biofilm. During the acclimatization period, the 24-hour operating cycle included approximately a thirty-minute filling period. The reactor was supplied with air via an air pump, the aeration air diffusers were placed on top of the settling region to allow large particles disconnected from the biofilm to settle during the aeration process.

As a seeding material for the reactor, activated sludge was collected from a local municipal wastewater treatment plant. The operation of reactor procedures, such as feed, aerate, settle, and withdraw, were all monitored by timers. A cap was set over the reactor, but it was not sealed. The aerobic and anaerobic intermittent environment was set up by an air compressor. Normally, the status of microbes in the SBBR is affected by biofilm carrier, which is a critical parameter for the successful starting up of a reactor. Although the biofilm supports bacteria attachment, it also acts as a filter that prevents suspended solids (SS) and other contaminants from entering the treated water. As a result, the SS contents in the effluent in this SBBR system may be less than 0.5 mg/L, which is better than in conventional SBBR systems [Dinçer and Kargi, 2001].

Experimental Conditions

The wastewater in this research was collected from the discharge point of the manhole for many houses in the Abo al-Khaseeb area in Basrah city south of Iraq. As shown in table 1, the main characteristics of the sewage constituents used in this study were compared with universal concentrations of domestic wastewater.

With parameters such as BOD, COD, TP, and TSS, it is clear that raw Basrah sewage is of medium strength. Raw Basrah sewage, on the

other hand, has high strength with parameters like ammonia, TN, and TDS. The TDS levels were high due to increased salinity in Basrah water supply. The homes in Basrah city use septic tank systems to treat their wastewater on-site. When a septic tank is not properly maintained, high levels of nitrogen (Ammonia and TN) can be released into the sewage system.

During the time of acclimatization, Initially, in the reactor, 6 L of activated sludge is seeded with no additions, and the air was provided by diffusers, and the Dissolved Oxygen (DO) concentration is kept above 3.0 mg/L within the aerobic process for biofilm maturation, [Rusten et al., 2006]. In order to maintain the biofilm under suitable conditions, a minimum concentration of DO equal to 3 mg O₂/L was maintained in the SBBR reactor. The volume of exchange was set at 50 percent, and the temperature was controlled around 25–35°C in the experimental processes to sustain the high efficiency of microorganisms, which have a significant impact on their respiratory rate.

Start-up Reactor and operation

During the start-up phase, SBBR is operation at 12/24 h cycle times during a day that is composed of wastewater (fill 0.5 hr., anaerobic time 3.0 hr., aerobic time 8.0 hr., settle 1.0 hr., and discharge 0.5 hr.), a total of 12 hours. After a one-month start-up cycle for the biofilm growth on the fibrous filler, the SBBR research test period lasted two months. SBBR was run for approximately one month to ensure that the biological treatment systems were mature and that the start-up requirements were reached.

COD variations within the period of start-up

At the beginning stage during the start-up cycle, SBBR reduced up to 35 percent of COD, and the effluent concentrations were decreased by

Table 1. Comparison of the properties of Basrah sewage with a universal concentration of raw domestic sewage

Pollutants (mg/L)	Mean Values of raw wastewater (mg/L)	The Concentration of International Sewage [Metcalf et al., 2003]		
		Low	Medium	High
BOD	210	110	190	350
COD	430	250	430	800
Ammonia	48	12	25	45
TN	58	20	40	70
TP	6.5	4	7	14
TSS	270	120	210	400
TDS	4450	270	500	860

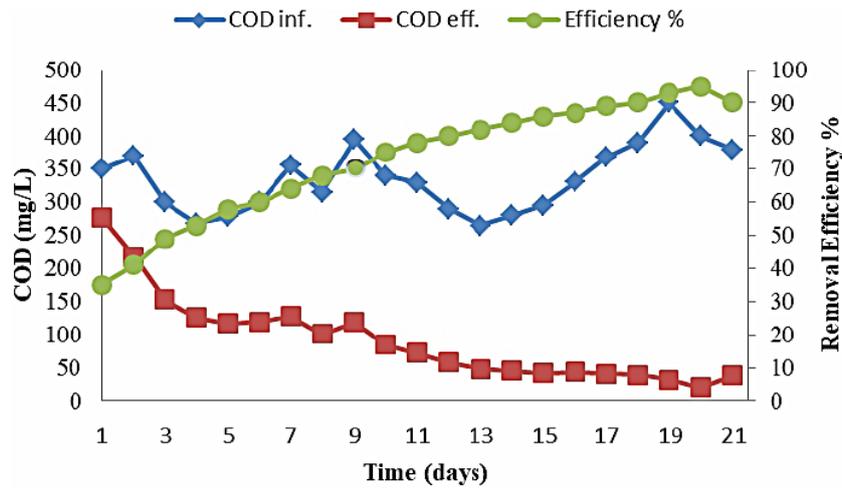


Figure 2. COD Variations within the Start-Up Period

about less than 280 mg/L, as clear in Figure 2. The removal efficiency of COD was steadily increased as the acclimation period was extended after two weeks, with a stability efficiency of 85–95 percent and an average effluent COD concentration of 36 mg/L. During the entire start-up phase, the COD removal efficiency in the reactor was nearly 95.0 percent, indicating that the reactor had achieved a successful start-up for COD removal.

NH₃-N variations within the period of start-up

The variance of NH₃-N was close to that of TN, as seen in Figures (3 and 4), and the NH₃-N effluent concentration is varied clearly. The amount of ammonia nitrogen was steadily degraded firstly, probably due to the poor metabolism of Ammonia Oxidizing Bacteria. The NH₃-N effluent concentration then decreased from 44 mg/L to 5 mg/L, meaning that the reactor was efficient in the removal of nitrogen.

TN variations within the period of start-up

The Total Nitrogen (TN) variations in SBBR are shown in figure 4. In the SBBR reactor, TN had some changes when compared to the COD trend. After one week, the TN levels in the reactor have dropped from 51 mg/L to 9.8 mg/L, indicating the removal efficiency of TN is high. The Total Nitrogen concentration tended to rise as domestication time progressed, but then gradually decreased to about 8.0 mg/L.

TP variations within the period of start-up

The Total Phosphorus (TP) concentration was reduced from 6 mg/L to 1.3 mg/L within the first two days., as shown in Figure 5.

However, on the fifth day, the total phosphorus concentration effluent in the SBBR reactor was raised to 3.2 mg/L; afterward, the total

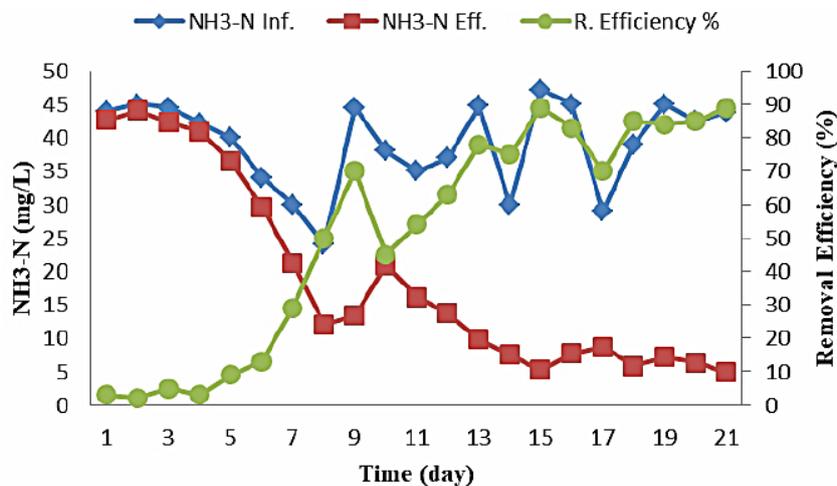


Figure 3. NH₃-N Variations within the Start-Up Period

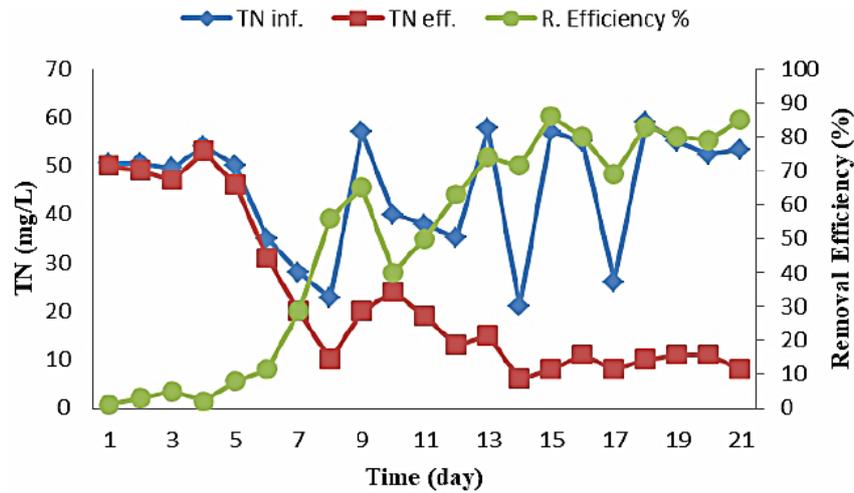


Figure 4. TN Variations within the Start-Up Period

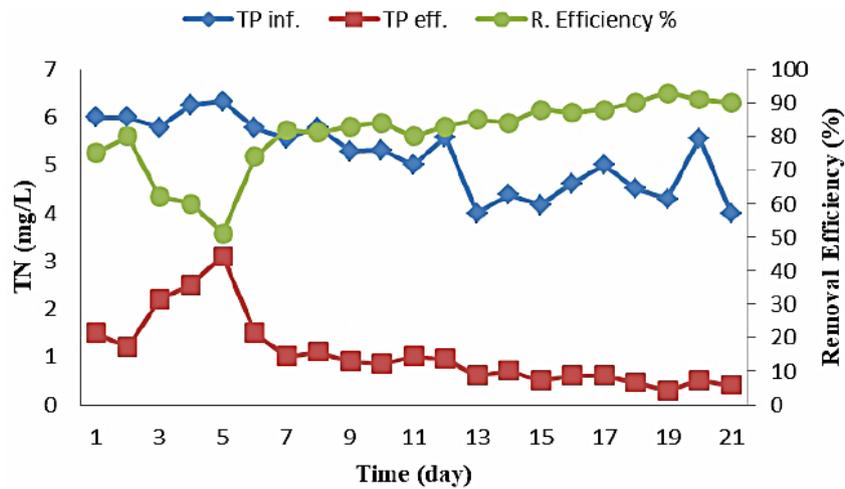


Figure 5. TP Variations within the Start-Up Period

phosphorus concentration effluent in the SBBR gradually decreased to less than 0.5 mg/L, and TP removal efficiency increased to 93.0 percent.

RESULT AND DISCUSSION

SBBR System in Normal Operation to Remove Different Pollutants

It is possible to divide the operation of SBBR into two conditions, start-up and steady-state. The system of SBBR was worked in the start-up

condition before the steady-state condition. When the removal of the rate of COD, NH₃-N, TN, and TP could be consistently held at 95 %, 89 %, 85 %, and 93 %, respectively, this indicates to the steady-state condition is reached. As shown in Table 2, the SBBR process was performed at steady-state in three different cycle operation modes, referred to as 1st, 2nd, and 3rd cycle modes.

Every SBBR operation cycle mode is consisted of the fill, react and draw phases. The react time for any cycle mode was the total cycle excluded the times for the fill and draw, within two months

Table 2. Three various operation modes for the SBBR system

Cycle mode	No. of period per day	Fill (min)	Aeration (hr)	Settle (hr)	Draw (min)
1 st Mode	Twice	15-30	4	1	15-30
2 nd Mode	Twice	15-30	5	1	15-30
3 rd Mode	Twice	15-30	8	1	15-30

of operation and acclimatization, the SBBR had reached a steady state. The average results of the third operation cycle mode for the SBBR system will be discussed in the sections below.

The COD, NH₃-N, TP, and TN effluent concentrations were measured within the 3rd operation cycle mode for 8 hours of aeration in order to evaluate a more suitable aerobic period. The concentration of DO was recorded between 2.0 and 4.9 mg/L. The concentration of COD dropped significantly in the first two hours of the aerobic process, reaching 299 mg/L, as shown in Figure 6. After 8 hours, the COD concentration has decreased to 42 mg/L. The concentration of NH₃-N dropped significantly and reached 16.36 mg/L after 6 hours, meaning that the nitrifying bacteria were active.

Since the conversion of NH₃-N to NO₃ and NO₂, the concentration of Total Nitrogen did not change rapidly at the beginning. After 5 hours, the TN concentration had dropped slightly, and after 7 hours, it had dropped to 15 mg/L Figure 7. The concentration of NH₃-N gradually decreased simultaneously, indicating that nitrification and denitrification were occurring at a similar time at this phase.

In the early aerobic stages, the TP concentration dropped quickly, indicating that the polyhydroxy butyrate (PHB) accumulated in the body has been completely oxidized.

As shown in Figure 8 after 5 hours, in the SBBR system, the Total Phosphorus concentration had stabilized at 2.25 mg/L, indicating that the phosphorus removal process had been accomplished. Aeration

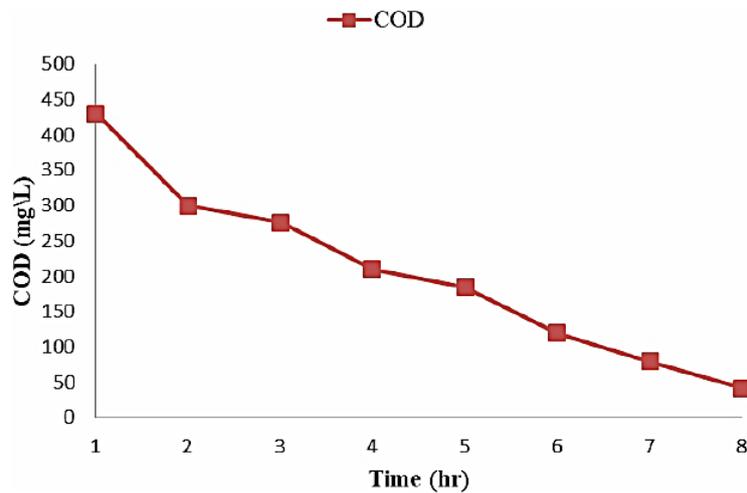


Figure 6. COD Variation in the 3rd operation mode

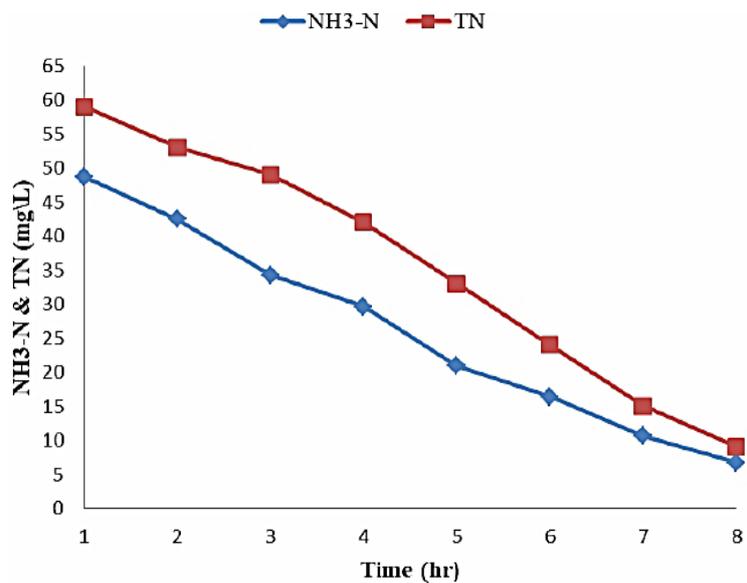


Figure 7. NH₃-N and TN Variation in the 3rd operation mode

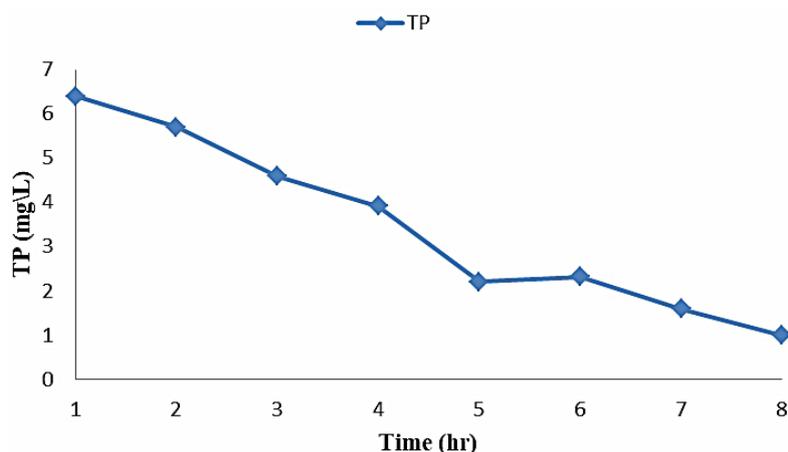


Figure 8. TP Variation in the 3rd operation mode

for a long time causes the bacteria to produce more PHB, which reduces their ability to remove phosphorus [Metcalf et al., 2003]. In the SBBR system, the 8 hours aerobic period is preferable due to the varying times for different reaction processes.

Evaluation of the SBBR Performance

Two approaches have been followed to investigate the performance of biological treatment by the SBBR system as below:

Comparing with other SBBR Studies

The removal efficiency of present SBBR research was compared with the removal

efficiencies of other SBBR studies is shown in Table 3. Some researchers examined how contaminants were removed in a smart, monitored SBBR for domestic sewage treatment.

The COD removal efficiency of this study was closer to that of [Ding, et al., 2011; Wang, et al., 2015 and Cai, et al., 2013], while is far from a study by [Jin, et al., 2012]. The ammonia removal efficiency in the current study was the closest to that of [Wang, et al., 2015; Ding et al., 2011], and [Ding et al., 2010]. The TN removal efficiency in the current study was closest to that of research by [Ding et al., 2010]. The TP removal efficiency of the present study was not close to any removal efficiencies results of studies in Table 3.

Table 3. Comparison removal efficiency of the present SBBR with other SBBR studies

Reference	Year	Removal Efficiency (%)			
		COD	Ammonia	TN	TP
Cai et al., 2013	2013	86	---	---	92
Jin et al., 2012	2012	85	92	90	93
Wang et al., 2015	2015	93	85	80	90
Ding et al., 2011	2011	90	90	---	---
Ding et al., 2010	2010	95	90	87	---
This study	2021	90.23	86.24	84.75	84.38

Table 4. The comparison of SBBR Effluent with standards of effluent discharge

Parameter	SBBR Effluent (mg/L)	International Standards of Effluent Sewage (mg/L)		
		WHO [WHO, 2006]	European [EWS, 2004]	China [ZDHC, 2016]
COD	42	100	125	100*
Ammonia	6.7	6	10	15
TP	1	2	5	4
TN	9	15	20	25

* This is the same value of COD for Iraqi wastewater discharge standard [C3]

Comparing the quality of effluent with International Standards

Table 4 compares the quality of the SBBR effluent to international standards for the discharge of treated wastewater into surface waters (WHO, European, and Chinese). COD, Ammonia, TN, and TP concentrations of the SBBR effluent meet all required standards limits of WHO, European, and Chinese Standards. It is worth noting that while Iraq does not have limits on all pollutants, some of them, such as COD, do not exceed 100 mg/L [MOHE, 2012].

CONCLUSIONS

1. In this research, the SBBR system has been used for domestic sewage treatment. The SBBR operation method has three cycle modes (first, second, and third). The following conclusions can be drawn from the tests and results conducted in the current study:
2. When the sewage characteristics of Basrah were compared to the typical characteristics of untreated domestic wastewater, BOD (210 mg/L), COD (430 mg/L), TP (6.5 mg/L), and TSS (270 mg/L) were considered to be in the medium strength range, while Ammonia (48 mg/L) and TN (58 mg/L) were found to be in the strong range.
3. The SBBR method proved to be effective in treating domestic wastewater in Basrah city. COD, NH₃-N, TN, and TP concentrations in the effluent were 42, 6.7, 9.0, and 1.0 mg/L, respectively, with the removal efficiency rates of 90.32 percent, 86.24 percent, 84.75 percent, and 84.38 percent.
4. The effects of aeration time on the efficiency of the SBBR were also studied in terms of removal chemical oxygen demand (COD), ammonia, total nitrogen TN, and total phosphorous TP under different levels of dissolved oxygen DO (2.0 – 6.8) mg/L.
5. When comparing the SBBR effluent value to the WHO, European, and Chinese discharge standards, it was observed that the COD concentration (42 mg/L) met these standards. while ammonia (6.7 mg/L), TN (9.0 mg/L), and TP (1.0 mg/L) met the WHO, European, and Chinese standard only.

The SBBR efficiency was investigated in this study, and it performed well as a suitable biological treatment method for the treatment of domestic wastewater from Basrah.

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