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IMPACT OF DISSOLVED OXYGEN ON HOSPITAL WASTEWATER QUALITY TREATED BY SBBR IN BASRAH CITY, IRAQ

Key words: hospital wastewater, SBBR, laboratory experiment, COD, DO, TN, TSS, TP

Introduction

Hospital wastewater (HWW) is created by all hospital activities, including medical, and non-medical activities such as surgery, emergency & first aid, laboratory, diagnosis, radiography, cooking, and laundry (Majlesi, 2001; Zgórska & Grabińska--Sota, 2019). Microorganisms that cause disease as (viruses and bacteria), residuals of medication and chemical materials used in hospital laboratories (chloroform, phenol, antibiotics, and others), toxic chemicals, and organic substances biodegradable which is found in hospital wastewater (protein, fat, carbohydrate) (Radha, Kalaivani & Lavanya, 2009).

Each hospital in the developed country produces daily 400–1,200 l per capita of wastewater, comparison with 100–400 l per capita of daily municipal sewage production, whilst in developing countries, daily value is 200–400 l per capita (Mishra, Sharma, Sarita & Ayub, 2016; Yong, Bashir, Ng, Sethupathi & Lim, 2018).

Generally, the properties of hospital wastewater are the same as those of domestic wastewater, although a part of hospital wastewater contains toxic/non-biodegradable/infectious contaminants (Sharma et al., 2015). The effluent of hospitals is commonly discharged into municipal sewage systems and frequently dumped without any treatment to reduce public health risks in developing countries (Timraz, Xiong, Al Qarni & Hong, 2017).

A biological treatment method for removing pharmaceuticals is a more cost-

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-effective and ecologically friendly alternative to ozonation and activated carbon (Zorita, Mårtensson & Mathiasson, 2009). There are two types of biological wastewater treatment processes: suspended growth and attached growth. Suspended growth biological treatment, such as the activated sludge treatment utilized in most WWTPs, is a common example of this type of treatment. In spite of several improvements that have been reported for conventional activated sludge (CAS) (Schaar, Clara, Gans & Kreuzinger, 2010), on the other hand, numerous microorganisms, are considerably persistent in the treatment by the activated sludge method (Miège, Choubert, Ribeiro, Eusèbe & Coquery, 2009). In comparison to the activated sludge, some of these chemicals have been removed with better clearance rates in attached biofilm procedures (Zupanc et al., 2013). This shows that the biological treatment process may be further optimized, by utilizing a biofilm-based technique whereby sequencing batch biofilm reactor (SBBR) is one practical way to take advantage of the attached growth processes.

In aerobic wastewater biological treatment, oxygen serves as a terminal electron acceptor. In the activated sludge process, dissolved oxygen (DO) is an essential parameter. Low DO can enhance filamentous bacteria growth, resulting in poor sludge settleability, reduce extracellular polymer synthesis, and reduce nitrifying activities and in most cases, the reactor's DO should be kept above 2 $mg \cdot l^{-1}$ (Dangcong, Bernet, Delgenes & Moletta, 2001).

The SBBR is based on attaching microorganisms for biological wastewater treatment. It depends on the sequence batch reactor (SBR). Because of its different advantages, SBBR is extensively researched and used as a recent biological sewage treatment technology, there has been an increase in biomass, but there has been minimal sludge, simple and easy to operate, and efficient in sewage treatment (Gieseke, Arnz, Amann & Schramm, 2002; Jasem, Jumaha & Ghawi, 2018).

The objective of this research is to utilize the potential of the SBBR as a type of attached growth biological processes reactor to treat the hospital wastewater from a local hospital at Basrah city (south of Iraq) to remove a different pollutant parameter such as COD, TN, NH_3-N, and TP under variation of dissolved oxygen (DO) with range of 2.15––6.55 $mg \cdot l^{-1}$ and then compared the results of SBBR with international standards of effluent sewage.

Material and methods

Reactor set-up and operation

The reactor used in this experiment is a laboratory bench-scale SBBR vessel with a cylindrical shape, the volume approximately 26.0 l with an internal diameter is 300 mm, a depth is 400 mm, and the working volume is 13.0 l. SBBR, is made from transparent plastic material of 4.0 mm thickness to easily monitor sludge and biofilm in the SBBR tank. The wastewater was fed from the bottom into the SBBR reactor as illustrated in Figure 1. Plastic fibrous filler units were attached to the reactor, which length is 300 mm with many strands of fiber. During aeration in the SBBR vessel, flexible fiber thread swayed with the wastewater to increase absorption in the biofilm, and many filaments were diffused to produce a large surface area. An air pump was used to supply air to the SBBR reactor. The aeration air sprays were positioned at the top of the sedimentation zone to permit big particles

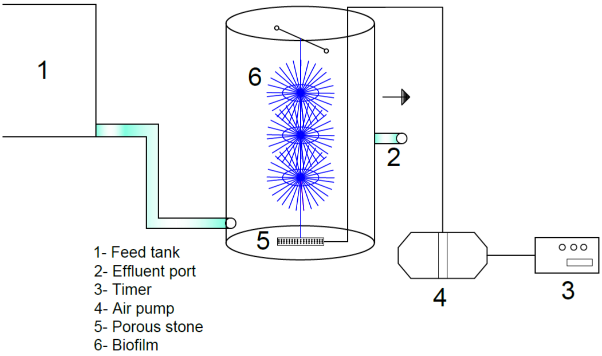

FIGURE 1. SBBR system schematic (adopted from Al-Rekabi, 2021)

that were not attached to the biofilm to settle during the aeration operation (Al-Rekabi, Al-Khafaji, Hassan & Janna, 2021).

Activated sludge was collected from a local municipal wastewater treatment plant as seeds material for the SBBR system. Timers were used to monitor the operation of reactor processes such as feeding, aeration, settling, and discharge. A cover was placed over the reactor, but it was not sealed, and an air pump was used to create an aeration condition.

Usually, biofilm carriers influence the condition of microorganisms in the SBBR, which is an important property for the reactor's proper startup.

Even though biofilm helps microorganisms the attachment, it as well serves as filters, keeping suspended solids (SS) and other pollutants out of the treated water area (Dinçer & Kargi, 2001).

The operation cycle of the SBBR was 8/24 h. The operation of the SBBR was divided into (0.5-hour fill, 6.0-hour reaction time, 1.0-hour settle time, and 0.5-hour settles time). When the aerator was powered up, it allowed the DO of the reactor to be kept at 2.15–6.55 $mg \cdot l^{-1}$. During the period of starting up one month to create a biofilm on fibers filler, the SBBR research test period lasted about one month. The SBBR was operated for approximately one month to guarantee that the biological treatment processes were overripe and that start-up conditions were reached.

Analytical methods and collection samples

Dissolved oxygen, pH and temperature (the device was calibrated using standard solutions prior to measurement) were examined by a digital device. The COD, BOD, TSS, TDS, TP, NH_3-N and TN under the standard method (American Public Health Association [APHA], 1998). The samples tests are analyzed by using $DR_{5,000}$ and $DR_{1,900}$ Hach spectrophotometric. The samples of wastewater are filtered by using filter paper (pore size 0.45 µm) when the test needs that.

For this research, samples were gathered from the SBBR influent and effluent in a cleaned plastic bottle adopting standard methods (APHA, 1998). Samples were taken one time a day at (12 a.m.) throughout October and the beginning of November. All of the samples were analyzed immediately after the samples were collected with a field device, and the other duplicate samples were kept in a fridge at 5°C in the sanitary laboratory at the University of Basrah's College of Engineering.

Result and discussion

In this study, raw wastewater was collected from one of the outlet points of a manhole in the Al-Taalemie hospital in Basrah 400 beds, Iraq. For the present study, the important properties of hospital wastewater components are compared with universal concentrations of wastewater (Table 1).

Concerning contaminants like COD, BOD, TSS, and TN, it indicates that raw sewage is more than medium concentration and less than high concentration. On the contrary, raw hospital wastewater has high concentrations with respect to contaminants such as TDS and NH_3-N. TDS level was higher because of rising saline in Basra's drinking water supplies (United Nations Children's Fund [UNICEF], 2019).

As during the acclimatization period, originally 6–8 l of activated sludge was a seed in the reactor without additives, the aeration is supplied using many diffusers, and for biofilm maturation, the concentration of DO is controlled higher than 3 $mg \cdot l^{-1}$ during the aerobic condition, in accordance with Rusten, Eikebrokk, Ulgenes and Lygren (2006), to keep the biofilm active in the normal conditions, they ensure a minimal level of DO equals to 3 mg of O_2 per 1 l in the reactor of SBBR. In the experiment operations, the exchange volume was put at 50% and the temperature was kept at 26–33°C to maintain the high performance of microorganisms, which has a substantial effect on their oxygen consumption ratio.

TSS removal

The SBBR was able to reduce total suspended solid perfectly as compared with normal bioreactors in hospital wastewater treatment plants, settling time has a significant impact on normal bioreactors that are dependent on gravity separation to remove TSS (Yong et al., 2018). SBBR's reduced TSS is due to the presence of biofilm, which absorbs insoluble contaminants in the wastewater (Rittmann, 2017). To remove TSS, SBBR adsorption is a better option than the separation process. As a result, it's thought that SBBR could help biological treatment by removal soluble recalcitrant chemicals and insoluble pollutants so that TSS removal efficiency was 91% conducted by SBBR for hospital wastewater in this study.

TABLE 1. Standard raw domestic wastewater concentrations comparison with Al-Taalemie hospital Wastewater characteristics in Basrah

Contaminants	Raw wastewater average values [$mg \cdot l^{-1}$]	*SD*	Concentrations of standard wastewater (Metcalf & Eddy, 2003)		
			low	medium	high
COD	550	7.12	250	430	800
BOD	280	7.48	110	190	350
TN	55	3.56	20	40	70
NH_3-N	44	2.90	12	25	45
TP	6.4	0.88	4	7	14
TDS	2325	4.97	270	500	860
TSS	225	2.16	120	210	400

Effect of dissolved oxygen on the removal of various pollutants

The aeration quantity was monitored in this research so that the DO level in the SBBR raised progressively from 2.15 to 6.55 mg·l^{-1}. Table 1 shows the quality of raw sewage at this phase. Aerobic conditions have a significant impact on COD, NH_3-N, TN and TP removals in microbiological investigations, and aeration with a medium volume is considered preferable for all pollutants removal except TP removal.

COD removal at different DO concentration

The SBBR was conducted periodically in an individualized bioreactor through anaerobic and aerobic operation, resulting in a balance of anaerobic and aerobic microorganisms that allowed for COD removal. COD elimination was attributable to the SBBR's efficient removal of organic materials; however, the SBBR also partially removed difficult compounds, resulting in COD removal that was higher than the hospital wastewater treatment plant. This finding confirms the theory that polychlorinated biphenyls can be successfully destroyed by alternating anaerobic and aerobic treatments (Pathiraja, Egodawatta, Goonetilleke & Te'o, 2019). When the COD concentration in the effluent reached 215 mg·l^{-1}, and the level of the DO was about 2.1 mg·l^{-1}, the water quality was bad. Concentrations of COD effluent considerably reduced to approximately 95 mg·l^{-1} or as a result when the DO concentration was equal to 2.83 mg·l^{-1} (Fig. 2).

Due to insufficiency of appropriate DO concentration, microbial behavior was decreased, and microorganisms were unable to degrade organic matter sufficiently in the case of insufficient oxygen. In this study, SBBR improved COD removal by decomposing refractory components in hospital wastewater including lignin and its derivatives. As a result, SBBR removed refractory chemicals more effectively than conventional bioreactors, resulting in improved COD and another pollutant removal which is existed in wastewater of hospitals.

COD removal efficiency by SBBR under different DO concentrations is shown in Figure 3. This figure shows that increasing DO concentration led to reducing COD concentration in effluent then COD removal efficiency increased so that the DO with

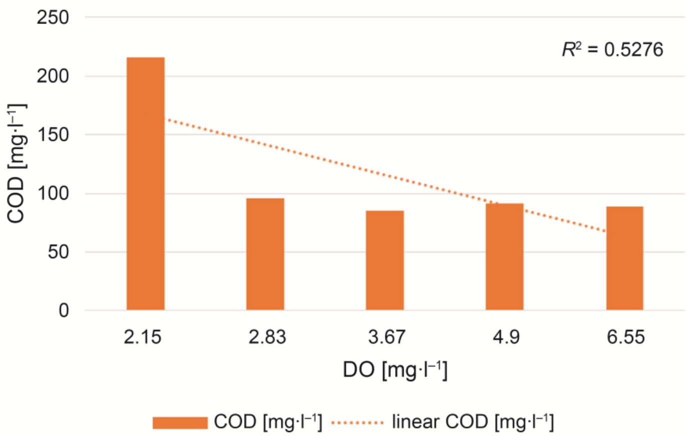

FIGURE 2. COD removal variation under different DO concentration

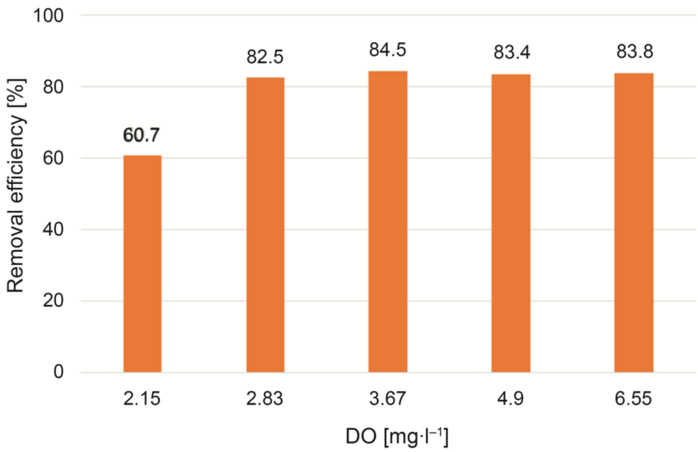

FIGURE 3. COD removal efficiency with different DO concentration

concentration value 3.67 mg·l^{-1} is taken as the best effluent value with 84.55% removal efficiency.

NH_3-N and TN removal at different DO concentration

As shown in Figures 4 and 5, the concentration of the NH_3-N and TN was decreased by increased concentration of DO and reduced by TN's effluent levels from 50 to 12 mg·l^{-1} for DO concentrations 2.15 and 3.67 mg·l^{-1} respectively. Although at 4.9 mg·l^{-1} of DO concentration the level of NH_3-N in the effluent stays high and equal to 18 mg·l^{-1}, while for DO 6.55 mg·l^{-1} the concentration of TN effluent has stayed low, the effluent content was 16 mg·l^{-1}.

In the SBBR reactor, microorganisms attach themselves to the fibrous membrane

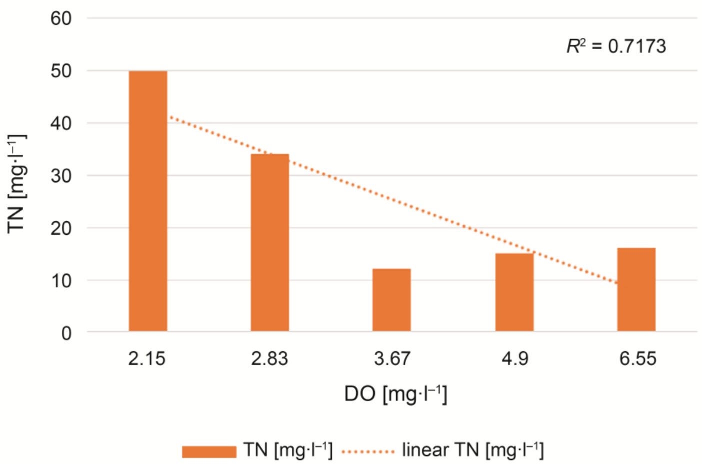

FIGURE 4. TN removal variation under different DO concentration

and then grow to become dense biological membranes. These are called biofilms. As the wastewater is attached to the biofilm, suspended organic particles are adsorbed on the biofilm surface, and because of the thickness of the biofilm, DO offers a gradient, necessitating a DO transfer process from the water to the zone of the biofilm. DO concentration in biofilms zone is very poor approximately equal to 2 mg·l^{-1} at the start of the research, which reduces the efficiency of aerobic nitrifying bacteria, for example, nitrification is not fully accomplished. As a result, the effluent contained high levels of NH_3-N and TN, although, the rate at which oxygen is transferred to the biofilm is enhanced at higher DO levels equal to 4.9 mg·l^{-1}.

The higher DO level extends the stratum of aerobic and compresses the stratum of anoxic, then increases the degradation rate for organic matter. As a result, all denitrification processes and sources of carbon are decreased, implying that denitrifying bacteria efficiency is reduced and nitrate nitrogen cannot be converted to nitrogen (Pochana, Keller & Lant, 1999; Marek, Pawęska & Bawiec, 2021). As a consequence, the effluent of TN concentration progressively raises. Effective TN removal takes place at DO approximately equal to 3.67 mg·l^{-1} according to the results of this research.

As shown in Figure 6, TN removal efficiency is increased with increased DO concentration until DO 3.674 mg·l^{-1} which give 78.18% as removal efficiency, while the removal efficiencies for DO 4.9 and 6.550 mg·l^{-1} is decreased to 72.73 and 70.91% respectively so that will be considered DO 3.67 mg·l^{-1} as the most suitable DO for TN removal in the operation of SBBR for hospital wastewater treatment in this research.

The NH_3-N removal efficiencies are shown in Figure 7, this efficiency is increased clearly with increased DO especially for DO 2.15 and 2.83 mg·l^{-1} with removal efficiency 11.36 and 43.18%, while removal efficiency is increased slightly for DO 3.67, 4.9 and 6.55 mg·l^{-1} with removal efficiencies 65.9, 59.10 and 67.05% respectively, concerning these results the removal efficiencies of NH_3-N was fairly good in the last three values for DO 3.67, 4.9 and 6.55 mg·l^{-1}, this due to raising the rate of nitrification when

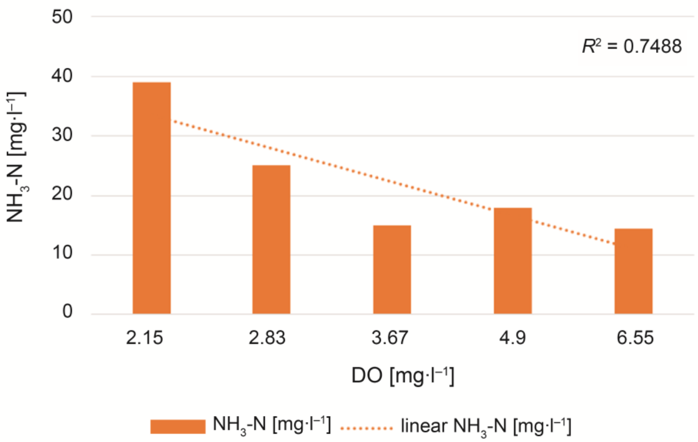

FIGURE 5. NH_3-N removal variation under different DO concentration

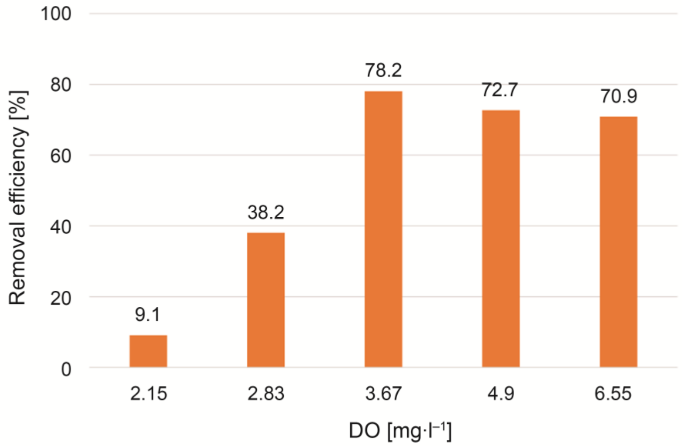

FIGURE 6. TN removal efficiency with different DO concentration

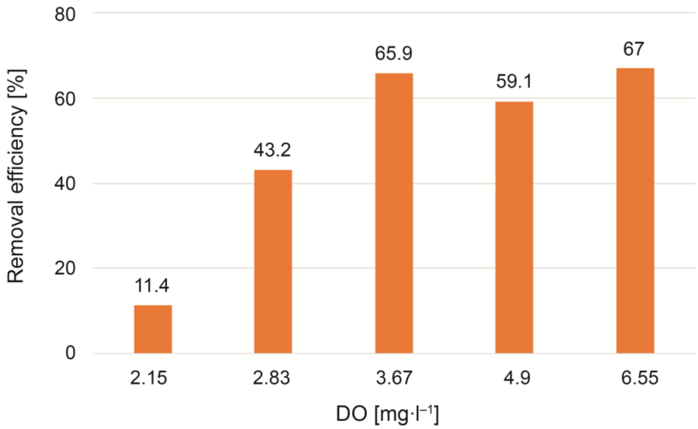

FIGURE 7. NH_3-N removal efficiency with different DO concentration

the dissolved oxygen is high so that removal efficiency increased.

As concluded above results the NH_3-N removal efficiency of 65.9% for DO 3.67 mg·l^{-1} is near to the NH_3-N removal efficiency of 67.05% for DO 6.55 mg·l^{-1}, so that in this study will be considered DO 3.67 mg·l^{-1} as the most suitable DO for NH_3-N removal in the operation of SBBR for hospital wastewater treatment.

TP removal at different DO concentration

As the DO concentration raised from 2.15 to 6.55 mg·l^{-1}, the effluent of TP concentration was reduced from 4.9 to 1.3 mg·l^{-1} (Fig. 8). The effluent of TP concentration was supposed to increase with DO concentration in the early phase, besides that, no this activity was noticed. It was due to the efficiency of phosphorus absorbing is decreased during that period. It could be ob-

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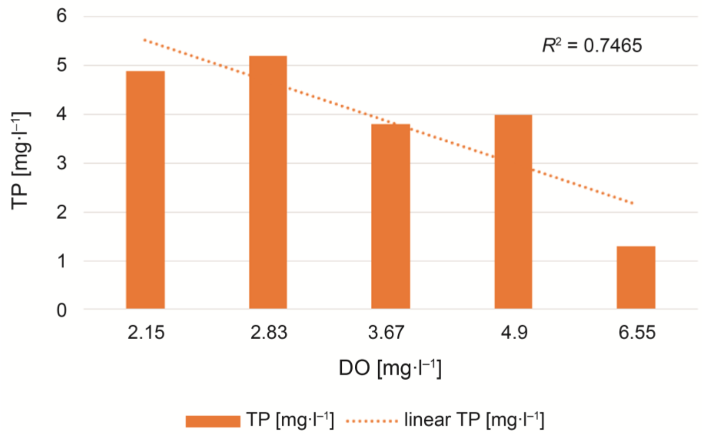

FIGURE 8. TP removal variation under different DO concentration

served that increasing the concentration of DO, as a result, there is more aerobic phosphorus absorption and thus reduces the time required for the desired aeration at the same phosphorous released content (Rong, Peng, Zhang & Fang, 2008). The concentration of DO was confirmed to be around 3.67 mg·l^{-1} for the current study, with the aeration period to be 5 h, based on the rate of phosphorus removal, phosphorus utilization rate, aeration period, and usage of energy.

TP removal efficiency increased with rising dissolved oxygen values up to 6.55 mg·l^{-1} within the limits of this study is 2.15–6.55 mg·l^{-1}, as shown in Figure 9. Therefore, it can be concluded that the value of DO with the removal efficiency of 79.70% is the most suitable value for total phosphorous removal in the case of SBBR to hospital wastewater treatment in this study, while the value of DO 3.67 mg·l^{-1} is not suitable to TP removal

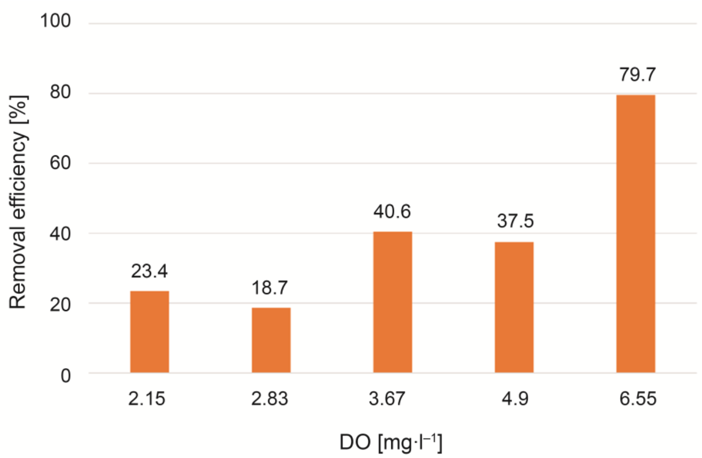

FIGURE 9. TP removal efficiency with different DO concentration

as compared with COD, NH_3-N, and TN removal efficiencies under same DO concentration.

SBBR performance as compared with global standards

The effluent quality from SBBR is compared with global standards for the discharge of treated sewage into the water body as detailed in Table 2. Values of COD, TN, and TP in the effluent of SBBR comply with all WHO, European, and Chinese standards, while ammonia satisfies just Chinese standards and outside WHO and European standards.

Conclusions

For the recent study, the reactor of SBBR is being used in the treatment of hospital wastewater. Operation of SBBR cycle mode was divided into (0.5-hour fill, 6.0--hour reaction time, 1.0-hour settle time, and 0.5-hour settles time), and the range of DO as 2.15–6.55 $mg \cdot l^{-1}$. The following conclusions can be obtained from the current study's tests and results:

1. Influent wastewater of Al-Taalimi hospital in Basrah was compared to untreated domestic wastewater's typical characteristics, BOD is 280 $mg \cdot l^{-1}$, COD is 550 $mg \cdot l^{-1}$, TN is 55 $mg \cdot l^{-1}$, and TSS is 225 $mg \cdot l^{-1}$, were taken into consideration more than medium strength and less than high strength, on the contrary, raw hospital wastewater has high concentration with respect pollutants like NH_3-N is 44 $mg \cdot l^{-1}$ and TDS is 2,325 $mg \cdot l^{-1}$, while TP is 6.5 $mg \cdot l^{-1}$ are considered to be in the median concentration value.
2. SBBR system is considered efficient in the treatment of hospital wastewater in Basrah city under different DO concentrations, for DO 3.67 $mg \cdot l^{-1}$ the removal efficiencies of COD, NH_3-N, and TN, were 84.55, 65.91 and 78.18% respectively, while DO 6.55 $mg \cdot l^{-1}$ given higher removal efficiency for TP 79.7%, this means that total phosphorus needs higher value for DO to get higher removal efficiency.
3. Comparison effluent values of SBBR with European, WHO, and Chinese discharge standards, it was mentioned that concentration of COD 85 $mg \cdot l^{-1}$, TN 12 $mg \cdot l^{-1}$, and TP 1.3 $mg \cdot l^{-1}$ will meet all standards (European, WHO, and China), while NH_3-N 15 $mg \cdot l^{-1}$ satisfies just China standard and outside (WHO and European) standards, SBBR's efficiency was studied in this paper, and it achieved properly as appropriate biological treatment operation for hospital wastewater treatment in Basrah city.

TABLE 2. SBBR effluent compared with effluent discharge standards

Contaminants	Effluent of SBBR [$mg \cdot l^{-1}$]	*SD*	Global standards of effluent wastewater [$mg \cdot l^{-1}$]		
			European (van Riesen, 2004)	WHO (WHO, 2006)	China (ZDHC, 2016)
COD	85	1.41	125	100	100
NH_3-N	15	2.16	10	6	15
TP	1.3	0.26	5	2	4
TN	12	2.20	20	15	25

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Summary

Impact of dissolved oxygen on hospital wastewater quality treated by SBBR in Basrah city, Iraq. The hospitals close to the residences can make problems for the environment as a consequence of sewage drained into the water stream. Sequencing batch biofilm reactor (SBBR) offers advantages for treating sewage; such as simple operation, flexible process, and cost-effective. The laboratory bench-scale experiments were carried out treating hospital wastewater (HWW) of one of Basrah hospital city by a fabricated SBBR reactor of 26 l working volume. The hospital wastewater has the following characteristics (average values): pH 7.3, BOD equal to 280 $mg \cdot l^{-1}$, COD equal to 550 $mg \cdot l^{-1}$, total phosphorus (TP) equal to 6.4 $mg \cdot l^{-1}$, ammonia (NH_3-N) equal to 44 $mg \cdot l^{-1}$ and total suspended solid (TSS) equal to 272 $mg \cdot l^{-1}$. This research aims to estimate the performance of the SBBR system for treating hospital wastewater to enhance different effluent parameters such as COD, total nitrogen (TN), ammonia, and total phosphorous (TP) with various dissolved oxygen (DO) with range of 2.15–6.55 $mg \cdot l^{-1}$, the best DO values give these removal efficiencies for COD equal to 84.55%, NH_3-N equal to 65.91% and TN between 78 and 18% for DO equal to 3.67 $mg \cdot l^{-1}$, while TP removal efficiency was 79.70% for DO equal to 6.55 $mg \cdot l^{-1}$. By comparison of the SBBR effluent with international standards for effluent sewage, it noticed COD concentration 85 $mg \cdot l^{-1}$, TN 12 $mg \cdot l^{-1}$ and TP 1.3 $mg \cdot l^{-1}$ met all standards (European, WHO, and China), while NH_3-N 15 $mg \cdot l^{-1}$ was outside WHO and European standards, while satisfies only Chinese standard.