Original Article

Efficiency of SBR Process with a Six Sequence Aerobic-Anaerobic Cycle for Phosphorus and Organic Material Removal from *Municipal* Wastewater

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ABSTRACT

Background: Various chemical, physical and biologic treatment methods are being used to remove nitrogen and phosphorus from wastewater. Sequencing batch reactor (SBR) is a modified activated sludge process that removes phosphorus and organic material from sanitary wastewater, biologically.
Methods: This study was conducted in 2016.The performance of an aerobic-anaerobic SBR pilot device, located at Ahwaz West Wastewater Treatment Plant, Ahwaz, southern Iran in phosphorus and organic material removal was evaluated to determine the effect of the aerobic-anaerobic step time on the efficiency of nitrogen and phosphorus removal, the effect of changing the sequence of steps and the effect of time ratio on phosphorus removal efficiency. A reactor of 8 L was used. Influent contained 397 and 10.7 mg/l COD and phosphorus, respectively. The pilot plant started with a 24 h cycle including four cycles of 6 h, as follows: 1- Loading (15 min), 2-Anaerobic (2 h)-Aerobic (2 h), 3- Settling (1 h), Idleness (30 min) and 5- decant (15 min).
Results: After reaching steady conditions (6 months), Removal percentages of phosphorus, BOD_5, COD, and TSS in The SBR over a period of 6 months was 79%, 86%, 89% and 83%, respectively.
Conclusion: Result of this study can be used for designing and optimum operation of sequencing batch reactors.

Keywords: Environment, Phosphorus, SBR, Wastewater.

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INTRODUCTION

Generally, the nutrient is one of the most important constituents of organic loading and contamination of wastewater. Surface runoffs in agricultural zones, wastewaters of different workhouses, fish and poultry farms contain high contents of nitrogen and phosphorus. Introducing these contaminants in water reservoirs causes eutrophication that is a specified environmental hazard [1-4]. Therefore, water quality management is developed in designing wastewater treatment plant all over the world [1, 5, 6]. Biological processes are used to remove nitrogen and phosphorus include conventional activated sludge, Anaerobic-Anoxic-Oxic process (A2/O), Anoxic-Oxic process (AO), Oxidation Ditch (OD), sequencing batch reactor, biofilm reactor, lagoon, photostrip, modified Bardenpho and University of Cape Town process (UTC).

Sequencing batch reactor (SBR) as modified version of activated sludge is one of the most successful methods in nutrient removal [7-10]. SBR systems have replaced other conventional systems in the biological treatment of industrial and sanitary wastewater due to their numerous advantages. These advantages include optimum energy usage through control of metabolic activity, low cost and appropriate contaminant removal efficiency, lower required space, nitrogen and phosphorus removal via proper control of oxygenation and flexible operation, ability to eliminate most of sludge thickening filamentous microorganisms via control of SBR operational cycle, biological ability of SBR to overcome hydraulic and organic loading shocks, simplicity of the process, no need to secondary sedimentation tank and pump the returned sludge, low suspended solids in effluent and scalability, which made SBR, one of the most widely used wastewater treatment systems [11-14].

An SBR pilot plant was studied in simultaneous removal of organic carbon and nitrogen from slaughterhouse wastewater and reported removal efficiency of nitrogen to be 86%-95% for soluble chemical oxygen demand (SCOD) and 96.6% for nitrogen [6]. Biological removal of nutrients was studied in a moving bed SBR, and at different ratios of COD/TP, the system had appropriate efficiencies

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of 97.56% and 93.52% for TP and COD, respectively ([15].

In this study, the performance of an SBR system with a six sequence modified aerobic-anaerobic cycle was evaluated in order to determine the best cycle time for simultaneous removal of phosphorus and organic material regarding the time of aeration, sedimentation, and mixing. The SBR pilot was located in Ahwaz West Wastewater Treatment Plant, Ahwaz, southern Iran.

MATERIALS AND METHODS

Pilot Specifications

A Plexiglas cylindrical reactor of 8 L and a tank for collecting effluent were used (Fig. 1). Moreover, two valves were embedded on the tank and under its piping in order to discharge effluent and excess sludge (Table 1).

The static method was used in the loading phase. Besides, two valves, one installed 15 cm above the bottom of the reactor and the other one installed on the reactor bottom were used to discharge effluent and excess sludge. Decanting was performed for 15 min in every cycle.

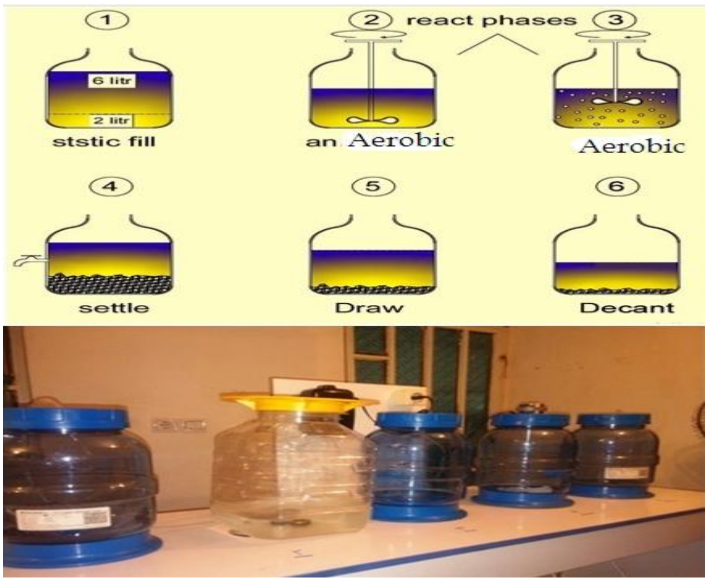

Figure 1. Schematic of the experimental setup was used in this study.

Table 1. Technical specifications of the pilot.

	Sequences	Duration	Technical specifications
1	Loading	15 min	Inner Diameter: 22 cm
2	Anaerobic	2 h	Height: 31 cm
3	Aerobic	2 h	Volume: 8L
4	Sedimentation	1 h	
5	Idleness	30 min	
6	Decant	15 min	
Six sequence cycle		6 h	

Aeration and Temperature Control

The reactor was aerated using a stone diffuser and aeration pump of HAILEA-ACO.5505. Dissolved oxygen and optimum temperature were kept at 2-3 mg/l and 20-28 °C, respectively.

Influent Wastewater Characteristics

Six liters of effluent wastewater of the primary sedimentation tank of Ahwaz West Wastewater Treatment Plant was collected as SBR influent. Moreover, 2 L of returned activated sludge was used to fill the tank (Table 2).

Table 2. Characteristics of Influent wastewater.

Parameter mg/l	BOD	COD	TSS	TN	TP	pH	DO
Value (mg/l)	213.6	397	112	33.2	10.7	7.3	2.9

Reactor Seeding

Two liters of returned activated sludge was used to seed the reactor. No bulking problem was observed. Activated sludge was collected from the returned sludge entering aeration tank manually and immediately transferred to the reactor.

The reactor reached steady state after 4 wk. COD of effluent and MLSS were analyzed to ensure a steady state of the reactor.

Reactor Startup

At first, 2 L of activated sludge was collected from sludge return line of Ahwaz Plant and was poured in the reactor, and then the reactor was filled with water. After a manual sampling of returned activated sludge and influent wastewater, aeration was performed for 30 min, and then it was settled in a tank. Afterward, the liquid phase was discharged and the solid phase was transferred to the tank. For reaction sequence of the system that included anaerobic-aerobic sequence, the anaerobic sequence was done firstly (Table 1). In anaerobic sequence (2 h), every 30 min the content was mixed gently for 5 min with a mixer of 10 rpm. Mixer speed was controlled by a dimmer and the mixer shaft had a length of 26 cm.

After the anaerobic sequence, the aerobic sequence starts by aeration pump (5.5 L/sec) and surface mixing impeller with speed of 40 rpm (Fig. 2- 3). After aeration, sedimentation and idleness sequences begin (Table 1). Afterward, samples are taken from clear effluent and sediments manually.

All the mentioned sequences were done in 6 h and 4 cycles every day. All samples were analyzed the day they were taken. Accordingly, 30 samples were taken for every parameter each month and finally, their average was used as monitoring criteria.

Figure 2. The reactor anaerobic sequence.

Figure 3. Aerobic sequence and mixing.

The Studied Variables

The reactor schedule was set according to the first series of experiments. After pilot startup, for one-month samples were taken after each cycle and MLSS, pH, COD, BOD, TSS and DO were measured. Spectrophotometer apparatus (HACH) was used to measure COD and phosphorus concentration. DO, pH and temperature were determined using a multi-probe device (HACH). BOD was measured using BOD track device (HACH) according to standard methods [16].

This study was conducted in 2016 and via pilot-plant and industrial wastewater and completely safe condition and any waste were collected and disposed of in accordance with environmental laws.

RESULTS

BOD_5 Concentration Changes of the SBR over Time Cycles

The monthly average concentration of BOD_5 of influent and effluent were 213.66 and 27.76 mg/l, respectively. Finally, the high removal efficiency shows the high capability of the SBR system to remove organic materials in experimental and full-scale and a good adaption of microorganisms in activated sludge [Fig. 4].

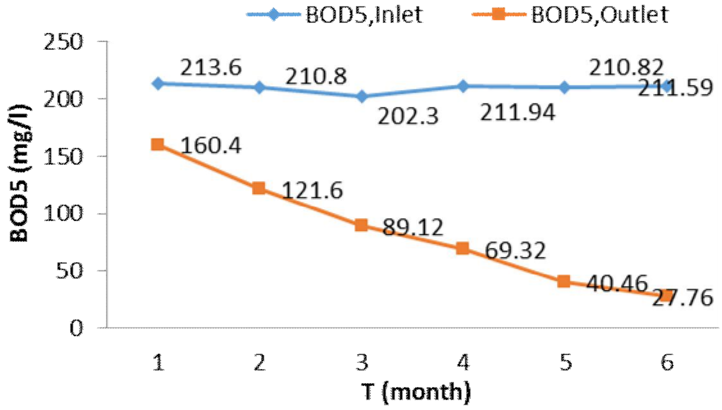

Figure 4. BOD_5 removal in the SBR system with six sequences.

COD Concentration Changes of the SBR over Time Cycles

The monthly average of COD concentrations of influent and effluent were 397 and 43.67 mg/l, respectively. Removal efficiency was 89% that shows a good quality and quantity of MLSS in reaction tank (Fig. 5).

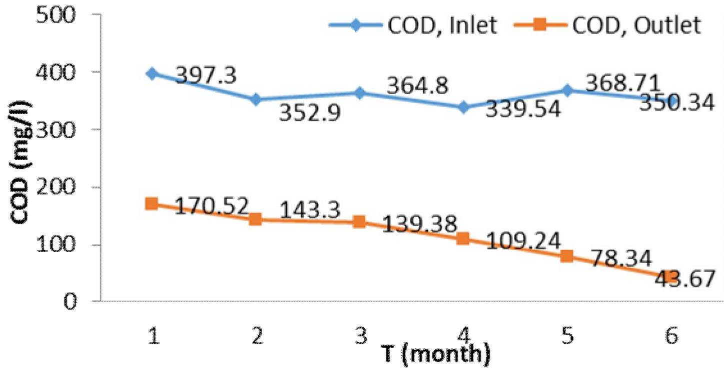

Figure 5. COD removal in the SBR system with six sequences.

TSS Concentration Changes of the SBR

The monthly average of TSS concentration decreased for 112 to 19.04 mg/l that shows removal efficiency of 83% (Fig. 6).

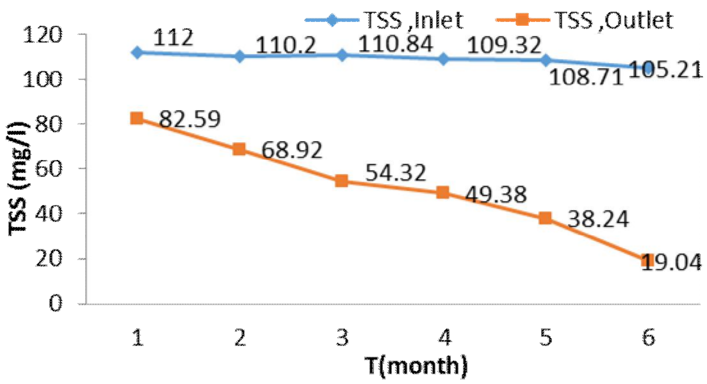

Figure 6. TSS removal in the SBR system with six sequences.

Phosphorus Concentration Changes of the SBR

Studying monthly average of TP over a six-month period (Fig. 7) showed that monthly average concentration of phosphorus decreased from 10.7 to 2.24 mg/l, which equals to removal efficiency of 79%. In this phase, pH of the system was not less than 7.

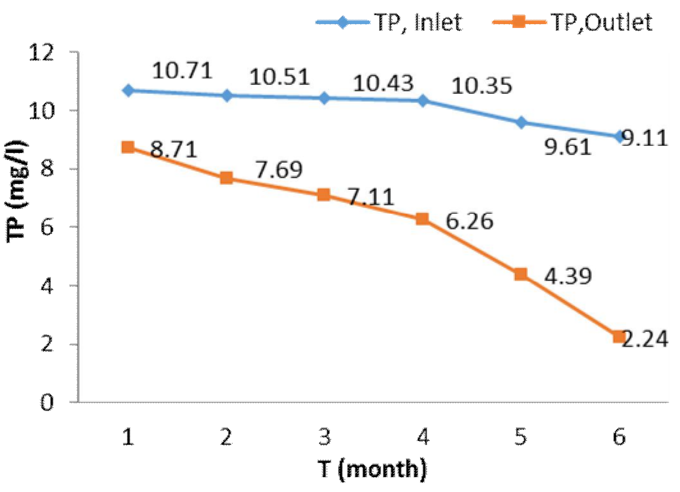

Figure 7. TP removal in the SBR system with six sequences.

MLSS and COD Changes in Effluent of the SBR

An increase in sludge age increases MLSS and causes a significant decrease in COD of effluent (Fig. 8). This means in wastewater treatment by SBR process an increase in *mixed liquor suspended solids* (MLSS) (2710 mg/l) decreases COD level (43.67 mg/l). Table 3 shows removal profiles of different parameter in hydraulic retention time of 4 h (HRT=4h) and cell residence time of 10 d ($\theta_c = 10\ d$).

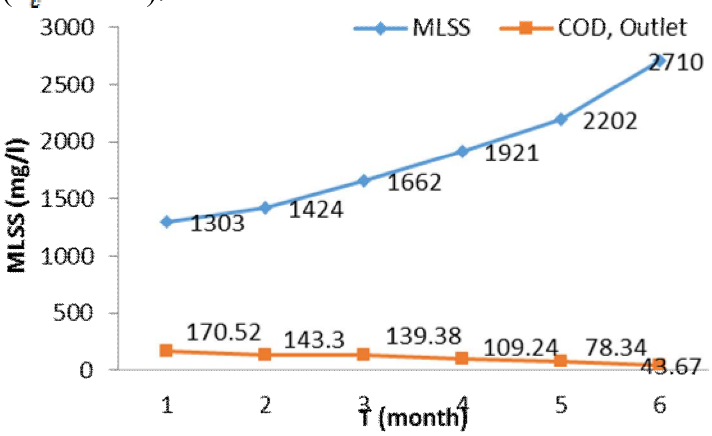

Figure 8. MLSS and COD in effluent.

Table 3. Removal profile of phosphorus and organic material in the SBR over a six-month period.

Parameter	BOD_5 (mg/l)		COD (mg/l)		TSS (mg/l)		TP (mg/l)	
Time	Influent	effluent	Influent	effluent	Influent	effluent	Influent	effluent
Month 1st	213.6	160.4	397.3	170.52	112	82.59	10.7	8.71
Month 2nd	210.8	121.6	352.9	143.30	110.2	68.92	10.51	7.69
Month 3rd	202.3	89.12	364.8	139.38	110.84	54.32	10.43	7.11
Month 4th	211.94	69.32	399.54	109.24	109.32	49.38	10.35	6.26
Month 5th	210.84	40.46	368.71	78.34	108.71	38.24	9.61	4.39
Month 6th	211.59	27.76	350.34	43.67	105.21	19.04	9.11	2.24
Removal Efficiency (%)	86		89		83		79	

DISCUSSION

The removal efficiency of the aerobic-anaerobic modified system was reported to be about 86%. A full-scale research was done in a treatment plant with a capacity of 850000 people and achieved a removal efficiency of higher than 90% and BOD_5 concentration of less than 2 mg/l in effluent [17]. The difference in removal efficiencies can be due to the different hydraulic and organic loading and SRT. The removal efficiency of 93.3% was gained [18]. Iranian environmental standard defined BOD concentration of effluent to be 100 mg/l for agricultural and irrigation and 30 mg/l to be discharged in surface runoffs. Therefore, the SBR system has a BOD concentration less than the standard limit.

A removal efficiency of 97.4% was obtained and decreased COD from 8800 mg/l in influent to 226 mg/l in the effluent using a lab scale SBR designed to treat animal sewage [19]. The removal efficiency of COD in a research was 95.5% [18].

BOD to COD ratio in sanitary wastewater is 0.3-0.8. If the ratio is more than 0.5, the wastewater can be treated biologically. If the ratio is less than 0.3, the wastewater may contain toxic materials or adapted microorganisms may need to stabilize the wastewater [17]. Iranian environmental standard defined COD concentration of effluent to be 200 mg/l for agricultural and irrigation and 60 mg/l for discharging in surface runoffs. Therefore, the SBR system has a COD concentration less than the standard limit.

EPA defined standard limits of 120 and 30 mg/l for agricultural and irrigation applications and discharging in surface runoffs, respectively. Therefore, the SBR effluent is not suitable for these applications.

The efficiency is higher than the efficiencies obtained [9, 20], which were 78.4% and 79.4%, respectively. The higher efficiency is due to better aeration according to the defined time (2 h). Moreover, high TSS removal is reported to be because of higher activities of aerobic microorganisms and sedimentation. Iranian environmental standard defined standard limits of 100 and 40 mg/l for agricultural and irrigation applications and discharging in surface runoffs, respectively. Therefore, TSS of the SBR effluent is appropriate for agricultural and irrigation applications and discharging in surface runoffs.

Actually, phosphorus removal efficiency of biological systems drops significantly in pH of less than 5.6. When pH exceeds 10, phosphorus removal efficiency is high and removal efficiency decreases by SRT increasing which complies with this study. The biological removal of nutrients using a membrane bioreactor instead of activated sludge process was studied [12] and found that total phosphorus removal was exactly related to the anaerobic and aerobic sequences and by increasing the time of the anaerobic sequence, phosphorus removal efficiency could be increased due to the domination of phosphorus removing microorganisms.

CONCLUSION

The monthly average concentrations of TP, TSS, COD, and BOD5 were 2.24, 19.04, 43.67 and 27.76 mg/l, respectively. The treated wastewater complied with Iranian environmental standard regarding the mentioned parameters and can be discharged in receiving water or can be reused in agricultural applications.

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