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Evaluation of sequencing batch reactor performance for petrochemical wastewater treatment

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ABSTRACT

Sequencing batch reactor (SBR) technology has found many applications in industrial wastewater treatment in recent years. The aim of this study was to determine the optimal time for a cycle of the sequencing batch reactor (SBR) and evaluate the performance of a SBR for petrochemical wastewater treatment in that cycle time. The reactor was operated with a suspended biomass configuration under aerobic conditions. Carbon removal and operating parameters such as pH, temperature and dissolved oxygen (DO) were monitored during the wastewater treatment. The SBR was run at different cycle times and amongst the cycle times tested, the best performance was obtained with a 7 h cycle time composed of a fill time of 15min, reaction of 6 h, settling of 30 min, and withdrawal of 15 min. The SBR with the determined cycle time was used to study the treatment of wastewater with various organic loading rates (12.88 gr COD/L.d, 18.02 gr COD/L.d and 31.39 gr COD/L.d). The SBR performance was evaluated by chemical oxygen demand (COD), total solids (TS) total suspended solids (TSS) removal efficiencies. During the shock loading tests, the maximum COD, TS and TSS removal efficiencies were 84%, 67% and 92%, respectively.

1. Introduction

Oil industries require large amounts of water for different purposes such as cooling [1]. Industrial wastewater such as petrochemical wastewater usually has a high COD, low biochemical oxygen demand (BOD), and high total dissolved solids (TDS) as well as containing color, heavy metal and toxic materials. One of the economical and efficient methods for controlling and protecting the environment is the biological treatment of industrial wastewater [2,3]. However, toxic materials in industrial wastewater have an inhibiting effect on the growth of microorganisms. Batch mode operations like sequencing batch reactors can be a viable solution for this problem [4].

SBR is a fill and draw type batch activated sludge process. Wastewater is added to the reactor in a time known as fill time. In the reaction time, the microorganisms under aerobic/anoxic conditions use the pollutant as substrate. In the settling time, the activated sludge is allowed to settle and the effluent is withdrawn from the reactor. In this process, equalization, aeration and sedimentation are done in the same tank, whereas in continuous flow systems, the operations are conventionally done in separate tanks [5-7]. The advantages of SBR include flexibility in sequence time, minimum space requirement, elimination of a clarifier, and no need for a sludge return pump; nonetheless, it has some disadvantages such as the need for frequent start/stop equipment and a higher pressure drop due to changing liquid levels [8,9]. Previous research has shown that SBR is a suitable activated sludge process for domestic wastewater treatment [7,8]. The SBR has shown relatively efficient performance compared to a conventional activated sludge system in treating complex chemical effluent [4]. This system is useful for treating pharmaceutical [10], dairy [11,12], brewery [13], petroleum refinery [3], wood fiber [14] and chemical wastes [4]. In this study, the treatment of actual petrochemical wastewater at varying organic loading rates in a sequencing batch reactor was studied.

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2. Material and methods

2.1. Wastewater characteristics

The wastewater used in this study was collected from an olefin plant in the Pars special economic zone in the south of Iran. This plant consumes ethane and naphtha as feed. The pollutants expected in the feed were components that were derived from steam cracking ethane and naphtha as saturated hydrocarbons, aromatics, phenol and benzene. The characteristics of the feed are shown in Table 1.

Table 1. The characteristics of wastewater in the feed

Sample No.	pH	COD(ppm)	TS(ppm)	TSS(ppm)
1	13	6280	530	210
2	13	5260	2568	303
3	13	7360	2895	790
4	13	12820	4146	1026

2.2. SBR configuration and operation

A sequencing batch reactor was fabricated from Plexiglas material. The reactor had an internal diameter of 13.5 cm and a height of 38.8 cm. The operating volume and working volume was 4.2 L and 3 L, respectively. A schematic diagram of the SBR system used in this study is shown in Figure1. The reactor was operated in suspended growth configuration in sequencing batch mode under aerobic conditions. Feeding, withdrawing and sludge waste were accomplished by gravitational force. The reactor was fed with 3 L of the olefin plant wastewater and the influent flow rate of feed was 3 L/d. The suspended biomass concentration of feed was 3000 mg/L. The COD influent and SRT were 6280 mg/L and 10 days, respectively. Carbon removal and operating parameters such as temperature, pH and dissolved oxygen (DO) were monitored during the wastewater treatment. The air supply was provided by an air compressor (Resun ACO-010) with a constant flow of 4.5 L/min. Influent neutralization and pH was adjusted by sulfuric acid in the feed tank before feeding. The reactor was seeded by activated sludge prepared from an aerobic chamber of an industrial wastewater treatment plant located in the Pars special economic zone in the south of Iran. During the initial 20 days, the SBR was operated with no sludge withdrawal to acclimatize the microbial population to the wastewater. The cycle time and SRT was set at 10 days. The mixed liquor suspended solids (MLSS) at the start of the SBR operation was 3000 mg/L. Then for the first run, the reactor was operated under the following conditions: 15min: fill, 23 h: reaction, 90 min: settling and 15 min: withdrawing cycle time. At the end of the aerobic period, the sludge was removed from the reactor to maintain sludge retention time (SRT) at 10 days. The temperature was almost constant at 22 ºc. The variation of COD, pH, oxidation reduction potential (ORP) and DO during the sequence were monitored. The ability of this system was tested by employing different organic loading rates (OLR) using the 3 synthetic samples presented in Table1. The COD, TS and TSS removal efficiency was monitored at the end of each cycle.

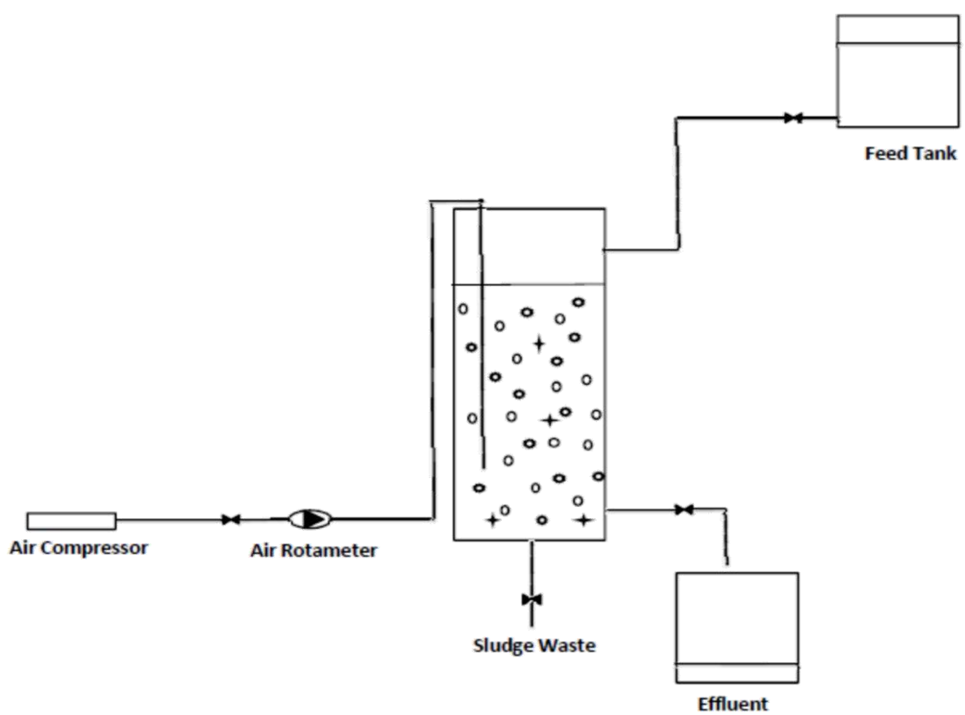

Fig. 1. Schematic of experimental set up

2.3. Analysis

All the analysis including COD (5220 D), TS (2540 B), TSS (2540D), MLSS (2540 G), TSS (2540 D), sludge value index (SVI) (2710D), Turbidity (2130 B), Dissolved Oxygen (DO) (4500-O G. Electrode method), pH (4500-H+ B, Electrometric method) and ORP (2580 B, Electrometric method) were carried out according to the Standard Methods for Water and Wastewater Examination [15].

3. Results and discussion

3.1. Optimum time of aeration and settling phases

Figure 2 shows the efficiency of COD removal. As shown in Figure 2, COD removal efficiency increased with rising aeration time up to 23 h, but the COD removal rate significantly decreased after 6 h of aeration. With regards to the reduction of COD concentration in the early hours, the chemical compounds in the wastewater were not resistant to biodegradation. Aeration is the main parameter in the cost operation, so a decrease in aeration time is very important. Increasing the aeration more than 6 h till 23 h increased the energy consumption almost 4 times, but the COD removal efficiency improved only 11% Based on this; 6 h was selected as the optimum aeration time. The COD removal efficiency increased to 61% in 6 hours and thereafter gradually increased to 72% at the end of the SBR cycle. The variation of turbidity with settling time was measured. Figure 3 shows the effect of settling time on the turbidity of the effluent. Based on the standard of treated wastewater in Iran (Nephlometric turbidity unit (NTU) <20 NTU), the optimum settling time selected was 30 minutes. The minimum time for fill and withdrawal was 15 min, so the optimum cycle time achieved was 15min: fill, 6 h: reaction, 30 min: settling, and 15 min: withdrawal. Thus, the total cycle time result was 7 h and the hydraulic retention time (HRT) was 9.8 h. At this time, the COD efficiency reached 61%. Effluent turbidity, TS and TSS were 17.9NTU, 70 mg/L and 50 mg/L, respectively. The DO concentration in the reactor was kept above 3 mg/L throughout the SBR cycle. For comparison of the results we were drawing out the related data from literature and presented in Table 2. As shown in Table 2, the initial effluent of COD concentration in this research with 6280 mg/L was greater than the other works. The high removal efficiency achieved in the Andereottola and Hudson study was due to its low COD in the feed 1400 and 1500 mg/L respectively and the high cycle time of operation 12 and 24 respectively.

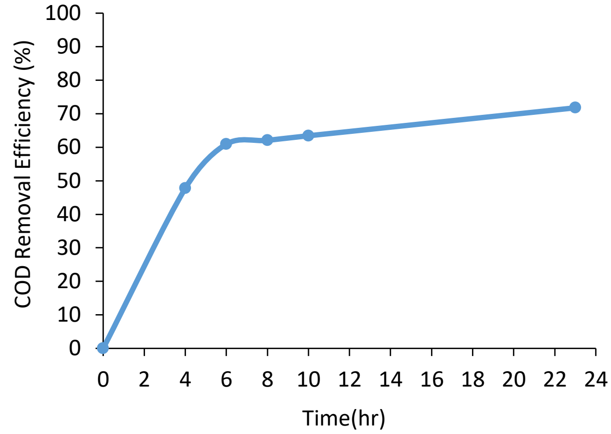

Fig. 2. COD removal efficiency during cycle operation

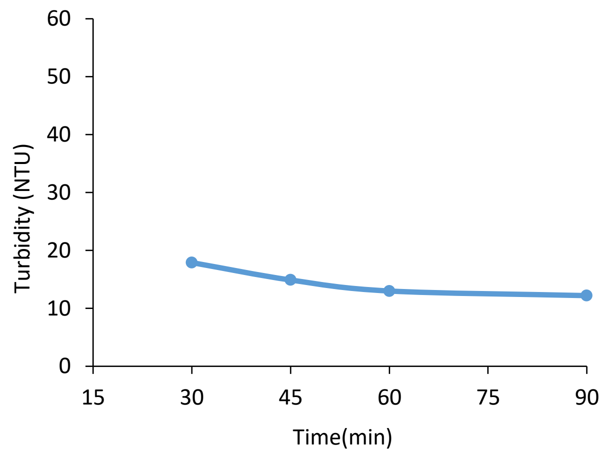

Fig .3. Turbidity variation during cycle operation

Table 2. Comparison with the results of other works on industrial wastewater

Removal efficiency (%)	Total cycle time(h)	COD (mg/L)	References
91	12	1400	Andereottola et al,2001 [16]
93	24	1500	Hudson et al, 2001 [17]
80	24	3500	Venkata et al, 2007 [4]
70	8	4000	Farina et al,2004 [18]
84	7	6280	This research

3.2. SRB Performance

The COD removal efficiency for different organic loading rates is shown in Figure 4. The OLR at each step increased. The efficiency of the reactor to treat the COD of the OLR in the SBR run was 84%. The obtained removal efficiencies are not steady state values and can only be used for comparative purposes.

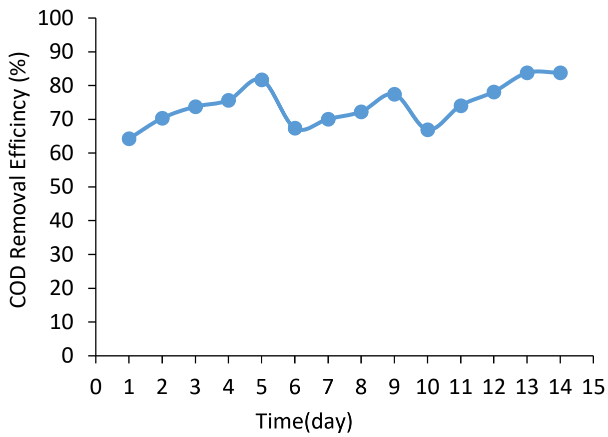

Fig. 4. COD removal efficiency in effluent

4. Conclusions

In this research the performance of sequencing batch reactor on COD removal of petrochemical wastewater was investigated and the operation parameters were optimized. The optimum cycle time for the sequences of SBR was 15min: fill, 6 h: reaction (aeration), 30 min: settling and 15 min: withdrawal. Furthermore, SBR efficiency in the achieved time and at different organic loading rates resulted in the removal of COD: 84%, TS: 67% and TSS: 92%. It can be concluded that the response of SBR to the variation of the organic load rate of wastewater was acceptable. Whereas the reduction of total time of operation is an effective economical factor (increasing the aeration time up to four times), this strategy for treatment of petrochemical wastewater is comparable with another works.

Nomenclature:

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved oxygen
HRT	Hydraulic Retention Time
MLSS	Mixed Liquor Suspended solid
NTU	Nephlometric Turbidity Unit
OLR	Oxygen Loading Rate
ORP	Oxidation Reduction Potential
SBR	Sequencing Batch Reactor
SRT	Sludge Retention Time
TDS	Total Dissolved Solid
TS	Total Solids
TSS	Total Suspended Solids

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