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Feasibility of Continuous Flow Sequencing Batch Reactor in Synthetic Wastewater Treatment

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Abstract: The purpose of this study was to determine whether continuous flow SBR could provide efficient pollutant removal in synthetic wastewater. The experiment was carried out using pilot scale at Tehran University of Medical Sciences. The results showed that the removal efficiency that has been achieved by the system were 97.7, 94.9, 85.4, 71.4 and 55.9% for BOD, COD, TKN, Total N and Total P, respectively could be achieved by the system. Maximum TSS concentration in final effluent was 6.3 mg L^{-1}.

Key words: Continuous flow SBR, synthetic wastewater, organic removal, nutrient removal

INTRODUCTION

Eutrophication of an enclosed water area is caused by contaminants, especially BOD, nitrogen and phosphorus. Long-term accumulation of nutrients will cause eutrophication and influence the quality of water resources[1]. The study used synthetic wastewater the influent for a single continuous flow sequencing batch reactor (a new modification of conventional SBR) to determine the removal efficiency of BOD, COD, N, P and TSS of the system.

In recent year, sequencing batch reactors (SBRs) have gained great interest for wastewater treatment, because of their simple configurations (all necessary processes are taking place time-sequenced in a single basin). SBRs could achieve nutrient removal using an alternation mode of anoxic and aerobic periods, so nitrification and denitrification are achieved in the mentioned periods, while the separation of treated wastewater and biomass is accomplished by ceasing aeration and/or mixing at the end of process cycle[2,3]. Due to its operational flexibility, it is quite simple to increase the efficiency in treating wastewater by changing the duration of each phase rather than adding or removing tanks in continuous flow systems.

While the conventional SBR system has many advantages, it does have some shortcomings, such as: (1) it needs at least two reactors or an equalization/storage tank (2) when designing with two tanks, one basin can not be taken out of service for maintenance purposes, (3) flow and loadings to plant vary during day which results in unequal mass and hydraulic loadings, (4) control system is based on water level in reactor and since diurnal flow variations occur, the cycling results in different actual aeration times for the biological reactions and (5) in biological nutrient removal systems, continuous carbon source is essential. In such systems raw wastewater is used as carbon source, while in SBR this source is interrupt during phases[4].

For removing the obstacles mentioned and to achieve more pollutant removal a pilot plant study has been performed. This plant is a modification of the superior technology of the conventional SBR. The system allows continuous inflow of wastewater to the basin. Influent flow to the basin is not interrupted during the settle and decant phases or at any time during the operating cycle.

In conventional SBRs there are five phases: fill, react, settle, draw and idle[5]; but in this system there is only three phases: react, settle and draw. It must be noted again that influent never disrupts in any phase. Continuous inflow allows the process to be controlled on a time, rather than flow basis and ensures equal loading and flow to all basins. Use of a time-based control system facilitates simple changes to the process control program. The duration of each cycle and segment of each operating cycle are the same among all basins in a time-based

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system. Therefore, changes to the process are made simply by changing the duration of individual segments.

The reactor was separated into two zones (pre-react and main react) by a baffle wall. The pre-react zone acts as a biological selector enhancing the proliferation of the most desirable organisms while limiting the growth of filamentous bacteria, as an equalization tank and as a grease trap[6].

Influent in SBRs is batch and in cases that we want continuous inflow there must be at least two reactors. This increases the cost of construction. Additionally the bath inflow causes unequal loading (organic and hydraulic) in basins which could affect on biomass. This research is done to remove disadvantages of the SBR and specially batch influent. We wanted to determine whether system could remove pollutants when influent is continuous.

The purpose of this research was to determine the best cycle capable to remove BOD, COD, N, P and TSS from synthetic wastewater.

MATERIALS AND METHODS

Continuous flow SBR reactor: Experiments were carried out using a lab scale continuous flow SBR reactor with an operating volume of 36 L. The reactor was seeded with sludge from the return line of aerobic basin of a domestic wastewater treatment plant. An air pump and diffusers provided sufficient aeration and mixing of the mixed liquor. Temperature varied between 10-30°C. Wastewater was introduced into pre-react zone, using a diaphragm dosing pump and flowed through openings at the bottom of the baffle wall and into the main react zone where BOD removal and nitrification occur. Effluent was discharged by gravity though a solenoid valve. Analog timers controlled the operation of the system. A schematic of pilot is shown in Fig. 1.

Synthetic wastewater characteristics: The synthetic wastewater was prepared in a 60-liter barrel. The feed contained *glucose* as the sole organic carbon source (about 370 mg L^{-1}) and *ammonium chloride* as nitrogen source (about 48 mg L^{-1}). A combination of potassium hydrogen phosphate (K_2HPO_4) and potassium dihydrogen phosphate (KH_2PO_4) was used both to buffer the mixed liquor in the range of 7.0-7.5 and to provide a phosphorus source for sludge. Sodium hydrogen carbonate ($NaHCO_3$) was added in excess to ensure that the nitrification process was not limited by alkalinity[7].

Experimental procedures: In general a typical sequencing batch reactor (SBR) includes five distinct phases namely fill, react, settle, draw and idle. In the present work there are only three phases namely react, settle and draw; which in all of these phases wastewater flows to reactor and does not disrupt. First the wastewater enters to pre-react zone, with low MLSS concentration to create a high F/M ratio that prevents filamentous growth causing sludge bulking. After a short retention time (15-20 min) wastewater flows to main react zone through openings at the bottom of baffle wall. Distribution of wastewater is accomplished by "distribution tubes" that are inserted at the bottom of reactor. In react phase air diffusers provide air supply and mixing of mixed liquor in aeration basin. In settling phase, a thick sludge blanket is formed. This blanket is heavy enough to prevent disruption of settled sludge. Organic constituents are used by microorganisms during passage of wastewater from this layer. In draw phase, clear supernatant is removed through a floating decanter. Figure 2 shows typical phases of this system. All of the decanted effluent is collected and analyzed.

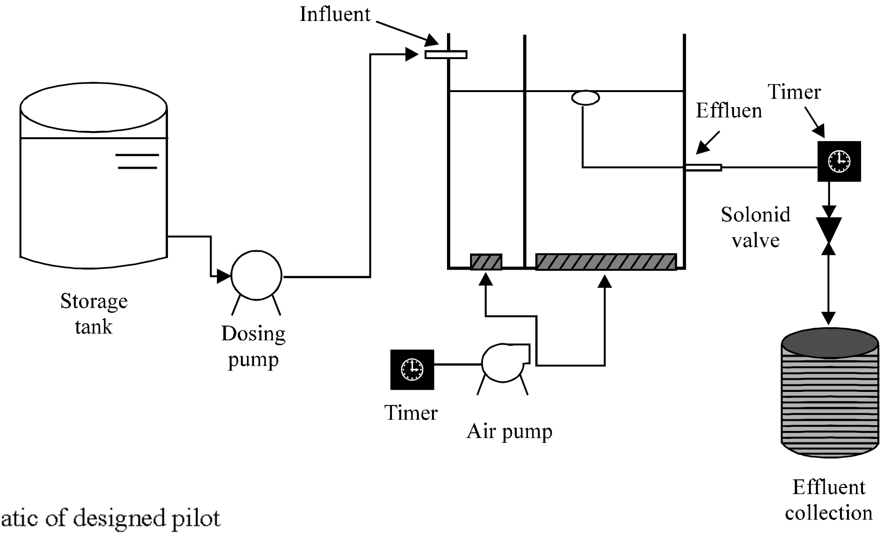

Fig. 1: Schematic of designed pilot

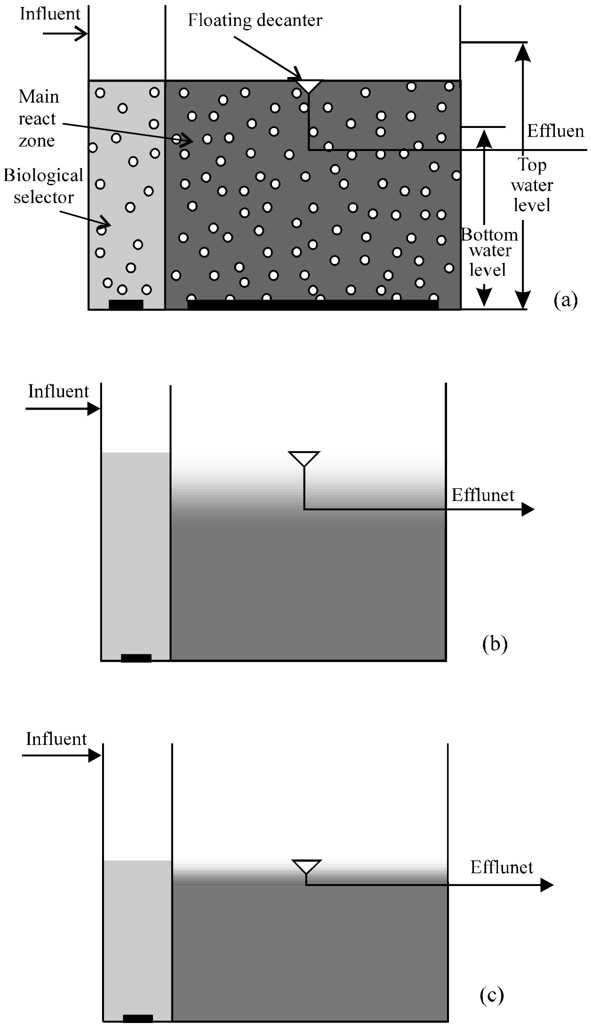

Fig. 2: Different phases of a continuous flow SBR (a) aeration phase, (b) settle phase and (c) decant phase

Experiment was done in three runs: Run 1: 4 h cycle ($Q = 1\ L\ h^{-1}$, HRT = 20 h); Run 2: 6- h cycle ($Q = 1\ L\ h^{-1}$, HRT = 22 h) and Run 3: 8 h cycle ($Q = 1\ L\ h^{-1}$, HRT = 24.4 h).

It must be noted that in all runs 50% of total cycle time was allocated to aeration, 25% to settling and 25% to decanting.

RESULTS AND DISCUSSION

Each of the runs lasts one month under mentioned conditions. Average operating conditions and influent and effluent concentration for each run (Table 1) showed solids retention time (SRT) ranged from 12.5 to 24 days, hydraulic retention time (HRT) varied form 12.4 to 16.7 h, reactor MLSS ranged from 6002 to 6146 mg L^{-1} and average temperature ranged from 10 to 24°C.

Table 1: Average operating conditions and influent and effluent (in parenthesis) concentrations.

Test run (reactor)	1	2	3
Cycle time (h)	4.000	6.000	8.000
Aerated fraction	0.500	0.500	0.500
HRT (hr)	20.000	22.000	24.400
SRT (day)	37.000	28.000	24.000
F/M	0.111	0.122	0.132
MLSS (mg L^{-1})	6680.000	6337.000	5906.000
MLVSS (mg L^{-1})	5005.000	4694.000	4152.000
Temperature (°C)	23.000	22.000	23.000
COD (mg L^{-1})	371 (15.200)	375.000 (7)	373 (10.800)
BOD_5 (mg L^{-1})	342 (7.500)	345.000 (3.4)	343 (5.400)
TKN (mg L^{-1}-N)	44.500 (2.3)	44.900 (4)	46.200 (6)
NO_3^- (mg L^{-1}- N)	(6.300)	(5.500)	(11.600)
NO_2^- (mg L^{-1}- N)	(0.470)	(.470)	(0.450)
Total N (mg L^{-1})	45.300 (9.07)	46 (9.970)	47 (18.500)
Total P (mg L^{-1}-P)	16.400 (14.2)	16.200 (14.1)	16.600(13.8)
pH	7.100	7.600	7.500

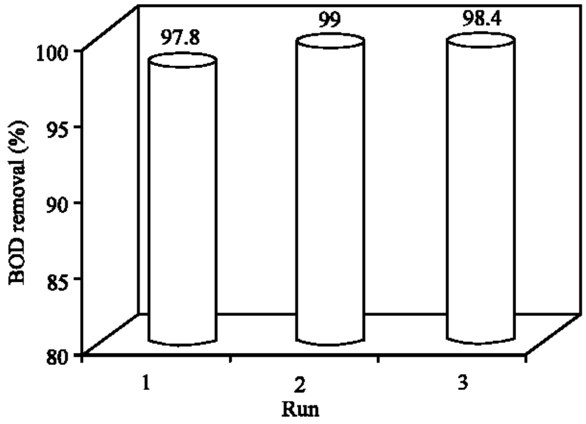

Fig. 3: BOD removal in runs 1 to 3

BOD removal: BOD values in feed and effluent were followed throughout the work. Soluble and total BOD was measured. Influent total BOD was about 345 mg L^{-1}. Removal of BOD in runs no. 1 to 3 were 97.8, 99 and 98.4%, respectively (Fig. 3).

Statistical analysis indicated that run no. 2, with alpha = 0.05 is the best run for this purpose.

COD removal: COD values in feed and effluent were followed throughout the work. Soluble and total COD was measured. Influent total COD was about 370 mg L^{-1}. Removal of COD in runs no. 1 to 3 were 95.5, 98.1 and 97.1%, respectively (Fig. 4).

Statistical analysis indicated that run no. 2, with alpha = 0.05 is the best run for this purpose.

Nitrogen removal: The results showed that organic and ammonium nitrogen in terms of Total Kjeldahl Nitrogen (TKN) could be removed in runs no. 1 to 3, 91.1, 91 and

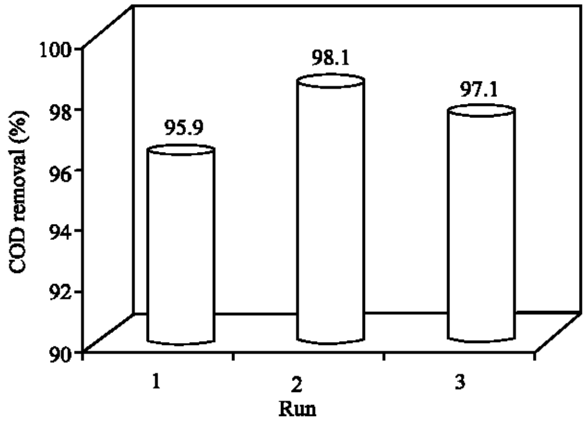

Fig. 4: COD removal in runs 1 to 3

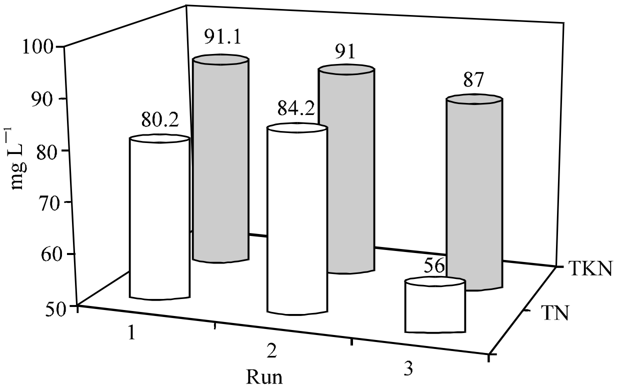

Fig. 5: Total kjeldahl nitrogen (TKN) and total nitrogen (TN) removal in runs 1 to 3

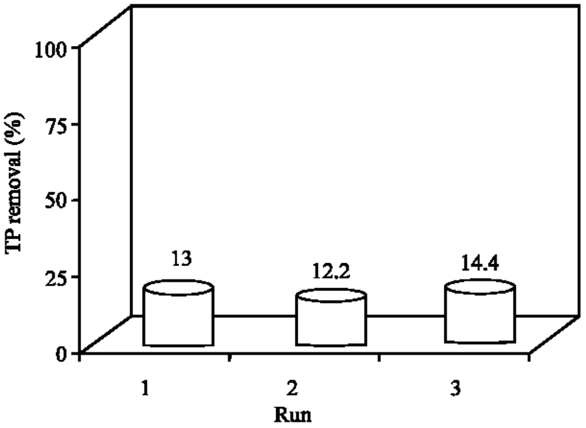

Fig. 6: Total phosphorus removal in runs 1 to 3

87%, respectively (Fig. 5). In run 3, temperature was between 8 to 14°C. Nitrification and denitrification are both temperature dependent[8] so that the activities of nitrifying bacteria are completely stopped at 5°C[6].

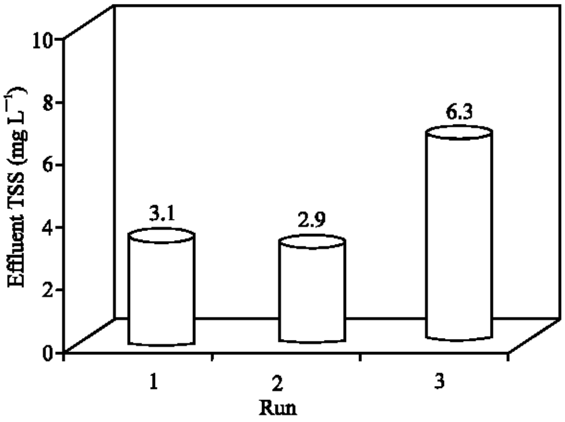

Fig. 7: Effluent TSS in runs 1 to 3

The TKN removal in runs no. 1 to 3 was in the range of 87 to 91%. Also TN removal in run no. 1 to 3, were 80.2, 84.2 and 56%, respectively. This indicated that in settle and decant phase dissolved oxygen reached to zero and anoxic conditions becomes predominant, so that denitrification occurred[9].

Statistical analysis indicated that there are no significant differences in total nitrogen removal between run no. 1 and 2.

Phosphorus removal: Phosphorus concentrations in feed and effluent were followed throughout the work. Only total Phosphorus was measured. Influent total phosphorus was about 16 mg L^{-1}. Removal values of total phosphorus in runs no.1 to 3 were 13, 12.2 and 14.4%, respectively (Fig. 6), which is low like other activated sludge processes.

Statistical analysis indicated that there are no significant differences in total phosphorus removal between run no. 1 and no.2.

This low phosphorus removal is expected in a system without addition of chemicals. Phosphorus was assimilated in cells growing and mobilized again in cell decay during the sludge turnover.

Biological phosphorus removal in a system without true anaerobic stages (no nitrate present) will not give a satisfactory result. Where phosphorus removal is seen to be important, chemical precipitation combined to system seems a possible solution. This, however, dispossesses the continuous flow SBR process with the extra advantages of easy attendance and operation.

TSS removal: TSS in effluent was followed throughout the work. In influent there was not particulate matter. Effluent TSS in runs no. 1, 2 and 3 were 3.1, 2.9 and 6.3 mg L^{-1}, respectively (Fig. 7). This indicated that settling of sludge is completely efficient and continuous inflow does not disrupt settling of mixed liquor during settle and decant phases.

It is demonstrated that high removal of BOD, COD, N, TSS, in continuous flow sequencing batch reactor could be achieved in treating domestic wastewater. COD removal to as high as 98.1%, BOD removal to as high as 99%, total nitrogen removal to as high as 84.2% TP removal to as high as 13% could be achieved from this treatment. The method could be used in small to medium communities' wastewater treatment plants. Nitrogen removal is accomplished as a side reaction. High MLSS concentration in aeration tank aids to create anoxic conditions as soon as after aeration phase to achieve denitrification for nitrogen removal.

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