American Journal of Applied Sciences 1 (4): 348-353, 2004
ISSN 1546-9239

Feasibility of Continuous Flow Sequencing Batch Reactor in Domestic 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 domestic wastewater. The experiment was carried out using a pilot scale at Tehran University of Medical Sciences and in wastewater treatment plant. The results showed that 97.7% of BOD removal, 94.9% COD removal, 85.4% TKN removal, 71.4 % TN removal, 55.9% TP removal and 99% TSS removal could be achieved by the system.

Key words: Continuous Flow SBR, Domestic Wastewater, Treatment

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 the grit chamber effluent in the Shahrak Gharb Wastewater Treatment Plant as inflow to a single continuous flow sequencing batch reactor which modified from a 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 great interest for wastewater treatment, because of their simple configuration (all necessary process is taking place time-sequenced in a single basin). SBRs could achieve nutrient removal using alternation of anoxic and aerobic periods[2], nitrification and denitrification are achieved in an SBR by mentioning periods, while the separation of treated wastewater and microorganisms is accomplished by ceasing aeration and/or mixing at the end of process cycle[3]. Due to its operational flexibility, it is quite simple to increase its 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’t be taken out of service for maintenance purposes. (3) Flow and loadings to plant varies during day that results in unequal mass and hydraulic loadings. (4) The control system is based on water level in the reactor and since diurnal flow variation occurs, 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 in interrupt during phases[4].

Removing the motioned disadvantages and to achieve nitrogen removal an experimental study (pilot plant) has been performed. This system is a modification and enhancement 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 influence never disrupts in any phase. Continuous inflow allows the process to be controlled at 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 is the same among all basins in a time-based 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].

In SBRs influence 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 hydraulically) 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 the system could remove pollutants when influenced in continuous.

The purpose of this research is to determine the capability of the system in removing BOD, COD, N, P and TSS from raw 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 liters. The reactor was seeded with sludge from the return line of the aerobic basin of the Goods Wastewater Treatment Plant. An air pump and diffusers provided sufficient aeration and mixing of the mixed liquor. The temperature varied between 10-30oC. Wastewater was introduced into pre-react zone, using a diaphragm dosing pump and flows through openings at the bottom of the baffle wall and into the main react zone where BOD removal and nitrification occur. The effluent was discharged by gravity through a solenoid valve. Analog timers controlled the operation of the system (Fig. 1).

Domestic Wastewater: Typical composition of domestic wastewater used in the second stage is shown in Table 1.

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 the reactor and doesn't disrupt. Firstly the wastewater enters into 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). The wastewater flows to main react zone through openings at the bottom of baffle wall. Distribution of wastewater is accomplished by "Distribution Tubes" that are installed at the bottom of the reactor. In react phase air diffusers act air supply and mixing of mixed liquor in the aeration basin. In settling phase, a thick sludge blanket is formed. This blanket is enough heavy to prevent disruption settled sludge. Organic constituent is used by microorganisms during passage of wastewater from this layer. In draw phase, clear supernatant in removed through a floating decanter. Figure 2 shows typical phases of this system. All of the decanted effluent is collected and analyzed.

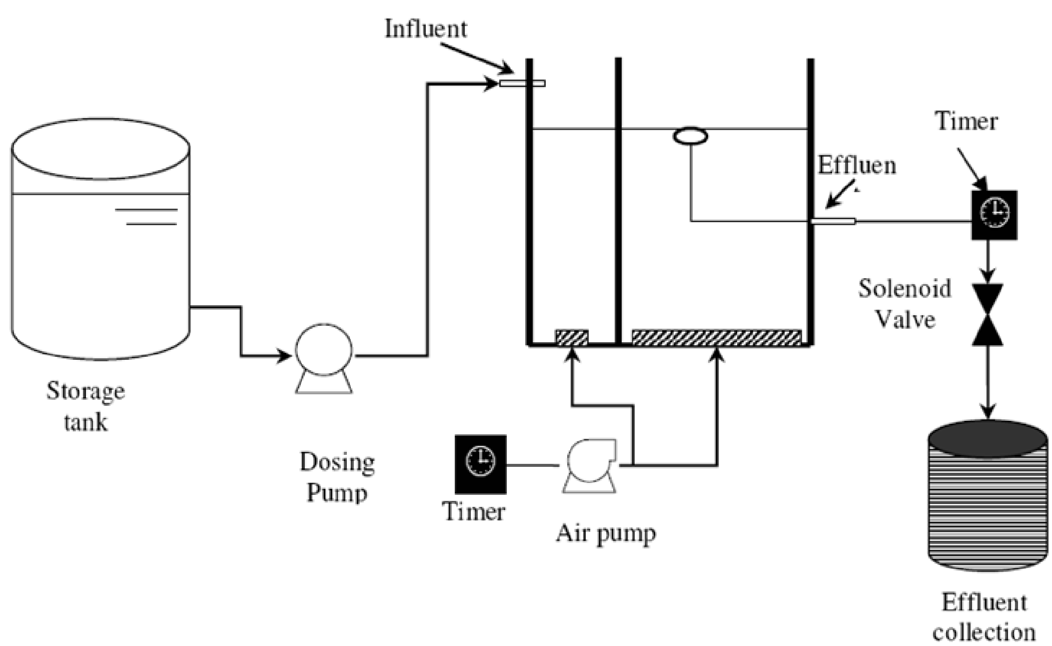

Fig. 1: Schematic of Designed Pilot

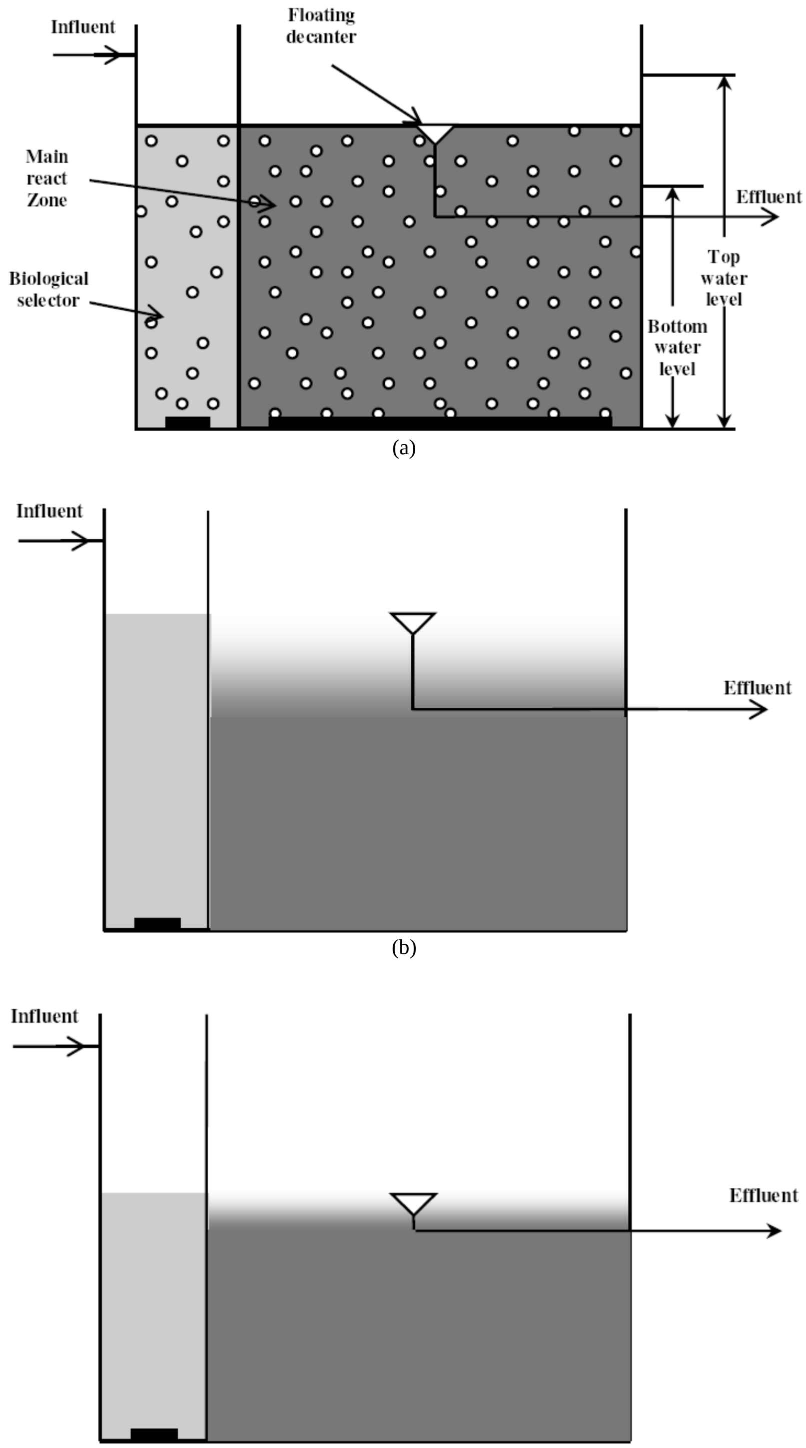

Fig. 2: Different Phases of a Continuous Flow SBR; (a) Aeration Phase; (b) Settle Phase and (c) Decant Phase

Experiment was done in three runs: Run 1: 6- hour cycle (Q = 1.5 L/hr, HRT = 16.7 hr); Run 2: 6- hour cycle (Q = 2 L/hr, HRT = 14 hr); and Run 3: 6- hour cycle (Q = 2.5 L/hr, HRT = 12.4 hr).

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

Table 1: Typical Composition of Domestic Wastewater

Substrate	Concentration
COD	417 mg/L
BOD	230 mg/L
TJN	48 mg/L
TSS	255 mg/L
Tot.	P 16 mg/L

RESULTS AND DISCUSSION

Each of the runs, last one month under mentioned conditions. Average operating conditions and influent and effluent concentration for each run are listed in Table 2. Solids Retention Time (SRT) ranged from 12.5 to 24 days, hydraulic Retention Time (HRT) varied from 12.4 to 16.7 hours, reactor MLSS ranged from 6002 to 6146 mg/L, average temperature ranged from 10 to 24°C.

BOD Removal: BOD in the feed and effluent were followed throughout the work. Soluble and total BOD was measured. Influent total BOD was about 230 mg/L. Removal of BOD in runs 1, 2 and 3 were 97.7, 97.2 and 96.8 % respectively. In other modifications of activated sludge BOD removal is between 60-95[7]. In this system BOD removal is more than other processes. Figure 3 shows system capability in BOD removal in different runs.

COD Removal: COD in the feed and effluent were followed throughout the work. Soluble and total BOD was measured. Influent total COD was about 420 mg/L. Removal of COD in runs 1, 2 and 3 were 94.9, 94 and 93 % respectively (Fig. 4).

Figure 4 shows system capability in COD removal in different runs.

Nitrogen Removal: The results show that organic and ammonium nitrogen in terms of Total Kjeldahl Nitrogen (TKN) could be removed in runs 1, 2 and 3, 85.4, 84.2 and 69 respectively. In run 3, temperature was between 8 to 14oC. Nitrification and denitrification are both temperature dependent[8] so that the activities of nitrifying bacteria are completely stopped at 5°C[6]. The TKN removal in runs no. 1 to 3 was in the range of 69 to 85 %. Also TN removal was in run no. 1, 2 and 3, 71.4, 69.8 and 57.9 percent respectively. This indicated that in settling and decant phase dissolved oxygen arrived to zero anoxic conditions becomes predominant, so that denitrification occurs[8]. As a result, nitrite and nitrate levels in effluents were relatively low (below 7 mg/L) in all run. Figure 5 and 6 shows system capability in nitrogen removal in different runs.

Phosphorus Removal: Phosphorus concentration in the feed and effluent was followed throughout the work. Only total Phosphorus was measured. Influent total phosphorus was about 16 mg/L. Removal of total phosphorus in runs no.1, no. 2 and no. 3 was 38.5, 52.1 and 55.9 percent respectively, which is more than conventional processes. It's expected to run no. 1 on a system without the addition of chemicals and good to run no. 2 and 3. 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 of the advantages of easy attendance and operation. Figure 7 shows system capability in phosphorus removal in different runs.

TSS Removal: TSS in the feed and effluent were followed throughout the work. Influent TSS was about 256 mg/L. Removal of TSS in runs no. 1, no. 2 and no. 3 were 99, 97.8 and 96.7 percent respectively.

Table 2: Operating Conditions and Influent and Effluent (in Parenthesis) Concentrations

Test runs (reactor)	1	2	3
Cycle time (hr)	6	6	6
Aerated fraction	0.5	0.5	0.5
HRT (hr)	16.7	14	12.4
SRT (day)	24	16	12.5
F/M 0.	107	0.137	0.133
MLSS (mg/L)	6146	6002	6033
MLVSS (mg/L)	3678	3480	3469
Temperature (° C)	20	16	11
COD (mg/L)	417	417	417
	(21)	(25)	(29.2)
BOD5 (mg/L)	230	230	230
	(5.2)	(6.2)	(7.3)
TKN (mg/L-N)	47.9	47.9	47.9
	(7.1)	8.3)	(14.6)
NO3- (mg/L- N)	(6.8)	(6.3)	(5.6)
NO2- (mg/L- N)	(0.14)	(0.13)	(0.13)
Total N (mg/L)	48.7	48.7	48.7
	(14.04)	(14.73)	(20.33)
Total P (mg/L-P)	16.1	16.1	16.1
	(9.7)	(7.9)	(7.3)
PH	7.5	7.3	7.3

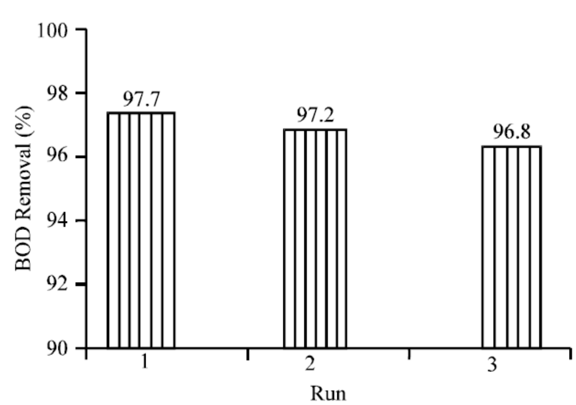

Fig. 3: BOD Removal in Runs 1 to 3

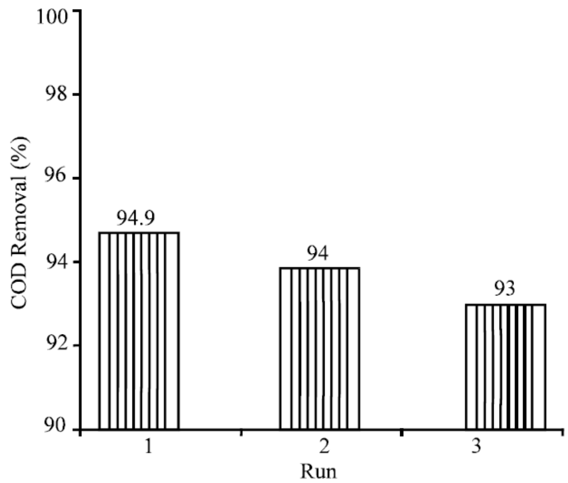

Fig. 4: COD Removal in Runs 1 to 3

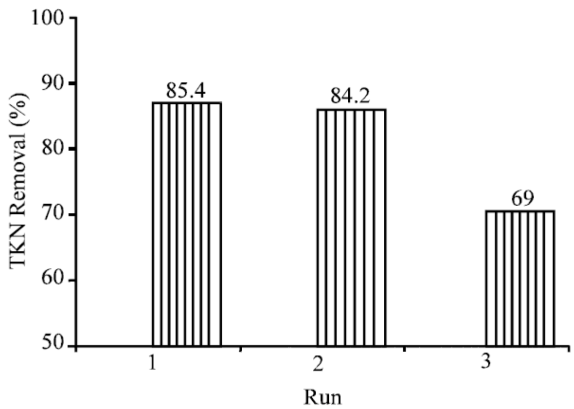

Fig. 5: Total Kjeldahl Nitrogen Removal in Runs 1 to

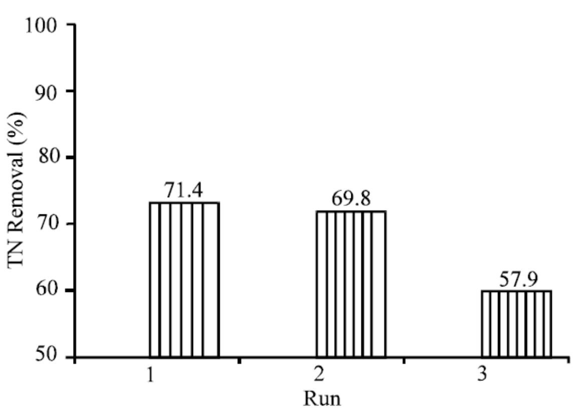

Fig. 6: Total Nitrogen Removal in Runs 1 to 3

This indicated that the settling of sludge is completely efficient and continuous inflow doesn't disrupt settling of mixed liquor during settle and decant phases. Figure 8 shows system capability in TSS removal in different runs.

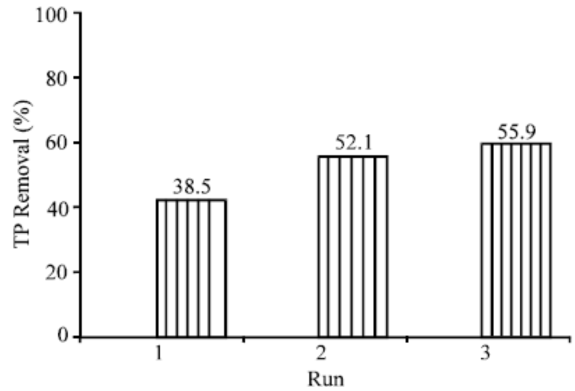

Fig. 7: Total Phosphorus Removal in Runs 1 to 3

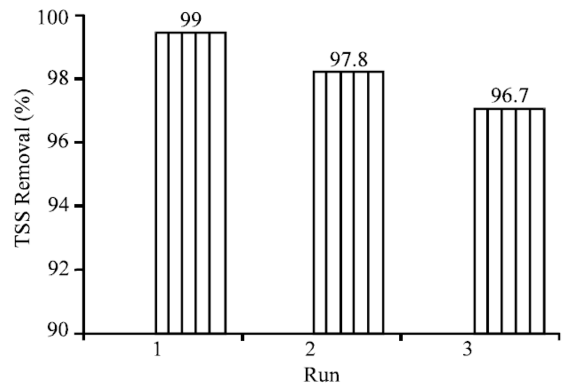

Fig. 8: TSS Removal in Runs 1 to 3

It is demonstrated that high BOD, COD, N, TSS, relatively high removal in continuous flow sequencing batch reactor could be achieved in treating domestic wastewater. COD removal as high as 94.9%, BOD removal as high as 97.7%, total nitrogen removal as high as 71%, TSS removal as high as 99% and TP removal as high as 55.9% could be obtained from this experiment. The method could be used in small to medium sized communities' wastewater treatment plant. Nitrogen removal is a byproduct. High MLSS concentration in aeration tank aids to create anoxic conditions as soon as after aeration phase to achieve denitrification for nitrogen removal.

ACKNOWLEDGEMENT

This research was supported by the Office of Research, Tehran University of Medical Sciences.

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