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RESEARCH ARTICLE

COMPARISON OF PERFORMANCE EVALUATION OF SEQUENCING BATCH REACTOR (SBR) AND SEQUENCING BATCH BIOFILM REACTOR (SBBR) FOR THE TREATMENT OF DOMESTIC WASTEWATER

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ABSTRACT

The present study is the application of Sequencing Batch Reactor (SBR) and Sequencing Batch Biofilm Reactor (SBBR) for treating the domestic wastewater. The SBBR used in this study contained biomass immobilized in inert support material (polyurethane foam cubes) as well as suspended biomass while in SBR only suspended biomass was used. The SBR was operated for long duration and from day 125 onwards the effluent phosphorus concentration reduced to less than 4 mg/l (80% P uptake). Denitrification was observed from day 120 onwards in the anaerobic phase while nearly complete nitrification was observed in subsequent aerobic phase with effluent ammonia nitrogen concentration less than 2 mg/l. The SBBR took 26 days to reach the steady state condition with treated wastewater Chemical Oxygen Demand (COD), phosphorus, ammonia-nitrogen and nitrate-nitrogen concentrations of 14 mg/l, 3.6 mg/l, 4.5 mg/l and 6.1 mg/l respectively. The SBBR was operated for 106 days and during the study nearly complete COD removal was observed and the effluent phosphorus concentration was in the range of 2.7 to 3.6 mg/l, ammonia-nitrogen concentration was less than 1 mg/l and denitrification was nearly 100% at the end of anaerobic phase. From this study it was found that SBBR was more effective in removing nitrate-nitrogen when compared to SBR.

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INTRODUCTION

Biological methods have been used successfully at municipal and industrial levels to remove nutrients. In this regard choosing the efficient treatment system is important. Sequencing Batch Reactor (SBR) is a modification of activated sludge process which has been successfully used to treat municipal and industrial wastewater. The conventional activated sludge process for nutrient removal is space oriented system. However, SBR is a time-oriented system which typically includes the following steps: FILL, REACT, SETTLE, DECANT and IDLE phases. SBR has been employed as an efficient technology for wastewater treatment, especially for domestic wastewaters, because of its simple configuration and high efficiency in COD and suspended solids removal (USEPA, 1993). The SBR is a fill and draw activated sludge system for wastewater treatment. Equalization, aeration, and clarification can all be achieved using a single batch reactor. They are uniquely suited for wastewater treatment applications characterized by low intermittent flow conditions (Hue *et al*., 2005). In recent years application of SBR to biofilm reactors was suggested by Wilderer to overcome the difficulties about the growth and maintenance of suspended activated sludge flocs, this combined system is called a Sequencing Batch Biofilm Reactor (SBBR). SBBR is considered to be the hybrid of fully developed SBR technology and one of the newer applications of sequencing batch reactor treatment technology to treat domestic wastewater for the removal of organic matter, nitrogen and phosphorus simultaneously. SBBR's have a potential advantage compared to suspended growth process because of less sludge and compact reactor design. SBBR operation is same as SBR except for the support media used.

Biofilms bear a greater potential for the simultaneous and efficient removal of organic carbon and nutrients like N and P in wastewater treatment. They are spatially heterogeneous, providing space for both, aerobic and anaerobic processes; they are well suited for nitrification, since attached growth of the slow-growing nitrifying bacteria protects them from

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washout; and they can be exposed to alternating anaerobic and aerobic conditions as necessary for Enhanced Biological Phosphorus Removal (EBPR). In this study the performance evaluation of SBR and SBBR were made with regard to removal of organic carbon, nitrogen and phosphorus from synthetic wastewater.

MATERIALS AND METHODS

Reactor System and Feed

The experiments were carried out in a 3 L working volume laboratory scale SBR and SBBR. SBBR initially was operated as conventional SBR which was later converted to SBBR after 5 days by adding 10 % of the liquid volume of the SBR with Porous Biomass Carrier (PBC) media. The PBC used was polyurethane foam of size 1 cm × 1 cm × 1 cm. Both the reactors were inoculated with cow dung slurry as seed culture and were aerated for several days to obtain a dense culture to start with. Later on the following phases were provided for both the reactors: fill, anaerobic phase, aerobic phase, settle and decant. At the end of each cycle, the mixed liquor suspended solids were allowed to settle for 30 min and 50 % of treated wastewater was removed for analysis. Aeration was provided by using aquarium pump connected to diffuser stones. Synthetic wastewater used throughout the study provided a source of carbon, nitrogen; phosphorus and trace elements required for biomass growth. It had the following composition: glucose, 400 mg/l; ammonium chloride, 125 mg/l; di-potassium hydrogen orthophosphate, 70.3 mg/l; magnesium sulphate, 50 mg/l; manganese sulphate, 5 mg/l; sodium hydrogen bi-carbonate, 10 mg/l; calcium chloride, 3.75 mg/l.

Operational Strategy of SBR and SBBR

SBR was operated for one cycle per day with the following predetermined operational strategy: fill, anaerobic, aerobic, settle and decant phases. In the fill stage synthetic wastewater was added to the reactor. During the react phase the biomass consumes the substrate under controlled conditions i.e. in anaerobic and aerobic. In settle phase, mixing and aeration were stopped and the biomass was allowed to separate from the liquid, resulting in a clarified supernatant. Finally in draw phase supernatant was removed for analysis. The operational strategy for SBR in a cycle was anaerobic-react phase (17 h), aerobic-react phase (6 h), settle, decant and fill phase (1 h) (APHA, 2005). SBBR was operated for one cycle per day with the following predetermined operational strategy: fill, anaerobic, aerobic, settle and decant phases. In the fill stage, synthetic wastewater was added to the SBBR to mix the biomass held in the tank. During the react phase the biomass consumes the substrate under controlled conditions: anaerobic, aerobic, and in settle phase the biomass was allowed to separate from the liquid resulting in a clarified supernatant. 50 % of treated effluent was removed from the SBBR at the end of each cycle followed by addition of fresh synthetic wastewater of same quantity. In the SBBR cow dung was used as seed material. Samples of the influent, end of anaerobic phase and effluent of SBR and SBBR were collected two to three times per week for routine monitoring. Before analysis samples were filtered through 0.45 µm filter paper to measure all dissolved chemical parameters. Immediate analysis of samples was carried out as soon as possible. Collected samples which could not be analyzed were kept in the sample preservator at 4 ºC. The samples were analyzed for Chemical Oxygen Demand (COD), ammonia-nitrogen, nitrite nitrogen, nitrate nitrogen and phosphorus in accordance with standard methods (APHA., 2005). The pH measurements were carried out by using pH analyzer. Biomass concentrations (total suspended solids and volatile suspended solids) were determined by filtering the samples through 0.45 µm filter paper and drying it in a hot air oven at 103 ºC for 24 hours and volatile solids were analyzed by vaporizing the samples at 550 ºC in muffle furnace for half an hour (Metcalf and Eddy, 2003).

RESULTS AND DISCUSSION

Performance of SBR

The SBR system was seeded initially with 250 ml of fresh cow dung slurry sieved through 2 mm standard sieve, further it was diluted to 1000 ml with the tap water and was fed with synthetic wastewater of 2 L. It is reported that normally seed culture contains heterotrophs, nitrifiers, denitrifiers and does not contain PAOs, hence in order to stimulate the growth of PAOs, the SBR was fed with synthetic wastewater containing orthophosphate in the influent. The system was given aeration using aquarium pump attached with two diffuser stones continuously in order to enhance the cell density as well as to increase dissolved oxygen and mixing. The biomass required for degradation was developed in the laboratory scale batch reactor. After acclimatization period of 3 weeks, during which VSS/TSS ratio neared to 0.7, the SBR cycle was given and operated for a period of 179 days. Fig. 1 (a) shows the variations of COD and phosphorus for the entire study period. The influent concentration of COD and phosphorus maintained was 400 mg/L and 12.5 mg/L respectively. COD removal in the anaerobic phase was not more than 7.5 % on the day 1, and corresponding phosphorus release observed was 13.7 %. COD uptake increased to 39.9 % with the release of phosphorus increasing to 47.5 % on day 22. COD remaining at the end of anaerobic phase was 120 mg/L and the corresponding phosphorus concentration was 15.1 mg/L. On day 64, COD uptake increased and it was 28 mg/L at the end of anaerobic phase (86.14 %) and the phosphorus release was also increased to 19.7 mg/L (62.2 % P release). This is in accordance with the researcher's (Chang *et al*., 2000 and Ahn *et al*., 2006), wherein the phosphorus release is associated with the COD uptake in the anaerobic phase.

From Fig. 1 (b) it can also be observed that when COD uptake was less, phosphorus release was not observed and once the COD uptake rate increased, phosphorus release also increased simultaneously. The effluent phosphorus concentration was 10.7 mg/L and it reduced by 50 % the effluent phosphorus concentration was 5.4 mg/L (70.04 % P uptake). More than 80 % phosphorus removal was observed. Figure (b) shows the variations of ammonia nitrogen and nitrate nitrogen at the end of anaerobic and aerobic phases. The influent ammonia was 32 mg/L, and ammonia nitrogen in the

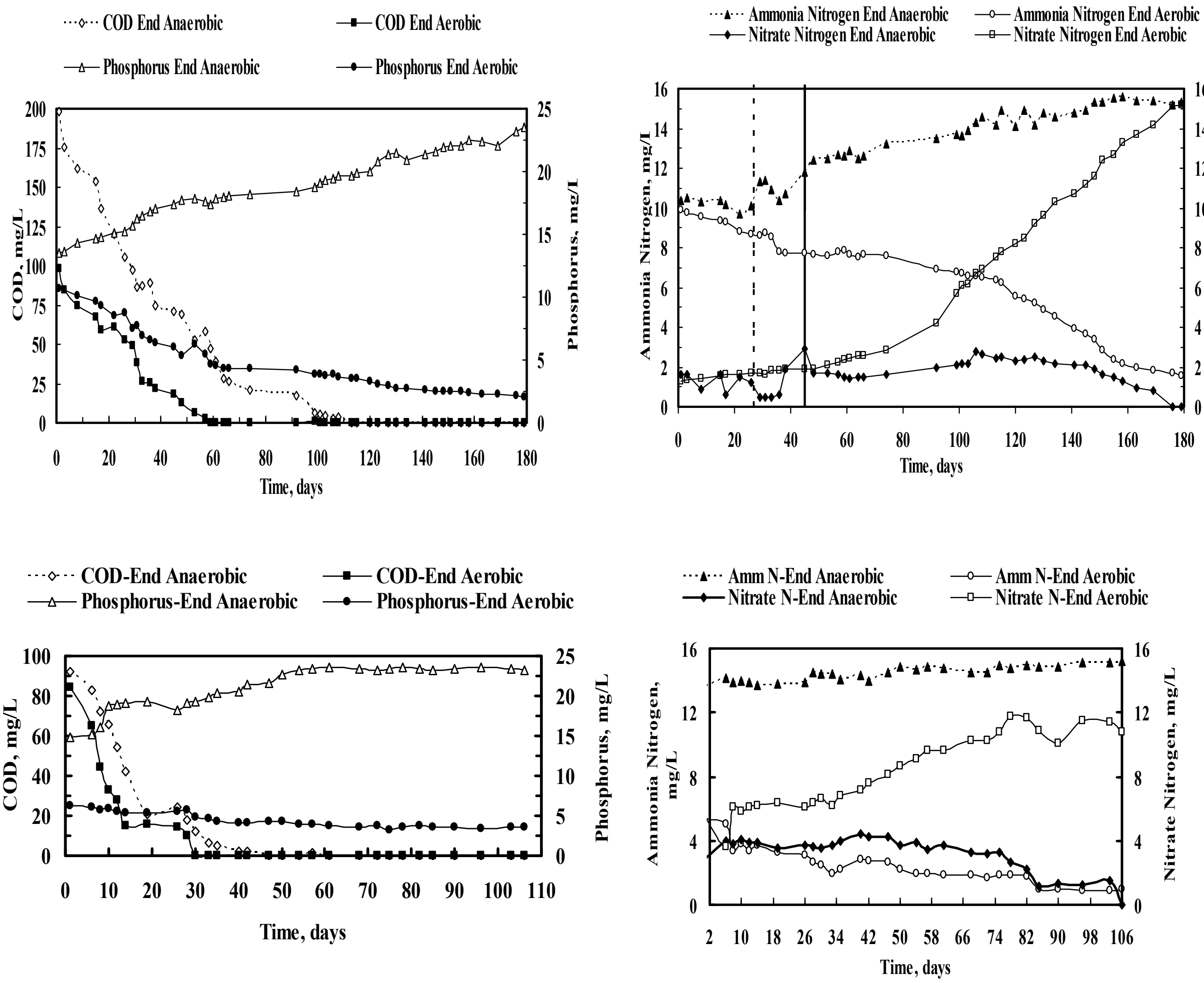

Figure 1. (a) Profiles of COD and phosphorus in SBR (b) Profiles of ammonia nitrogen and nitrate nitrogen in SBR (c) Profiles of COD and phosphorus removal in SBBR (d) Profiles of ammonia nitrogen and nitrate nitrogen removal in SBBR

Table 1. Comparison of Performance of SBR and SBBR

Parameters	SBR	SBBR
	Anaerobic Phase	
P at the end of anaerobic phase, mg/L	23.5	23.2
P release (%)	68.77	56.25
COD at the end of anaerobic phase, mg/L	<6	<4
COD uptake (%)	96.63	99.07
Nitrate nitrogen Reduction, mg/L	7.62	6.16
Denitrification (%)	88	100
	Aerobic Phase	
Phosphorus at the end of aerobic / anoxic phase (mg/L)	2.1	3.5
P Uptake (%)	91.06	65.52
Ammonia-nitrogen removal, mg/L	1.1	13.6
Nitrification (%)	89.93	94.05
Nitrate nitrogen in the treated wastewater, mg/L	15.5	10.8

effluent was 7.6 mg/L indicating only 38.9 % oxidation. Since complete nitrification was not observed and nitrate nitrogen formation at the end of aerobic phase was very less. On the day 100 simple tests were conducted and it was found that some amount of ammonia nitrogen was lost due to ammonia stripping which led to the unstable performance of the SBR. Further, in order to improve the performance of the SBR, the SBR was seeded again with 100 ml of fresh cow dung slurry.

The reactor achieved the steady state after 18 days from the day of reseeding. The COD left at the end of anaerobic phase was completely consumed in the subsequent aerobic phase (17 mg/L). Release of phosphorus was observed in the anaerobic phase (18.4 mg/L) and uptake of phosphorus in the subsequent aerobic phase (4.1 mg/L). More than 79 % uptake of phosphorus was observed after 18 days of reseeding. 90-100 % nitrification was observed with effluent ammonia nitrogen concentration less than 2 mg/L.

Performance of SBBR

The performance of SBBR is typically comparable to the conventional SBR system. The SBBR system was seeded initially with 250 ml of fresh cow dung sieved through 2mm standard sieve, further it was diluted to 1000 ml with the tap water and was fed with synthetic wastewater. This reactor was operated as an attached cum suspended SBR system, wherein microorganisms responsible for the conversion of the organic material or nutrients were found attached to the porous biomass carriers. Air circulation for the void space was given by diffusers, providing oxygen for the microorganisms growing in the attached film. In SBBR, simultaneous nitrification and denitrification was achieved in aerobic phase also. Fig. 1 (c) shows the variations of COD and phosphorus for the entire study period. The COD uptake in anaerobic phase was 54.57 % and the corresponding phosphorus release observed was 32.11 %. Once the steady state was achieved the concentration of COD at the end of anaerobic phase was 29 mg/L and corresponding phosphorus release was 46.45 % and in the subsequent aerobic phase the concentration of COD was 22 mg/L and phosphorus uptake was 5.9 mg/L. The effluent concentration of the phosphorus was 3.5 mg/L (65.52 %). Fig. 1 (d) shows the variations of ammonia nitrogen and nitrate nitrogen at the end of anaerobic and aerobic phases. Ammonia oxidation was 83 % indicating that the ammonia oxidizing bacteria became dominant, the nitrite and nitrate that was accumulated in the aerobic phase was oxidized easily.

Comparison of Performance of SBR and SBBR

Both the reactors (SBR and SBBR) showed good performance with phosphorus uptake as well as nitrification and denitrification. The percent phosphorus release in the anaerobic phase was 68.77 % in SBR and 56.25 % in SBBR. In the subsequent aerobic phase, the phosphorus uptake was 91.06 % in SBR and 65.52 % in SBBR. The performance in terms of organic carbon removal was also very good in the two reactors, with 96 % and 99 % COD uptake in SBR and SBBR respectively. Further, it is observed that in SBBR nitrification rate was more because the attached growth enhanced the growth of nitrifiers. As a result the required aeration time for nitrification in SBBR was shorter than in SBR system. It is also noted that the phosphorus removal capability of SBR is slightly greater than in SBBR, this might be probably because of different nature of sludge systems. As observed from the Table 1, the treated wastewater contained less than 3.5 mg/L of phosphorus in both the SBR and SBBR. The nitrate nitrogen remained in the treated effluent was more in SBR when compared to SBBR i.e., SBBR achieved higher denitrification.

Conclusions

This study investigated the performance of the two reactors SBR and SBBR system for treating synthetic domestic wastewater. From the study following conclusions were obtained:

- The organic carbon removal, nitrification and denitrification rate was high in SBBR and phosphorus removal rate was slightly better in SBR.
- The treated effluent from the two reactors contained COD, ammonia nitrogen and phosphorus within the prescribed limits for the discharge of wastewater standards.
- SBR was operated for 179 days and it initially showed that COD removal in anaerobic phase was not more than 7.5 % and corresponding phosphorus release observed was 13.7 %. On day 74, effluent phosphorus concentration showed 70.4 % P uptake. Later from day 125 onwards the effluent phosphorus concentration showed 80 % P uptake. Denitrification was observed from day 120 onwards in the anaerobic phase with effluent ammonia nitrogen concentration less than 2 mg/l
- SBBR showed stable performance from day 26 onwards, the COD uptake and phosphorus release observed was 99 % and 65 % respectively with effluent concentration less than 4 mg/l and 3.5 mg/l. complete denitrification was observed and the effluent ammonia nitrogen concentration was less than 1 mg/l.
- When compared to SBR, SBBR had the edge with respect to nitrate nitrogen reduction. While in SBR the phosphorus removal was more when compared to SBBR.

REFERENCES

Ahn, C. H., Park, J. K. and Kim, K. S., 2006. Microbial adaptability to organic loading changes in an enhanced biological phosphorus removal process, *J. of Environ Engineering*., 132(8), 909-917.

APHA., 2005. Standard Methods for Examination of Water and Wastewater, American Public Health Association WWA, Washington, D.C.

Chang, H. N., Moon, R. K., Park, B. G., Lim, S. J., Choi, D. W., Lee, W. G., Song, S. L. and Ahn, Y. H., 2000. Simulation of sequencing batch reactor (SBR) operation for simultaneous removal of nitrogen and phosphorus, Bioprocess Engineering Research Center., 23, 513-521.

Hu, J. Y., Ong, S.L., Ng, W.J. and Liu, W., 2005. "Use of sequencing batch reactor for nitrogen and phosphorus removal from municipal wastewater", *J. of Environmental Engineering*, Vol. 131, No.5, pp 734-744.

Metcalf and Eddy, 2003. Wastewater Engineering-Treatment and Reuse", 4th edition Tata McGraw-Hill Publishing Company Limited.

U. S. Environmental Protection Agency (USEPA), Nitrogen Control Manual, U. S. Environmental Protection Agency, Office of wastewater enforcement and compliance, Washington, D.C., Technomic Publishing Company, Inc. USA 1993.

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