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Performance Evaluation of Aerobic Sequential Batch Reactor – A Review

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Abstract—*Sequencing batch reactor (SBR) is modification of activated sludge process (ASP) which has been successfully used to treat domestic wastewater. The aim of this study was to review studies conducted on the performance of the system under different operating conditions. Few researchers have conducted experiments using this technique. The studies show that high removal efficiencies of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5) and total suspended solids (TSS) are possible. This paper reviews some of the published works along with critical comments. Aerobic SBR has wide applicability for treating domestic wastewater. SBR is efficient biological treatment for domestic wastewater when it is assessed for the effect of variations in operating parameters. Further studies are required to assess its performance by varying operational parameters like F/M, OLR, cycle time and time-periods of various phases in a cycle.*

Keywords: *SBR, ASP, Domestic wastewater, Aerobic treatment, Operating conditions.*

1. INTRODUCTION

Discharge of domestic wastewater to surface or groundwater is very dangerous to the environment. Therefore treatment of any kind of wastewater to produce effluent with good quality is necessary. In this regard choosing an effective treatment system is important. Various aerobic, anaerobic, suspended growth and attached growth processes like membrane bioreactor, constructed wetland, up flow anaerobic sludge blanket, bio filter, and sequencing batch reactor are applicable for wastewater treatment. Sequencing batch reactor is modification of activated sludge process which has been successfully used to treat municipal and industrial wastewater. Process advantages are single tank configuration, small foot print, easily expandable, simple operation and low capital costs, etc. (Mahavi, 2008)

Basic processes of aerobic sequential batch reactor (SBR) are, a) Filling: wastewater enters the aerobic SBR tank and mixes with activated sludge mixed liquor solids within the tank. b) Aeration: provision of aeration to the tank contents until the desired degree of treatment has been achieved. c) Settling: after aeration, activated sludge solids settle to form a blanket on the base of the reactor vessel, leaving an over-layer of treated effluent. d) Decant: clarified treated effluent (supernatant) can be removed (decanted) from the tank without disturbing the sludge blanket e) Idle: unexpired time between cycles and wasting of excess activated sludge occurs. All these cycles represented in below Fig.1. Aerobic SBR performs all these processes in a single tank using timed control sequence.

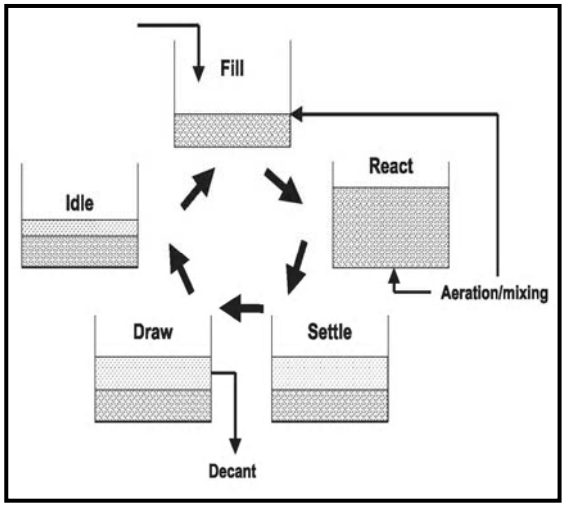

Fig. 1: Typical Cycles in SBR

In this paper, a review of the various operating conditions of aerobic SBR for domestic wastewater treatment is given.

2. REVIEW OF PREVIOUS WORK DONE

Literature survey has been carried out on an aerobic SBR for domestic wastewater and in discussed in this section.

Efficiency of SBR in the removal of selected microorganisms from domestic sewage was studied [9]. The relationships between the loading factor and Biochemical Oxygen Demand ($BOD_{5)}$, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), total coliform, fecal coliform and coli phage removals were explored using three laboratory SBRs receiving

a medium-to-low strength domestic sewage. SBRs were operated with different FILL/REACT ratios in a 6-h cycle. This study showed that there were considerable removals of total BOD, total COD and TSS in the SBR. There was also good removal of total coliforms, fecal coliforms and coli phages. The factor which determined removal performance was linked to settleability of the sludge and an effluent that was low in Suspended Solids (SS). Low Sludge Volume Index (SVI)s were found to indicate good compactibility but not necessarily good settleability of the sludge. Generally, higher loading factor is led to increases in effluent SS.

SBR system for nutrient removal by ORP and pH profiles were performed [2]. Two phases were studied with different Hydraulic Retention Time (HRT), Solid Retention Time (SRT) and organic loading rate (OLR). An efficient SBR system with an SRT of 15 days was successfully operated in Phase I. COD removal efficiency of the Phase I is 95%. The duration of 1.5 hr for the mixed-react and 4 hr for the react stage was found to be excessive for treating influent used in this study. So shorter SRT (10 days) and stage duration (1 hr for the mixed-react and 2 hr for the react stage) were implemented in the Phases II to reduce energy consumption and to increase the total treated volume. It was concluded that the system achieved removal efficiencies of 91%, 98% and 98%, respectively, for COD, total nitrogen and phosphate at the SRT of 10 days, with a cycle duration of 6 hr for the domestic wastewater treatment.

Biological treatment of grey water using SBR was studied [5]. Mixed Liquor Suspended Solids (MLSS), TSS, COD, BOD_5 and SVI parameters were analyzed during the study. The MLSS concentrations were maintained at 2.5 ± 0.3 g/L. Two different HRTs were applied, 0.6 and 2.5 days. The high COD removal was achieved in the reactor and the effluent COD was in average 20 mg/L at two HRTs. The SBR reactor achieved 90% COD removal and good sludge settling properties (SVI < 100 mL/g).

Coupling of SBR and UASB reactor for domestic wastewater treatment was studied [8]. An experimental study was conducted investigating the performance of the system under different operating conditions. Three experimental runs were considered. The retention time in the UASB was changed from 4 hr to 3 hr and the aeration time in the SBR cycle varied from 2 to 5, and then to 9 hr. The results indicated that the average percentage removal for the three runs for COD, BOD and TSS was 94%, 97% and 98% respectively. The quality of the treated wastewater at different operating conditions complies with standards regulating wastewater discharge into agriculture drains.

The effect of the Food-to-Microorganism (F/M) ratio on the formation and size of aerobic sludge granules was studied [1]. Study was carried out to investigate the effect of the sludge loading on the rate of aerobic granulation and the size of the granules in biological wastewater treatment. Four column batch reactors were used with a similar sludge SS concentration of around 2000 mg/L. The reactors were fed with a glucose-based wastewater at different COD concentrations, resulting in F/M ratios from 0.3 to 1.1 d^{-1}. A higher F/M ratio appeared to promote faster formation of larger granules and a lower F/M ratio led to slower formation of smaller granules.

Full scale SBR was analyzed for the performance and diversity of microbial communities [3].

This work described the performance and microbial diversity in a SBR of a decentralized full-scale system for urban wastewater treatment under limited aeration. The reactor was operated for 180 days. Each cycle had an average duration of 8hr, included feeding for 1hr, aeration for 3hr, settling for 3hr and effluent withdrawal for 1hr. throughout the operational period, the mean dissolved oxygen (DO) concentration was 0.3 mg/L. The SRT in SBR was about 107 days. The removal efficiency was 83% for soluble chemical oxygen demand (SCOD), 60% for $N–NH_4^+$, 70% for TSS and 80% for volatile suspended solids (VSS). The biomass concentration had a maximum value around 8.7 gVSS/ L for organic load rate of 0.6 gCOD/L.d. The F/M ratios showed average of 0.2 gCOD/gVSSd. The viability of a full-scale SBR to treat domestic wastewater, with variation of the applied loads and low C/N ratio (3 g-COD/g-N) was studied.

Aerobic granulation in a SBR using real domestic wastewater was performed [4]. These researchers studied the aerobic granulation in a SBR using real domestic wastewater with an OLR at or lower than 2 kgCOD/m^3.d. The reactor was operated in three different stages (Stage I, II and III), according to the applied OLR (1.4, 1.0, and 2.0 kgCOD/m^3.d respectively). The reactor was effective in removing carbon and nitrogen compounds, especially when operated with an OLR of 2 kgCOD/m^3.d providing an average removal efficiency of 92% for COD and 96% for nitrogen. The results demonstrated that aerobic granules can be formed, using real domestic wastewater, with an effective carbon and nitrogen removal.

3. SUMMARY AND DISCUSSION

Three laboratory SBRs with different FILL/REACT ratios in a 6-h cycle time performed and considerable removals of total BOD, total COD and TSS achieved [9]. For process modifications variations in cycle time can be tried like 4, 6, 8 and 12 hrs.

Two phases with different HRT, SRT and OLR performed and system achieved best removal efficiencies at 6 hr cycle time with SRT of 10 days [2]. OLR variations and more than 15 days as SRT can be also tried for this process.

Two different HRTs i.e. 0.6 and 2.5 days were applied and 90% COD removal achieved and good sludge settling properties (SVI < 100 mL/g), [5]. According to design criteria 15-20 hrs as HRT [7] can be also tried for above process.

Aerobic and anaerobic combinable experimented by coupling of SBR and UASB reactor and investigated the performance of the system under different operating conditions [8]. The aeration time in the SBR cycle varied from 2 to 5, and then to 9 hr. still more variations in the aeration time can be also tried.

The effect of the Food-to-Microorganism (F/M) ratio on the formation and size of aerobic sludge granules were studied. Four column batch reactors were used with a similar sludge SS concentration of around 2000 mg/L and resulting in F/M ratios from 0.3 to 1.1 d^{-1} [1]. The performance and microbial diversity in a SBR of a decentralized full-scale system for urban wastewater treatment under limited aeration was studied. The viability of a full-scale SBR to treat domestic wastewater, with variation of the applied loads and low C/N ratio (3 g-COD/g-N) was experimented [3]. Aerobic granulation in a SBR with an OLR at or lower than 2 $kgCOD/m^3.d$ was studied. The reactor was operated in three different stages (Stage I, II and III), according to the applied OLR (1.4, 1.0, and 2.0 $kgCOD/m^3.d$ respectively). OLR of 2 $kgCOD/m^3.d$ achieved average removal efficiencies [4]. still more variations in F/M ratio and OLR can be also worked out for SBR modifications.

It can be observed from the literature review that the limited studies were carried out on variations in SRT, HRT, OLR and cycle time for the COD and nutrient removal from domestic wastewater. The effect of F/M ratio on aerobic granulation was studied in some cases.

Hence there is need to assess the effect of variations in operating parameters. The parameters HRT, SRT, F/M ratio, OLR and cycle time plays key role in treatment process. It is also significant to assess the performance of SBR for treating wastewater from an individual household and cluster of houses.

4. CONCLUSION

Aerobic SBR has wide applicability for treating domestic wastewater. SBR is efficient biological treatment for domestic wastewater when it is assessed for the effect of variations in operating parameters. Further studies are required to assess its performance by varying operational parameters like F/M, OLR, cycle time and time-periods of various phases in a cycle.

5. ACKNOWLEDGEMENT

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