Short Communication

Evaluation of Sequential Batch Reactor (SBR) Cycle Design to Observe the Advantages of Selector Phase Biology to Achieve Maximum Nutrient Removal

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Abstract. Pilot plant studies of sequential batch reactor (SBR) cycles revealed the role of selector phase biology (SPB) involved in COD removal, nitrification, denitrification and total phosphate removal. The phases namely anoxic, anaerobic and aerobic in single tank reactor design of SBR were showed effective biological nutrient removal (BNR) > 90% on average in 4 h designed cycle time with 12 h of hydraulic retention time (HRT). The phases were 2 h fill which includes 1 h simultaneous fill and aeration, 1 h settle and 1 h decant. This cycle design found effective to create selective environment for microbes to carry biological organic and nutrient removal reactions with improvement in sludge volume index (SVI).

Keywords: Anoxic, anaerobic, aerobic, selector phase biology, biological nutrient removal.

1. INTRODUCTION

The traditional or conventional biological processes can remove nitrogen efficiently in separate aerobic and anaerobic phases which are generally carried out in separate bioreactors or using different aeration intervals (Jafarzadeh Ghehi et al., 2014). SBR system achieves BNR with single tank reactor design having higher HRT (Yilmaz et al., 2008). Sometimes separate selector zone required to achieve the nutrient removal reactions to carried out. Different design configurations with specific cycles and different lengths are reviewed for BNR in SBR (Keller et al., 1997). SBR involves stages such as fill, react, settle, decant and idle. Previous research explains various advantages and disadvantages of the SBR system (Aziz et al., 2013).

The mixed liquor suspended solids (MLSS) and carbon, nitrogen and phosphorus concentrations were considered and studied along with other parameters such as sludge drainage, F by M ratio and simultaneous nitrification and denitrification (SND) (Wang et al., 2009; Yu et al., 2000). The SBR is unique reactor operated in a batch mode with unsteady state conditions. The role of microbes was described such as role of nitrifiers, denitrifiers and phosphate accumulating organisms (PAOs) along with phenomena such as SND and enhance biological phosphate removal (EBPR) (Kim et al., 2008; Pochana and Keller, 1999). EBPR is considered as the most economic and appropriate method (no need to chemical precipitation) to remove phosphorous from wastewater (Azhdarpoo et al., 2014), where the design requires to provide separate selector zone with sludge recycle mechanism to create anaerobic environment. The lesser performance with regards to nutrient removal of this type of SBR systems with selector zone, triggers to modify the bioprocess system to achieve maximum nutrient removal. SBR is the ideal system to control the bioreaction environment effectively inside the reactor. So, use of different reaction condition by controlling cycle time could be used as a tool to get higher wastewater treatment efficiency.

In present study the role of SBR phases in a cycle along with their length were observed and analyzed at pilot scale plant. The 4 h cycle time was investigated to observe the chemical oxygen demand (COD) and biological oxygen demand (BOD) reduction, nitrification, denitrification and biological phosphorous removal pattern throughout SBR operation with the advantage of selector phase biology. The system advancement includes the effective nutrient removal at lower HRT as well as at lower capital and operational cost.
2. MATERIALS AND METHODS

2.1. Study Area and Sample Preparation

SBR pilot scale plant was operated on actual sewage at Sewage Treatment Plant (STP) site of Energy House, Thermax Ltd, Pune, India. The reactor volume was of 1150 liter which was operated to decant 345 liter per cycle (30% decant). The plant was designed for actual sewage water with COD, ammonical nitrogen and total phosphates in the range of 400-500 mg/L, 30 mg/L and 10 mg/L respectively. The MLSS, Mixed Liquor Volatile Suspended Solids (MLVSS) and Sludge Volume Index (SVI) were monitored as per design. The reactor was supplied with diffused aeration of 8 m$^3$/h flow as per calculation in aeration phase only and the HRT was maintained at 12 h.

2.2. Analytical Methods

For every cycle BOD, ammonical nitrogen, nitrates, total phosphates and MLSS were analyzed for inlet, inside reactor and outlet samples from the SBR using standard analytical (APHA, 2012) protocols. The COD analysis done with the use of total organic carbon (TOC) analyzer (TOC– V CPH, Shimadzu Ltd.) by using the multiplication factor of 2.66 (COD = TOC X 2.66) (Magdum et al., 2013). DO and pH were analyzed by Hanna make DO meter (Model no. HI9146-04) and pH meter (6230M, Jenco Instruments Inc., CA, USA) and maintained on regular basis. The 26 days Solids Retention Time (SRT) of was maintained throughout the study.

Fig. 1: a) SBR cycle design for selector phase biology b) COD and BOD degradation, c) ammonical nitrogen, d) phosphate reduction

2.3. Statistical Analysis

The plant was operated for one month to acclimatize the microbial activity with consistent outlet water quality with 4 h designed cycle time to follow the concept of selector phase biology (Figure 1a). The phase of 15 days was selected to observe the treatment data for different parameters. The analytical data were plotted to observe the SBR treatment consistence and performance. The half hour sampling was done at
each phase of a 4 h cycle from the reactor to understand the SBR treatment mass profiling by analyzing and plotting the concentrations of COD, ammonical nitrogen, phosphates and nitrates at same that phase.

3. RESULTS AND DISCUSSIONS

During overall experimentation, the Mixed Liquor Suspended Solids (MLSS) was maintained to 3000 - 4000 mg/L with Mixed Liquor Volatile Suspended Solids (MLVSS) of 2400 - 3200 mg/L governing food to microbe’s ratio (F/M) 0.2. The SVI of the plant was observed in the range of 80-100 ml/g, which was a sign of good settling sludge. The SBR operation samples were analyzed for COD, BOD, ammoniacal nitrogen and phosphates. The DO was maintained 2 - 3 mg/l during aeration phase; whereas pH of the treated water was found in the range of 6.9 to 7.2. The average inlet feed analyzed values of COD, BOD, ammoniacal nitrogen and phosphates. The DO was maintained 2 - 3 mg/l during aeration phase; whereas pH of the treated water was found in the range of 6.9 to 7.2. The average inlet feed analyzed values of COD, BOD, ammoniacal nitrogen and phosphates. The DO was maintained 2 - 3 mg/l during aeration phase; whereas pH of the treated water was found in the range of 6.9 to 7.2.

The single cycle with half hour interval sampling was analyzed for concentrations of all the parameters namely COD; ammonical nitrogen, total phosphates and nitrates were done. The data was plotted to analyze the changing mass profile of SBR reactor carrying different phases (Anoxic- Anaerobic-Aerobic) by controlling external factor such as aeration and wastewater feed (Figure. 2). The combination of different anoxic and aerobic time in a 6 h cycle were attempted to optimized the SBR cycle (Jafarzadeh Ghehi et al., 2014), but not analyzed the phase separation in each cycle type.

The recorded observations indicated that in the first hour of the cycle during the filling phase, biology was involved in denitrification as there was formation of anoxic environment due to the absence of aeration, presence of organics from current feed cycle and availability of nitrates from previous cycle. The nitrate reduction was observed from 8.2 mg/l to 0 mg/l in this anoxic reaction phase. Following to denitrification the anaerobic phase was produced where phosphate release was observed due to the presence of abundant organic and absence of molecular oxygen and nitrates. This was a half process of EBPR, where the phosphate concentration was increased from 2.21 mg/l to 5.9 mg/l. As microorganisms involved in this selector phase met high organic in absence of DO, the condition enhanced the growth of the floc-formers which resulted in speedy settling with SVI 80-100 ml/g. As soon as the aeration was started at second hour of cycle organic oxidation and phosphate uptake (second half process of EBPR) were observed due to the availability of organic carbon and dissolved oxygen. In this phase, the phosphate uptake was observed from 5.9 mg/l to 1.19 mg/l. The nitrification was observed to be started at aeration phase after decrease of COD value with nitrates formation and nitrate value again increased from 0 mg/l to 8.8 mg/l. After the end aeration cycle the reactor went to settle phase. The fourth hour of the cycle was decanting phase where the 30% of the volume of treated water was decanted from the bioreactor. The research was undertaken to examine the time courses of COD, NH3-N and DO during the SND process, with particular reference to the question of whether SND is a physical or microbiological phenomenon (Holman and Wareham, 2005). The present process claims for selector phase biology (SPB) which not works simultaneously as in SND.

4. CONCLUSION

The current SBR pilot plant study on sewage water evaluates the role of SPB in removal of organic and nutrients. Selecting the phases such as anoxic, anaerobic and aerobic in single tank reactor for fixed time period helped the biology to achieve efficient nutrient removal. The separate reaction environments enhance reaction rates than SND with the assurance of its effectively on overall increase in treatment quality with reducing cycle time. The further evaluation of microbial ecology present in SBP operated SBR could open new process in wastewater treatment.
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Fig. 2: Mass profile of SBR - Evaluation of different sequential phases (anoxic - anaerobic - aerobic) in designed 4 h SBR cycle

REFERENCES


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