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EFFECT OF FERROUS SULPHATE ON THE SIMULTANEOUS ORGANIC MATTER AND NUTRIENT REMOVAL PERFORMANCE OF SEQUENCING BATCH REACTOR

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ABSTRACT

The aim of this study was to evaluate the effect of ferrous sulphate on the simultaneous organic matter and nutrient removal performance of sequencing batch reactor (SBR). Two reactors, namely a SBR1 (with $FeSO_4.7H_2O$ dosing) and a SBR2 (control- without $FeSO_4.7H_2O$ dosing) were operated in parallel. The performance of both reactors with respect to COD, NH_4^+-N and TN removal was considerably similar. The total phosphorus (TP) removal efficiency in SBR1 was obviously higher than that in SBR2. The ferrous sulphate addition improved sludge settling property. It can conclude that the ferrous sulphate addition in sequencing batch reactor is an ideal option for simultaneous organic matter and nutrient removal from wastewater.

Keywords: Ferrous sulphate, sequencing batch reactor, nutrient removal, nitrification, settling

INTRODUCTION

The discharge of nitrogen and phosphorus from wastewater treatment plants to natural receiving sources causes their eutrophication. So, it is necessary to remove these nutrients from wastewater (Guo et. al., 2010). Biological nitrification and denitrification is a widely applied proces for nitrogen removal from wastewater. Nitrification is carried out in two steps. In the first step, ammonium is oxidized to nitrite by autotrophic ammonium bacteria. In the second step, nitrite is oxidized to nitrate by autotrophic nitrite oxidizers. In denitrification process, nitrate is reduced to nitrogen gas (N_2) by heterotrophic denitrifiers (Li and Irvin, 2007). Phosphorus is another important nutrient and in general, phosphorus removal can be partially accomplished by its uptake for biomass synthesis. There is a limitation on the total phosphorus (TP) removal capacity of the biological process, and sometimes the treatment objective cannot be met, especially for wastewater with high TP concentration. Chemical precitation, which serves as a supplement to biological methods, is widely used technology for controlling P discharge in wastewater treatment plant (WWTP) effluent. Chemical P removal is normally implemented by dosing of metals (Fe^{2+}, Fe^{3+}, Al^{+3}) (de Haas et.al. 2000a). Among those, $FeSO_4.7H_2O$ has the advantages such as the cheapest precipitant for phosphorus removal (Paul et. al., 2001), low theoretical molar ratio for phosphorus removal and its optimum pH falls around 7.2-8.0 which lies close to the pH of domestic wastewater (de Haas et.al., 2000b).

The sequencing batch reactor (SBR) process possesses many advantages over the continuous activated sludge processes and has been widely used in practice (Wilderer et. al., 2001). The simultaneous removal of organic and nitrogen removal in SBRs can be achieved under alternating aerobic-anoxic conditions (Qin and Liu, 2006). Whereas, phosphorus removal (10-30%) is mainly accomplished with sludge wastage. Therefore, the ferrous sulphate addition in aerobic phase may be a solution for high phosphorus removal. The aim of this study was to investigate the effect of ferrous sulphate on the simultaneous organic matter and nutrient removal performance of sequencing batch reactor.

MATERIALS AND METHODS

Sequencing Batch Reactor Operation

Two identical SBRs (SBR1 and SBR2) with working volume of 2 l, an internal diatemer 14 cm and a working height of 13 cm was used to carry out the study. SBR1 system was used as a test reactor (to which Fe^{2+} was dosed), while SBR2 served as control reactor (no chemical addition). The reactors were operated at a volume exchange ratio of 50% with a cycle of 8 h, 15 min feed, 165 min anoxic and 240 min aerobic phases, followed by 30 min settling, 15 min decantion and 15 min idle.

A peristaltic pump was used for feeding the wastewater into the reactor. In anoxic phase, mixed liquor suspended solids (MLSS) was kept in suspension with a mechanical stirrer. In aerobic phase, aeration was provided by pressurized air passing through stone diffusers and dissolved oxygen concentration during the aerobic phase was maintained at 2-2.5 mg/l. Effluent was discharged from the middle part of the reactor. The temperature of two SBRs was maintained at 25 ^{o}C and pH fluctuated between 7.2 and 8.3 without control. The solid retention time was maintained at about 20 d through direct removal of mixed liquor from aerobic phase (1/20 of the reactor volume).

Syntetic Wastewater and Seeding Sludge

Synthetic wastewater was used as the experimental influent. The influent contained, per liter: 850 mg $NaCH_3COO.3H_2O$; 107 mg NH_4Cl; 75.5 mg $NaH_2PO_4.2H_2O$; 90 mg $MgSO_4.7H_2O$; 36 mg KCl; 14 mg $CaCl_2.2H_2O$; and 1 ml nutrient solution. One liter of nutrient solution contained: 0.15 g H_3BO_3; 0.03 g $CuSO_4.5H_2O$; 0.18 g KI; 0.12 g $MnCl_2.2H_2O$; 0.06 g $Na_2MoO_4.2H_2O$; 0.12 g $ZnSO_4.7H_2O$; 0.15 g $CoCl_2.6H_2O$.

The reactors was initially inoculated with activated sludge collected from a local municipal treatment plant.

Addition of Ferrous Sulphate

Fe^{2+} (as $FeSO_4.7H_2O$) at a concentration of 20 mg/l was added in aeration phase.

Analytical Methods

The concentration of chemical oxygen demand (COD), total phosphorus (TP), Mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS), sludge volume index (SVI) were determined according to Standard Methods (APPHA, AWWA, WCPF, 1998). The total nitrogen (TN) and ammonium concentration were measured by Standard Kit (Merck Specquorant).

RESULTS AND DISCUSSION

Figure 1 shows COD removal efficiencies of SBR1 and SBR2. It is evident from figure that both systems presented an efficient operation for COD removal. In the first 15 days, COD removal efficiencies of two reactors increased from 45% to 90% and from 40% to 87% in SBR1 and SBR2, respectively. Afterwards, the average COD removal efficiencies attained stability and it were in the range of 90-94% and the corresponding to COD concentration of the effluent was found to be in the range of 25-40 mg/l. The present results is in agreement with the previous studies (Clark et. al., 2000; Lees et.al., 2001; Philips et.al., 2003).

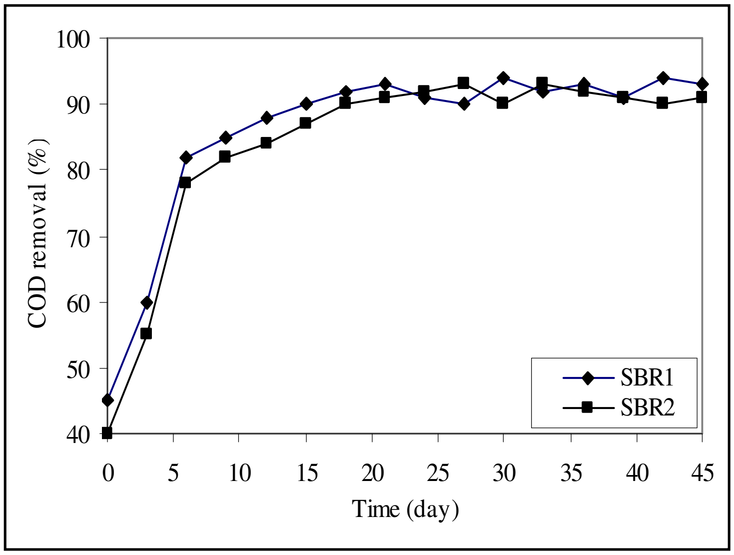

Figure 1. COD removal efficiencies in the SBR1 and SBR2

Nitrification is the primary important process in removing total nitrogen from wastewater. Incomplete nitrification resulted in decrease in TN removal efficiency of the system (Morita et. al., 2007). Nitrification is susceptible to inhibition by variety of compounds (Andrea et. al., 2005). Fig. 2 shows that both reactors exhibited similar NH_4^+-N removal performance. From day 20 to the end of the study, the average NH_4^+-N removal efficiencies of the two reactors were about 91.0%. The results clearly show that the influence of $FeSO_4.7H_2O$ on nitrification can be ignored.

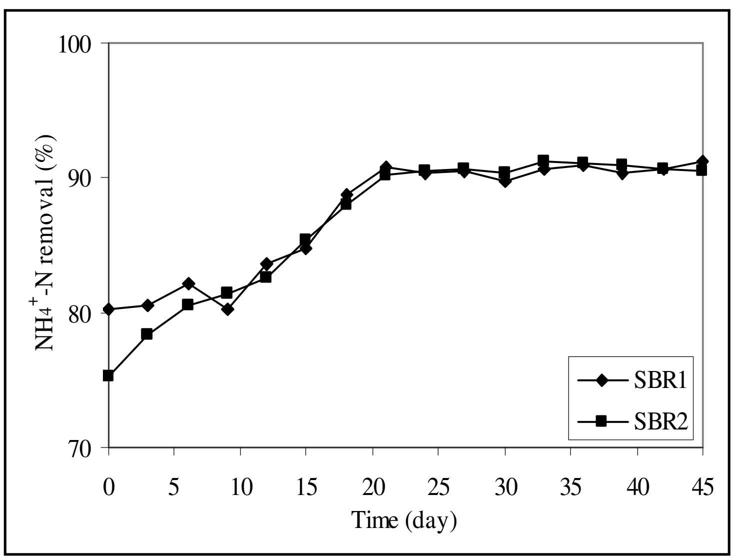

Figure 2. NH_4^+-N removal efficiencies in the SBR1 and SBR2

The average TN removal efficiencies of the both reactors are presented in Fig. 3. The average TN removal efficiency of SBR1 was about 60.8% whereas it was about 64.6% for the SBR2. It is evident from figure 3 that nitrogen removal efficiency remains unaffected by $FeSO_4.7H_2O$ addition.

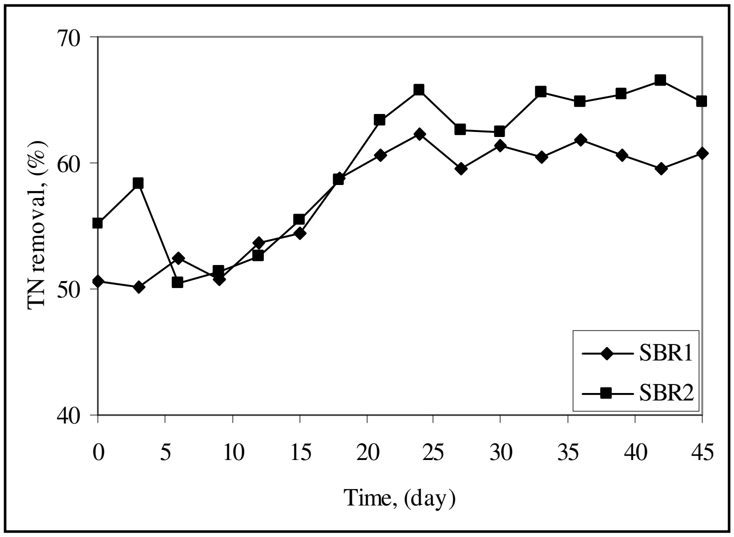

Figure 3. TN removal efficiencies in the SBR1 and SBR2

Phosphorus is the primary nutrient responsible for algal bloom and it is necessary to reduce the concentration of phosphorus in treated wastewater to prevent such blooms. The TP removal efficiencies of the both reactors are shown Fig.4. During 20-45 days, the average TP removal efficiency in SBR2 was 50.3% which is mainly accomplished with sludge wastage. The average TP removal efficiency in SBR1 was 78%. In aerobic phase of SBR1, the added ferrous ion are probably oxidized to the ferric ion. Subsequently, the generated ferric ion will precipate as ferric phosphate ($FePO_4$). The $FeSO_4.7H_2O$ addition improved TP removal efficiency significiantly as expected.

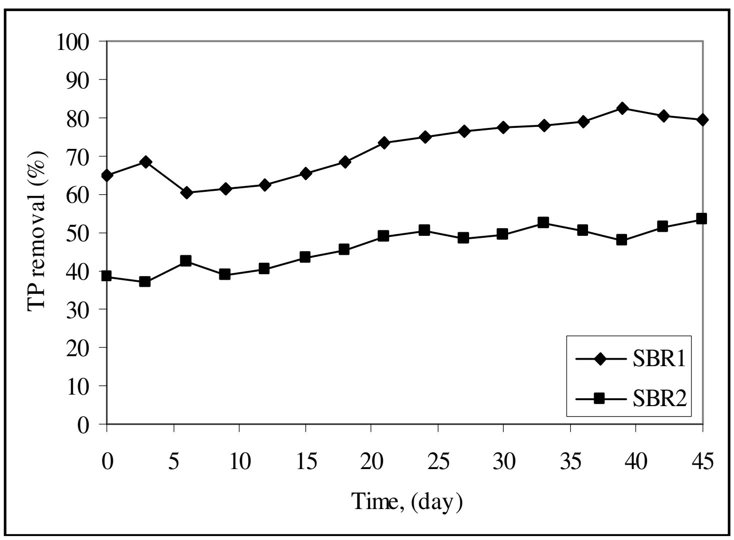

Figure 4. TP removal efficiencies in the SBR1 and SBR2

Fig. 5 shows the variation of MLSS and MLVSS concentration during the operational period of the reactors. The initial MLSS concentrations in SBR1 and SBR2 were 2.69 and 2.73 g/l, respectively. The solids concentration in both reactors increased steadily and reached a value of about 3.0 g/l on day 15 and MLSS concentration was maintained around 3.0-3.4 g/l. The volatile fraction of the mixed liquor solids was lower in the SBR1. The average MLVSS/MLSS ratio in SBR1 and SBR2 were found to be 75% and 82%, respectively. Thus, about 7% of lower a value was observed in SBR1. This clearly shows that inorganic fraction of the $FeSO_4.7H_2O$ accumulates in the reactor. The observed lower MLVSS/MLSS ratio could be comparable with result of 3-14% (depending on the Fe:P added) from previous study (Filali-Meknassi et.al., 2005).

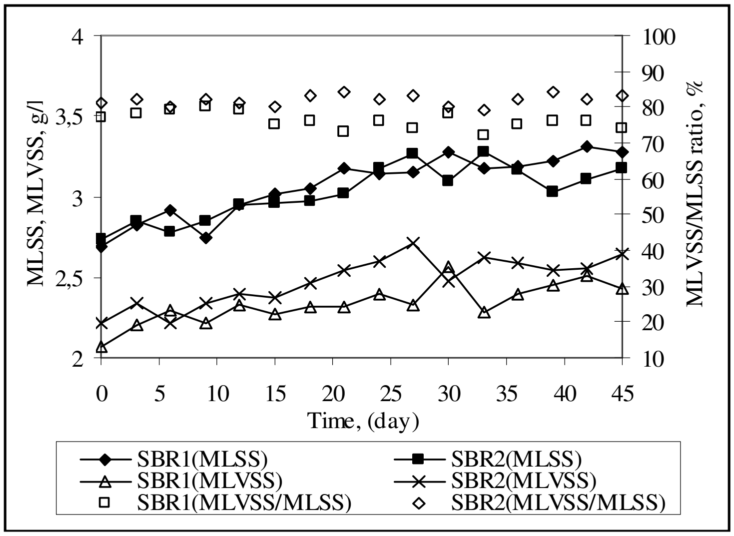

Figure 5. MLSS, MLVSS concentration and MLVSS/MLSS ratio in the SBR1 and SBR2

The sludge volume index (SVI) is an indicator of sludge settling capability. The SBR1 and SBR2 showed good settling properties, with sludge volume index values of less than 150 ml/g. As shown Fig.6, the average SVI values were 68 ml/g and 98.4 ml/g for SBR1 and SBR2, respectively. As compared with SBR2, lower SVI values were obtained in SBR1. The $FeSO_4.7H_2O$ effectively improved the sludge characteristics in SBR1.

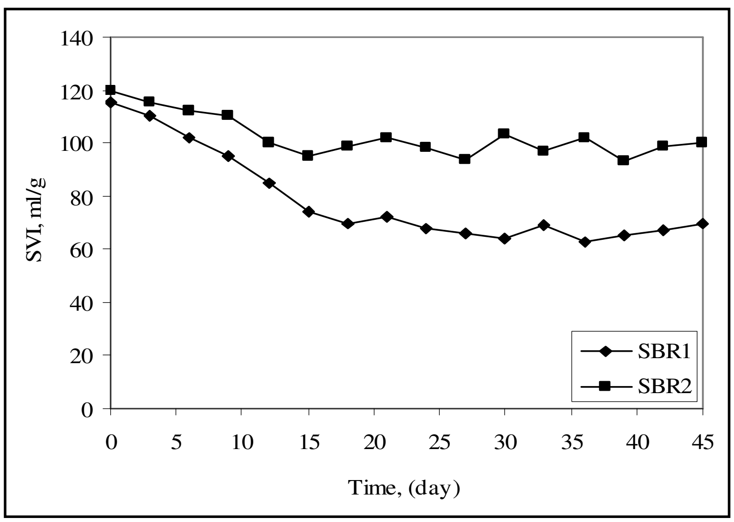

Figure 6. SVI values in the SBR1 and SBR2

CONCLUSIONS

The effect of ferrous sulphate addition on the performance of sequencing batch reactor was investigated. The ferrous sulphate addition did not affect the COD and nitrogen removal efficiency, but it improved TP removal. MLVSS/MLSS ratio in the SBR1 was reduced from 82% to 75% due to inorganic solids generated by phosphorus precipitation. Settle ability was improved by ferrous sulphate addition in the SBR1. These results showed that the addition of ferrous sulphate in sequencing batch reactor could be used as an ideal and efficient option for the simultaneous COD and nutrient removal from wastewater.

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