EFFECT OF INFLUENT C/P RATIO ON BIOLOGICAL PHOSPHORUS REMOVAL IN ANAEROBIC/ANOXIC SEQUENCING BATCH REACTOR

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ABSTRACT

Effect of influent C/P ratio on biological phosphorus removal performance was investigated in a anaerobic/anoxic sequencing batch reactor (A_2SBR) process. When C/P ratio was higher than 30, phosphorus removal efficiency was maintained at 89%. For C/P ratios lower than 30, phosphorus removal efficiency decreased to 45% and 33% when C/P ratios were 20 and 10. However, regardless of C/P ratio, excellent chemical oxygen demand (COD) removal efficiency (around 90%) was maintained throughout the experiments. Experimental results showed that the critical influent C/P ratio for A_2SBR process was 30 under a sludge retention time of 10 days.

Key words: Biological Phosphorus Removal, Anaerobic/Anoxic (A_2) Process, C/P Ratio, Sequencing Batch Reactor (SBR)

1. INTRODUCTION

Nutrient removal from domestic and industrial wastewater is a key factor in preventing eutrophication. Therefore, the anaerobic/anoxic (A_2) process based on the activity of denitrifying phosphorus accumulating organisms (DPAOs) has recently attracted much attention [1-4]. DPAOs are cabaple of accumulating high amounts of polyphosphate by using nitrate instead oxygen as electron acceptor, thereby removing N and P simultaneously without any extracellular carbon source [4]. They are activated under the alternate anaerobic/anoxic conditions and have metabolic characteristics similar to those of polyphosphate accumulating organisms (PAOs) [5,6]. Under alternating anaerobic and anoxic conditions, DPAOs take up volatile fatty acids (VFAs) and store them as polyhydroxyalkanoates (PHAs) through the hydrolysis of intracellular polyphosphate and the glycolysis of glycogen under anaerobic conditions. In the subsequent anoxic conditions, DPAOs utilize nitrate instead of oxygen as electron acceptor and utilize PHAs to generate energy for growth, glycogen synthesis and phosphate uptake [7,8]. The main advantage of applying DPAOs is the possibility to save COD (50%) and energy (30%) with less sludge production (50%) [9,10].

The C/P ratio are the key factor that affect the performance of biological phosphorus removal [11]. Therefore, the influent C/P ratio must be controlled at an adequate range to achieve good phosphorus removal. You et al. [12] stated that when the influent C/P ratio exceed the critical C/P ratio of the process, phosphorus was limiting and the effluent phosphorus concentration was under control. In contrast, when the influent C/P ratio was lower than the critical point, COD limiting and the effluent phosphorus concentration increased with an increase of influent phosphorus. Based on the above ideas, this study investigated the critical C/P ratio of A_2 process.

2. MATERIALS AND METHODS

2.1. Process and Operation

The anaerobic/anoxic (A_2)process was operated using an SBR with a 2 L working volume. The SBR was operated at a cycle of 6 h, consisting of a 15 min filling phase, a 105 min anaerobic phase, a 180 min anoxic phase, a 30 min settling phase, a 15 min decanting phase and a 15 min idle phase. The reactor was fed with synthetic wastewater of 0,9 L in filling phases. Nitrate solution of 0.1 L was fed into the reactor during the first 120 minutes of the anoxic phase. Nitrate concentration was 60 mmol. In decanting phase, 1.0 L supernatant was discharged, thus the hydraulic retention time of 12 h was maintained. The sludge retention time of A_2 proces was 10 days. The reactor was operated at 20^{o}C. pH is not controlled throughout the experiment.

2.2. Syntetic Wastewater and Seeding Sludge

The C/P ratio, that is influent COD/TP, was controlled at 10, 20, 30, 40 and 50 by adjusting phosphorus concentrations at the constant COD concentration, i.e. 400 mg/l. Synthetic wastewater used in this study contained (per liter): 850 mg $NaAc.3H_2O$, 40,26~201,3 mg $NaH_2PO_4.2H_2O$, 107 mg NH_4Cl, 90 mg $MgSO_4.7H_2O$, 36 mg KCl, 14 mg $CaCl_2.2H_2O$, 0.3 ml nutrient solution. One-liter nutrient solution contained: 1500 mg $FeCl_3$. $6H_2O$, 150 mg H_3BO_3, 30 mg $CuSO_4.5H_2O$, 180 mg KI, 120 mg $MnCl_2$. $2H_2O$, 60 mg $Na_2MoO_4.2H_2O$, 120 mg $ZnSO_4.7H_2O$, 150 mg $CoCl_2$. $6H_2O$.

The reactor was seeded with activated sludge from a municipal treatment plant designed for nitrogen and phosphorus removal and it was started to experimental studies when stable conditions supplied in reactors.

2.3. Analytical Methods

Chemical oxygen demand (COD), phosphate concentration and phosphorus content of sludge was measured by Standart Methods [13]. Mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) concentrations were determined using Whatman GF/C filter paper.

3. RESULTS AND DISCUSSION

Figure 1 shows the COD removal efficiencies at different C/P ratios (10, 20, 30, 40 and 50). At C/P ratios from 10 to 50, COD concentration of the influent was controlled at 400 mg/L. As shown in Figure 1, the COD removal efficiency was maintained around 90% and the COD removal efficiency was independent of influent C/P.

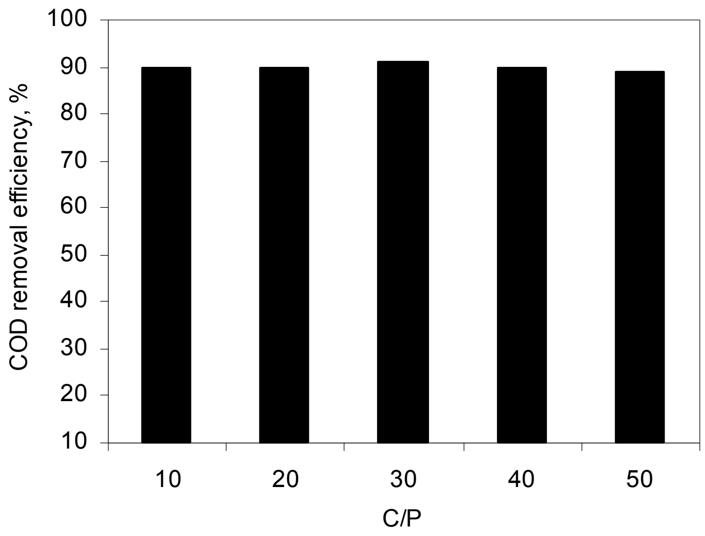

Fig. 1. *COD removal efficiencies at different C/P ratios.*

Figure 2 shows the phosphate removal efficiencies at different C/P ratios. It can be seen from Fig. 2 that when the influent C/P ratio exceed 30, the phosphorus removal efficiency was 89%. In contrast, when influent C/P ratio was less than 30, the removal efficiency of phosphorus reduced to 45% and 33% for C/P ratio of 20 and 10, respectively. It is apparent that the value of 30 for C/P ratio was the critical point between COD limiting and P limiting conditions in this system. This value was similar to reported values in the literature which was 30 for TNCU-I process [12], 32 for A^2O process [14] and 33 for Unifed SBR process [15].

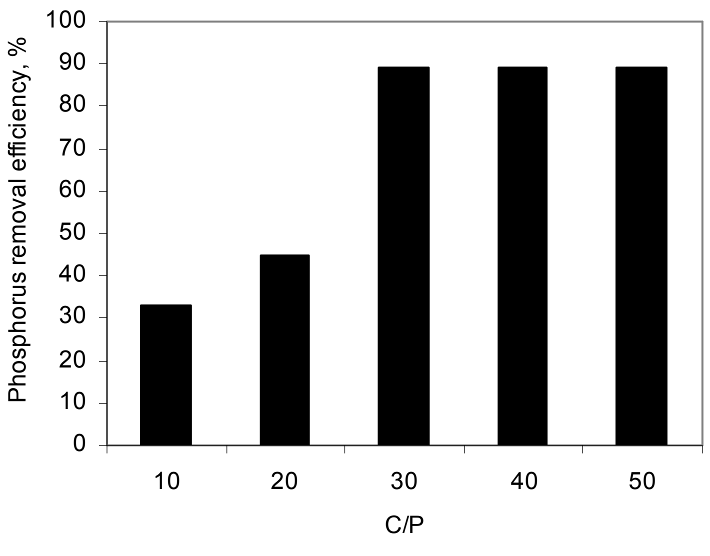

Fig 2. *Phosphorus removal efficiencies at different C/P ratios.*

Further, when the influent C/P increased to 40 and 50, the P removal efficiency kept at a constant value. This means that further increase of the C/P can not promote the phosphorus removal efficiency, mainly PAOs and DPAOs have the maximum capacity for carbon source consumption to synthesis PHB that determines the phosphorus uptake capacity, and can not consume extra carbon. Hence, the maximum phosphate removal capacity was stable. Filipe et al. [16] stated that at higher organic loading, available COD would not be completely utilized by the PAOs in the anaerobic zone, the excess COD would favor the growth of glycogen accumulating organisms (GAOs), which led to the reduction of the PAOs fraction in the activated sludge. Xiaolian et al. [17] stated that under ideal anoxic conditions of biological nutrient removal (BNR) processes (NO_3^->0, DO=0), nitrate was the only electron acceptor. Consequently, DPAOs could use nitrate as the electron acceptor for P uptake and growth. Meanwhile, non-DPAOs would not participate in any reactions. However, both P release and uptake under COD-rich conditions occured simultaneously in the anoxic reactor, the net reaction that was either P uptake or release depended on COD and nitrate concentrations. At higher organic loading, the excessive residual COD from the anaerobic zone into the anoxic zone and storage PHB; in the meantime, most of nitrates were reduced to nitrogen gas, the net reaction was P release. However, at lower organic loading, less residual COD entered into the anoxic zone; it was possible to achieve the maximum utilization of PHB stored in the anaerobic zone, which was used to accomplish P uptake and denitrification in the anoxic reactor. As a result, only when the initial COD is sufficiently high to promote suitable PHA formation and residual COD is not excessive, can good biological phosphorus removal be attained.

When the C/P ratio was lower than 30, phosphorus concentration in the mixed liquor after releasing phosphorus was quite high and exceeded the maximum phosphorus uptake capacity of DPAOs. The amounts PHB synthesized were not enough for DPAOs to take up all phosphorus in the mixed liquor. As a result, incomplete phosphorus uptake led to the reduction in phosphorus removal efficiency.

Figure 3 shows the MLSS and MLVSS concentratios at different C/P ratios. The MLSS concentration at the C/P ratio of 50 was only 66% of that at the C/P ratio of 10. However, the MLVSS/MLSS ratio increased as the C/P ratio increased. The decreasing MLVSS/MLSS ratio is correlated to the increase in polyphosphate content in sludge.

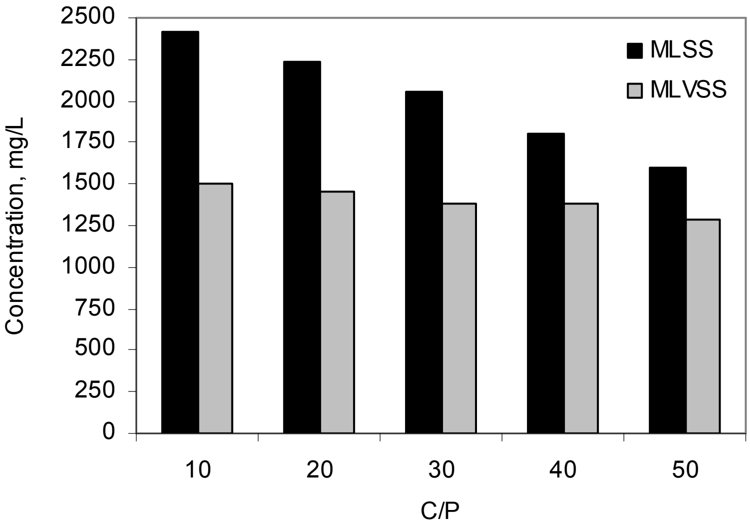

Fig. 3. *MLSS and MLVSS concentratios at different C/P ratios.*

Figure 4 shows that the mass percentage of phosphorus in sludge increased with a decrease of C/P ratio of influent when the C/P ratios exceed 30. However, the weight percentage of phosphorus in sludge reached a stable value of around 12,5% when the C/P ratios of influent were less than 30.

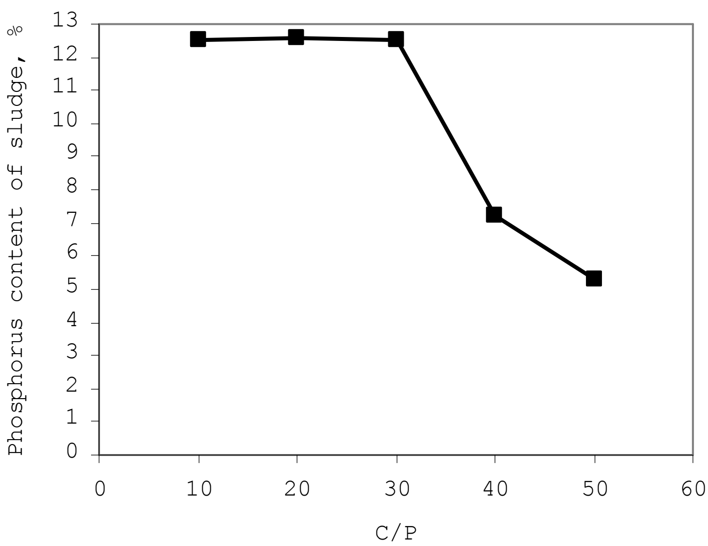

Fig. 4. *Phosphorus content of sludge at different C/P ratios.*

4. CONCLUSIONS

A laboratory-scale anaerobic/anoxic sequencing batch reactor was operated to examine the effect of varying ratios of influent C/P on the biological phosphorus removal. The influent C/P ratio had significant effect on the phosphorus removal efficiency. For C/P ratios higher 30, phosphorus removal efficiency remained at 89%, but when the C/P ratio was lower than 30, phosphorus removal efficiency decreased with decreasing of the influent C/P ratio. It was also found that COD removal efficiency was hardly affected by influent C/P ratio. Experimental results showed that the critical influent C/P ratio was 30 under a sludge retention time of 10 days.

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