STUDY ON SLUDGE REDUCTION OF A2/O PROCESS WITH LOW C/P RATIO

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ABSTRACT

Policy of energy conservation and emission reduction has been advocated during recent years in China. The development of wastewater treatment has presented some problems with a huge sludge production and high operating cost. Eutrophication occurred frequently in many water bodies of China and discharge standards for wastewater treatment plants (WTTPs) are strict with nutrient removal. However, many WWTPs in China are confronted with the problem with low influent C/P ratio resulting in poor effluent quality. In this paper, excess sludge from A2/O process with low C/P ratio was treated by ultrasound and then fed back to the system for improving the cryptic growth of microorganisms and stimulating the role of denitrifying phosphate accumulating organisms (DPAOs). Batch experiments displayed that about 67% of carbon source from the treated sludge (0.25 W mL⁻¹ ultrasonic intensity and 10 min sonication time) could be utilized, comparing with acetate. And the results indicated about 36% sludge reduction efficiency could be achieved, in which 50% of excess sludge treated by ultrasound was recommended in order to save energy. Also, the effluent quality, especially total phosphorus, was improved since organic materials from sludge decomposition were used as carbon source for enhancing the function of DPAOs, and TP removal efficiency increased by 27%.

INTRODUCTION

Policy of energy conservation and emission reduction has been advocated during recent years in China. Therefore, the implementation of this policy is significant in the operation and management of wastewater treatment plants (WWTPs). And the development of wastewater treatment has been nagged by the problem of huge sludge production and high operating cost. The investment and operating cost of sludge treatment and disposal may account for 25-65% of the total cost of WWTPs [1,2].

In recent years, sludge ultrasonic treatment, especially about the variations of its structure, rheological and dewatering properties has been studied [3-6]. Actually, in many researches, the intracellular materials released from the treated sludge by ultrasound could be reused as substrate for microbial metabolism, and could improve microbiological cryptic growth to reduce sludge production and accelerate the process of anaerobic digestion [7-12].

The nutrient removal of WWTPs became more and more important because of the issue of eutrophication and the strict discharge standards. However, many WWTPs in China have had to be confronted with low C/P ratio of the influent and bad effluent quality [13-15]. The objectives of the paper are firstly to evaluate the possibility of the excess sludge as an alternative for carbon source, and secondly, to display how the decrease of sludge production and the improvement of effluent quality of A2/O (anaerobic-anoxic-oxic) process with low C/P ratio are achieved.

METHODS

1. Experimental Setup

The lab-scale experimental setup was basically composed of an A2/O process in the main flow, and an ultrasonic treatment reactor attached in the side flow (Fig. 1). The inlet flow of the system was 60 L d⁻¹; the solids retention time (SRT) was maintained at 12 d; the DO concentration in the anaerobic, anoxic and aerobic reactor was respectively kept around 0-0.2, 0.1-0.3 and 2-4 mg L⁻¹; the sludge return ratio was kept at 100% and the mixed liquor recycle ratio was

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kept at 200%. Excess sludge was directly discharged from the aerobic reactor and then into the ultrasound treatment reactor. In this study, ultrasonic intensity of 0.25 W mL⁻¹ and sonication time of 10 min were applied.

2. Wastewater Characteristics and Analyses

Synthetic wastewater contained CH₃COONa, NH₄Cl, KH₂PO₄ and the trace solution. Main characteristics of the wastewater are indicated in Table 1. The seeding sludge was taken from a municipal WWTP in Beijing. In the experiment, COD, BOD, NH₄⁺, NO₃⁻, TP, DO and pH were measured according to the standard analysis methods of China [16].

RESULTS AND DISCUSSION

1. Utilization of Carbon Source from Ultrasonic Treated Sludge

It is known that ultrasonication can facilitate sludge disintegration, as a result, the intracellular organic matters release from broken cells. And SCOD (soluble COD) would increase with prolonged sonication time obviously and could be utilized for cryptic growth by microorganisms [7-12]. In order to check the effect of ultrasonic sludge as an alternative of carbon source, acetate was chosen for comparison in this experiment, since it is the simplest and easiest biodegradable organic material. Figure 2a displayed about 67% equivalent carbon source of ultrasonic sludge could be effectively consumed in 3 h, compared with acetate being used.

The utilizing rate of carbon source was compared in Fig. 2b, it was comparatively high during the first hour, and the utilizing rate of sludge was almost half the rate of acetate. Then the process became slow in the second hour and even stable in the last hour. Macro-molecular materials, which came from sludge disintegration, should be further treated with prolonged sonication time if extra degradation potential was expected. However, it would consume much more energy and therefore would not be applied in the practice.

2. Determination of the Treated Ratio of Excess Sludge by Ultrasound

The operating cost of sludge disintegration will rise with the increase of the ratio treated by ultrasound. Therefore, different ratios of excess sludge from A²/O process, which were 0, 25, 50, 75 and 100% respectively, were compared to find the suitable ratio in this experiment. The effect of sludge decomposition with different treated ratios is displayed in Fig. 3.

Intracellular materials released from broken cells caused the increase of SCOD and SCOD/TCOD (total COD) with the increase of treated ratios. As shown in Fig. 3, the effect of 25% ratio was finite and the effect of 100% ratio was obvious, but it will consume a mass of energy in the practice. And the effect with 75% ratio increased little compared with 50%. Therefore, further comparison on sludge reduction was executed with 50% and 100% treated ratio. The theoretic analysis and calculated method on sludge reduction were expatiated in the former study [12].

In order to display the operating situation of A²/O process with normal condition and with the recycle of the treated sludge, the normal operation was described in the former part of curves before zero, and the operation with ultrasonic treatment was displayed in the later part of curves after zero (Fig. 4). And the same meaning was expressed in the following figures.

Excess sludge with 50 and 100% treated ratios was separately returned to the anoxic reactor in an A²/O process. Effluent COD with 50% ratio (Fig. 4a) was a little lower than that of 100% ratio (Fig. 4b), but

<table>
<thead>
<tr>
<th>Item</th>
<th>COD</th>
<th>TN</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value (mg L⁻¹)</td>
<td>300-450</td>
<td>40-45</td>
<td>8-10</td>
</tr>
</tbody>
</table>
all of them achieved the discharge standard of 1st-level (GB18918-2002, China).

Sludge production of A2/O system decreased obviously after the recycle of ultrasonic sludge. However, the reduction efficiency with 100% treated ratio increased a little comparing with 50%, which was displayed in Fig. 5. Neither COD removal efficiency nor sludge reduction with 100% had shown any advantage. Therefore, 50% treated ratio was recommended in this experiment, since it was still more effective and economic.

For many WWTPs, the lack of influent carbon source became one of the main causes of nutrient removal process deterioration and failure, because there was a competition for carbon source between denitrifiers and PAOs (phosphate accumulating organisms) in the system. Based on the above-mentioned experimental results, ultrasonic treated sludge could be used as carbon source and reused by microorganisms for sludge reduction. Furthermore, it might intensify the role and function of DPAOs (denitrifying PAOs) when the treated sludge was sent back to the anoxic tank in an A2/O system. Therefore, in this study ultrasonic treatment was considered to be applied in an A2/O system with low C/P ratio. The decrease of sludge production and the improvement of effluent quality for this system were expected to be achieved at the same time.

50% treated ratio of excess sludge by ultrasound was determined to be adopted, based on the above result. For the sake of avoiding the upset of phosphor, which released from the broken cells with sludge disintegration by ultrasound, chemical phosphorous removal was applied for the supernatant of ultrasonic sludge before it was running back to the system.

3.1. Operation of A2/O system with low C/P ratio in the influent

A lab-scale A2/O process with low C/P ratio (C/P = 24) had been operating more than 1 month. The effluent COD and TN could meet the discharge standard of 1st-level (GB18918-2002, China), but the effluent TP normally exceeded 5 mg L\(^{-1}\), which was definitely caused by low C/P ratio in the influent. However, 0.5 and 1 mg L\(^{-1}\) effluent TP were respectively controlled by 1st A and 1st B level, and 3 mg L\(^{-1}\) effluent TP was limited by 2nd level. Admittedly, this fact has brought about extensive concerns when low influent C/P ratio occurred in WWTPs.

3.2. Effluent quality of A2/O process with ultrasonic treatment

Experimental results, especially the variation of
TP in the system, were interesting after the recycle of the treated sludge. Effluent COD and TN in an A²/O process with low C/P ratio (as displayed in Fig. 6a and 6b) were almost kept constant before and after the recycle of the ultrasonic sludge to the system. However, effluent TP was ameliorated obviously from 5 to 2 mg L⁻¹ (Fig. 7a), which should benefit from organic materials released from broken cells due to the recycle of treated sludge. In order to acquire further information, TP variation of the different tanks in the system was also measured and displayed in Fig. 7b.

Firstly, TP in the anoxic tank decreased about 40% after the recycle of treated sludge. This indicated strongly that DPAOs were accumulated and played a major role in denitrifying phosphorus removal in the anoxic tank. Some researches about DPAOs showed the same results and displayed DPAOs had much more capacity to remove phosphorus than PAOs [17-19]. The residual phosphorus was continuously utilized by PAOs in the oxic reactor. Therefore, TP removal was effectively improved by the addition of ultrasonic sludge in the A²/O process with low C/P ratio.

Secondly, TP in the effluent was always higher than TP in the oxic tank, which might be caused by P release from the sediment in the clarifier. Then it deserved much more attention on the deterioration of TP removal affected by the P release in the clarifier. And a much less effluent TP could be achieved if a good operating condition was maintained in the settler. In this experiment, TP in the oxic tank was also improved from 2.37 to 0.89 mg L⁻¹ after the recycle of treated sludge to the A²/O process, accompanied by TP in the effluent from 5 to 2 mg L⁻¹ (Fig. 7b). TP removal efficiency increased by 11, 27% separately in the oxic reactor and the clarifier.

3.3. Sludge reduction of the A²/O process with ultrasonic treatment

As mentioned above, organic materials released from ultrasonic treated sludge were sent back to the anoxic reactor, and then into the oxic tank. Intracellular products were reused for enhancing DPAOs’ phosphorous removal in the anoxic reactor and the residuals were further assimilated by ordinary heterotrophic bacterial for cryptic growth in the oxic tank, which were also consistent with the previous researches [11,12]. In this study, sludge production was available reduced and its efficiency was about 36%, as displayed in Fig. 8.

CONCLUSIONS

Using ultrasonic treatment on excess sludge in the A²/O system with low carbon source, it was synchronously carried out to reduce the sludge production and to improve the effluent quality, especially the ef-
fluent TP. Several conclusions are summarized as follows:

- Excess sludge was clearly disintegrated by ultrasonic treatment, and the organic materials released from sludge showed good biodegradability. Comparing with acetate, about 67% of comparative carbon source could be obtained from the treated sludge.
- The different treated ratios of excess sludge with ultrasound were checked by comparing effluent quality and sludge reduction efficiency. And 50% treated ratio was recommended in the experiment, because it was rather effective and economic.
- The effluent COD and TN were basically not affected by the low C/P ratio in an A\textsubscript{2}/O process and could meet the discharge standard of the 1st-level (GB18918-2002, China). However, the effluent TP was obviously worsened and normally exceeded.
- After adding excess sludge with ultrasonic treatment to the process, the effluent COD and TN were also kept constant, but the effluent TP was effectively decreased by enhancing DPAO’s phosphorous removal ability in the anoxic reactor and TP removal efficiency increased by 27%. And the second P release in the settling tank deserved much more attention.
- The reduction efficiency of 36% could be achieved in the A\textsubscript{2}/O process with the low C/P ratio under the ultrasonic intensities of 0.25 W mL\textsuperscript{-1} and sonication time of 10 minutes.

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