Modified Operation in SBR Applied to Decentralized Domestic Sewage Treatment for High Quality Effluent

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**ABSTRACT**

SBR can be used as the sole reactor for SS, COD, and nutrient removal and is suitable for decentralized wastewater treatment, but it is noticed that the SBR is difficult to obtain high quality effluent meeting up to Grade 1A standard in China in many practical cases. In this study sewage from a university campus was used as decentralized sewage, and its treatment of SBR was investigated. Two operating modes were adopted to study whether SBR can serve as sewage treatment with high quality effluent that may meet the standard of water reuse to some extent. The results show that, after changing anaerobic and aerobic stage, the SBR can remove as more as 90%, 92%, 67% and 89% of COD, ammonium nitrogen, total nitrogen and phosphate of the sewage, respectively, and effluent meet water quality for reuse. Proper alternation of anoxic condition (lasting for 30min before feeding), anaerobic condition followed (lasting 1h after feeding) and aerobic condition (for 2h with low dissolved oxygen less than 2mg/l all the way) is the foundation for effluent of good quality and stable operation. The results suggest that the SBR performed very well to treat sewage of low carbon to nitrogen ration and large fluctuation in water quality, and it is suitable for decentralized wastewater treatment and water reclamation. Operation control of the SBR can not only save energy, but also can dispense with advanced water treatment of water reclamation to some extent.

*Keywords*: Decentralized wastewater treatment; SBR; Water reclamation; Biological nutrient removal

1 INTRODUCTION

With increasing attention on water pollution control in China, treatment of wastewater discharged from area out of service of urban centralized drainage system, i.e. decentralized wastewater, becomes more and more urgent.

Decentralized wastewater has some distinguished differences from common municipal wastewater. For example, it is small in quantity in most cases. The quantity maybe varies from several cubic meters to hundreds. The figure may be thousands in some residential areas and towns and villages. Secondly, there is large fluctuation in both wastewater quantity and quality (Bian and Yuan, 2009). Due to obvious relevancy and high consistent with work and rest of residual in water used and discharge, both wastewater quantity and quality vary greatly with time throughout the day. Sometimes they are intermittent. There hardly has sewage discharged by community in midnight and from university campus in vacation. Finally, the strength of decentralized wastewater is usually lower compared with municipal wastewater, especially in carbon to nitrogen ratio (Ma et al., 2009).

In many cases of decentralized wastewater treatment, there are lack of professional
operator and manager who are absolutely necessary in big municipal wastewater treatment plant. Complicated treatment process, high capital cost and operation cost may not be acceptable in addition. Under these circumstances, treatment of low cost and simple process is welcome (Massoud et al., 2009).

Many designers are apt to adopt SBR (sequencing batch reactor) and its derivative technologies, such as CASS (cyclic activated sludge system) in decentralized wastewater treatment (Ng et al., 1993; Bernardes and Klapwijk, 1996; Kassaba et al., 2011). Based on investigation of performances of a few decentralized wastewater treatment facilities located in Xi’an city, China, it has been found that most of their performances are not stable and their effluents cannot meet discharge standard required (class 1B of GB 18918-2002). It is considered that proper operating strategy is the foundation of satisfying effluent. How to deal the conflicts among COD, nitrogen and phosphorus removal in the unique tank of SBR still needs to study.

If advanced treatment is applied after secondary treatment of decentralized wastewater to reclaim water, this process will lose advantage. In another scenario, if the effluent from common secondary treatment in the SBR is of high quality that can be served as reclamation water after filtration (if necessary) and disinfection for landscape water supply and green sprinkle, it will be appealing in practice.

A SBR was applied in this study to treat the sewage discharged from a university campus as decentralized wastewater. Key operation parameters and mode for secondary treatment for high quality effluent was studied in order to find out a solution for decentralized wastewater treatment and reuse.

2 MATERIALS AND METHODS

2.1 Experiment Setup

The experiment setup is illustrated in Figure 1. Reactor was a plexiglas tank with 250-liter effective working volume. Size of the tank is 92 ×60 ×55 cm (L×B×H) and water depth is less than 50 cm. 4 perforated tubes fixed on the bottom of the tank were applied as oxygen diffuser. Air supply rate was controlled via air flow meter. 2 stirrers were applied to mix liquid in the tank when there was no aeration.

2.2 Wastewater and Inoculation Sludge

Raw sewage from drainage of campus of a university in Xi’an city was applied. Water quality of the sewage is shown in Table 1. Activated sludge from A2O system of Deng Jia Cun municipal wastewater treatment plant was inoculated, and its concentration in the reactor was about 2200 mg/L (MLVSS) with SVI of 180 L/g.

2.3 Operating Procedures of the System

Reactor was operated 4 cycles (6 h per cycle) per day. Two operating modes were adopted, namely Run 1 and Run 2. The system was operated under Run 1 for 60 days and Run 2 for 120 days. Operating procedure of Run 1 was as follows: feeding with stirring for 0.5 h-anaerobic mixing for 1h- aeration for 2 h-anoxic mixing for 1h- aeration for 0.5 h-precipitation for 55 min- drawing for 5 min (i.e. Ana-O-Ano-O mode).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Quality of the sewage</th>
</tr>
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<tbody>
<tr>
<td>item</td>
<td>CODcr</td>
</tr>
<tr>
<td>Conc. (mg/L)</td>
<td>132~320</td>
</tr>
</tbody>
</table>
In Run 2, operating procedure was mixing for 0.5 h before feeding, and then feeding with stirring for 0.5 h. Anaerobic mixing for 1 h- aeration for 2 h- precipitation for 1 h- drawing for 5 min- idle for 55 min (i.e. pre-Ano–Ana-O mode) (Table 2). Temperature in the reactor was at 27–33°C during the experiment. SRT maintained at 15 d. Volume changing ratio was 50% in one cycle. DO was maintained at 2-4 mg/L in the aerobic phase in Run 1 and 0-1.5 mg/L in Run 2.

2.4 Analysis Methods

The concentrations of COD, ammonium, nitrate, total nitrogen, phosphate, and total phosphorus were determined following the methods set out in the standard methods (China EPA, 2002). COD was determined by dichromate method, ammonia by Nessler’s reagent colorimetric method, nitrates by ultraviolet spectrophotometric method, total nitrogen by potassium persulfate digestion- UV Spectrophotometric method, phosphate by ammonium molybdate spectrophotometric method, and total phosphorus by potassium persulfate digestion- ammonium molybdate spectrophotometric method.

3 RESULTS AND DISCUSSION

3.1 Performance of the System Operated in Run 1

Performance of the system operated in Run 1 is shown in Figure 2. As shown in Figure 2a to 2e, average removal rates of the system for COD, ammonium nitrogen, phosphate, total nitrogen and suspended solids are about 90%, 97%, 93%, 67% and 95%, respectively. The average concentrations of COD, ammonium nitrogen, phosphate, total nitrogen and suspended solids in effluent are about 32, 0.71, 0.21, 14.63 and 12.45 mg/L, respectively.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Operating modes in a cycle of Run 1 and Run 2</th>
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<tbody>
<tr>
<td>Period</td>
<td>0.5h</td>
</tr>
<tr>
<td>Run 1</td>
<td>F &amp; S</td>
</tr>
<tr>
<td>Run 2</td>
<td>S</td>
</tr>
</tbody>
</table>

Note: F-feed, S-stirring, P-precipitation, D-drawing, Ana-anaerobic.
As a whole, the system performed well on removing of ammonium, but not very well on its removal of total nitrogen and phosphate.
Figure 2d  Figure 2e

Figure 2  Performance of the system operated in Run 1

Figure 3  The profiles of ammonium phosphorus, nitrate, total nitrogen and COD in a typical cycle in Run 1
Figure 3 shows the profiles of ammonium, phosphorus, nitrate, total nitrogen and COD in a typical cycle in Run 1. As shown in the figure, the lower removal for nitrite and total nitrogen is considered to be due to scarce of carbon source in anoxic stage where denitrification occurred.

3.2 Performance of the System Operated in Run 2

To improve the removal ability of the total nitrogen and phosphate, operating mode of the system was changed into mode 2, i.e., Run 2. The performance of the system in Run 2 is shown in Figure 4.

As shown in Figure 4a to 4e, average removal rates of the system for COD, ammonium nitrogen, phosphate, total nitrogen and suspended solids are about 93%, 93%, 96%, 75% and 95%, respectively. The average concentrations of COD, ammonium nitrogen, phosphate, total nitrogen and suspended solids in effluent are about 27.4, 2.1, 0.07, 11.7 and 10.6 mg/L, respectively. The system performed better on removing of total nitrogen and phosphate ammonium compared with that of Run 1. What is more attractive, Run 2 has a lower energy cost in aeration due to control lower concentration in aerobic stage and shorter aeration period. But That it resulted in a little higher concentration of ammonium in effluent of Run 2 of about 2.1 mg/L (average) should be noticed.
Figure 4c  Performance of the system operated in Run 2
Figure 5 shows the profiles of ammonium, phosphorus, nitrate, total nitrogen and COD in a typical cycle in Run 2.

3.3 Discussion

It is commonly accepted that biological nitrogen removal conflicts with biological enhanced phosphorus removal due to competition for carbon source and different condition needed (Kuba et al., 1996; Third et al., 2003; Yuan et al., 2007). High effective biological nutrient removal in SBR will be more difficult due to unique tank. In order to remove nitrogen and phosphate in decentralized domestic sewage, alternating operation condition is indispensable (Pochana and Keller, 1999; Zhao et al., 1999).

From the results of this study, it is indicated that the system could achieve good performance on both nitrogen and phosphate removal operated in the two modes. There is hardly difference between the operations in Run 1 and Run 2 in removals of COD, SS, ammonium, total nitrogen and phosphate. It is suggested that the operating strategies of the system were proper. In Run 1, the removal of ammonium is more effective than that of Run 2, but it is reverse for total nitrogen and phosphate removal. The reason for high efficient removal of total nitrogen and phosphate achieved in Run 2 is considered as that pre-anoxic stage before feeding greatly benefited phosphate release of PAOs in anaerobic stage followed and simultaneously organic substance oxidization, nitrification, denitrification with excessive phosphate uptake in oxic stage whit DO of less than 1.5 mg/L (DO was almost null within the first 30 min, and in the 30 min followed, DO was less than 1 mg/L, finally it increased to not more than 1.5 mg/L).

Concentrations of COD, TN, ammonium nitrogen and phosphate in the effluents in the two operation modes are less than 50, 15, 5, and 5 mg/L, respectively. Qualities of the effluents of the reactor operated under both modes even met the Standard for Pollutants Discharged from Municipal Wastewater Treatment Plant (GB18919-2002) of 1A class, only SS of 12.45 and 10.63 mg/L in average in model 1 and 2, respectively, is slightly higher than the standard limitation of 10 mg/L. The effluents basically meet reclaimed water quality applied for miscellaneous usage in...
case of less requirements of SS. Otherwise, simple coagulation/ filtration applied can make SS in the effluents meet usage of more stringent requirements for reclaimed water. It is suggested that the treatment achieved wastewater treatment and water reclamation simultaneously.

From Figures 2 and 4, it can be seen that the influent of the system fluctuated very obviously in quality, but the effluent was very stable. It implies that the treatment of the SBR has a good capacity for water quality fluctuation, which is suitable for decentralized wastewater treatment. It is found that after feeding, COD to TN ratio in the reactor is 4:1 to 2:1, that means organic substance in the influent is not enough for nitrogen and phosphate removal (Narkisa, 1979; Chiu and Chung, 2003). As discussed above, by application of DO control strategy in aerobic stage, simultaneous nitrification and denitrification as well as denitrifying phosphorus accumulation of PAOs occurred (Figure 5), and as a result organic substance needed for nitrogen and phosphate removal was saved. It is demonstrated proper operation strategy set is basic for good effluent of the SBR.

CONCLUSIONS

Both Ana-O-Ano-O mode and pre-Ano-Ana-O mode can achieve effluents of good quality that may satisfy reuse purpose to some extent. Mode 2 with lower operation cost and simpler operation is more appealing for application. The SBR is adequate to decentralized domestic wastewater treatment with high quality effluent. Proper operation strategy is basic for good effluent.

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