Application of reversed $A^2/O$ process on removing nitrogen and phosphorus from municipal wastewater in China


ABSTRACT

The application of reversed $A^2/O$ process in practice in China is mainly discussed in this paper. As a new process on nitrogen and phosphorus removal, principle and technical features of reversed $A^2/O$ process are also summarized. The application in rebuilt wastewater treatment plant shows that reversed $A^2/O$ process not only has merits on high nitrogen and phosphorus removal efficiency, but also has merits on energy saving. The application in newly-build wastewater treatment plant shows that infrastructure and equipment investment of reversed $A^2/O$ process economized 15% and 10% respectively, compared to conventional $A^2/O$ process. The practical application shows that reversed $A^2/O$ process is a new nitrogen and phosphorus removal process, which is suitable for China's national conditions.

Key words | application, municipal wastewater, nitrogen and phosphorus removal, reversed $A^2/O$ process

INTRODUCTION

With the prompt development of social economy and speeding up urbanization, the situation of water pollution in China is increasingly serious, and eutrophication poses a serious threat to the normal function of urban water environment and the harm caused by eutrophication is becoming more and more serious. As the “Statistical Bulletin of national Environment in 2008” shows (Statistical Bulletin of national Environment in 2008, 2009), the monitoring sections of seven major water systems belonging to standard IV, V and inferior V accounted for 45%. The nitrogen and phosphorus pollution of inland lakes was heavier and has led to outstanding eutrophication. Red tides were found for 68 times in whole sea area, which accumulated more than 13,738 square kilometer area, and caused great economic loss and greatly influenced marine ecological environment. Although the mechanism of the red tide occurrence is complex, high content of nitrogen, phosphorus and other nutritive substances in the water are regarded as the fundamental reason. The reduction of nitrogen, phosphorus and other nutritive substances into the water body is a fundamental way to solve the eutrophication problem.

In the nearly 2030 years, the nitrogen and phosphorus removal technology has been a research hot spot in wastewater treatment field. After a great deal of basic research, a variety of nitrogen and phosphorus removal processes had been applied in China. Among which $A^2/O$ process, University of Capetown (UCT ) process, Virginia Initiative Plant (VIP) process have been the most commonly used ones (Zhang et al. 2006; Peng et al. 2008). However, these processes have usually related to high infrastructure investment, high operation cost, long and complicated process system, and require a high level management (Huang et al. 2004). In recent years, a lot of work on nitrogen and phosphorus removal has been done in China, but no major breakthrough have been made on developing theory and technology that is especially suitable for Chinese conditions. So developing new nitrogen and phosphorus removal process and optimizing the traditional process are certain choice.

PRINCIPLES AND CHARACTERISTICS OF REVERSED A²/O PROCESS

Based on plenty of experiments on nitrogen and phosphorus removal effect of reversed anaerobic/anoxic process and mechanism analysis and aiming at solution of problem on biological phosphorous removal, Bo Zhang put forward and validated an important theoretical viewpoints: that phosphorus-accumulating organisms (PAOs) release phosphorus effectively is not a necessary and sufficient premise for the best phosphorus removal capacity of a system (Zhang & Gao 1997). Then reversed A²/O process was put forward based on this viewpoint. In this process, he formed anoxic/anoxic/aerobic process flow. Compared to the conventional A²/O Process, the anaerobic and anoxic zone is reversed, internal circulation is canceled, and the rate of sludge return is proper adjusted. The flow chart of reversed A²/O techniques can be seen in Figure 1.

Compared to the conventional A²/O Process, reversed A²/O process has the following characteristics. First of all, the carbon source need for nitrogen removal is satisfied preferentially and the denitrification could be more sufficient what makes the nitrogen removal ability of the system is improved distinctly (Zhang & Gao 2000a, b). At the same time, the adverse effects on anaerobic environment induced by the nitrate in the returning sludge can be avoided (Hu & Si 2008). Secondly, the PAOs enter into the aerobic zone directly after anaerobic environment, and the biochemical efficiency of the aerobic zone is relatively high. So the power of excessive phosphorus uptake potential formed under the anaerobic condition can be utilized more effectively (Zhang & Gao 2000a, b; Gan et al. 2007). Third, all micro-organisms participated in the cycle experience of a complete anaerobic-aerobic process, giving rise to a "group effect", thus the nitrogen and phosphorus removal capacity of the system is improved obviously (Chen et al. 2007). Fourth, reversed A²/O process prolongs non-aeration time and amalgamates the sludge returning system with mixed liquid internal circulation system of traditional A²/O process. Accordingly, the process flow is simple and easy to manage, and the infrastructure investment and operating cost are decreased (Liu et al. 2008).

RESULTS AND DISCUSSION

Application of reversed A²/O process in rebuilt wastewater treatment plant

Productive demonstration study of reversed A²/O process in rebuilt wastewater treatment plant was carried out under different scale and different water quality in Licunhe Wastewater Treatment Plant (WWTP) and Tuandao WWTP in Qingdao China.

Licunhe WWTP locates in the south bank of Licun River with a service area of 29 km² and serves population of 250 thousand. The design scale of stage I is 80,000 m³/d; long-term capacity of the plant can reach 170,000 m³/d. Airspace of Licunhe WWTP is showed as Figure 2. About 70% of the
wastewater entering the Licunhe WWTP is industrial wastewater, including chemical plant wastewater, papermaking wastewater, printing and dyeing wastewater and food processing wastewater. Treatment effect in practical production of Licunhe WWTP can be seen in Table 1.

Tuandao WWTP locates in the west of Qingdao city, with a service area of 11.4 km² and serves a population of 250 thousand. The design scale is 100,000 m³/d, but at present the wastewater inflow is only 40,000–50,000 m³/d. Airscape of Tuandao WWTP is shown as Figure 3. More than 80% of the wastewater entering the Tuandao WWTP is domestic sewage. Treatment effect in practical production of Tuandao WWTP can be seen in Table 2.

Tables 1 and Table 2 shows the results of reversed A²/O process applied in Licunhe and Tuandao WWTP. The various treatment indexes of reversed A²/O process can meet the discharge requirements of GB18918-2002 first class Level B completely (Discharge standard of pollutants for municipal wastewater treatment plant 2002), and the removal efficiencies of organics (CODcr), Total nitrogen (TN), Total phosphorus (TP) reached 90%, 80% and over 90% respectively when treating the municipal sewage which mainly include industrial and domestic wastewater.

According to the analysis of long-term operation data of Licunhe and Tuandao WWTP, reversed A²/O process also had great merit on energy saving. Figures 4 and 5 show comparison between original designed process and reversed A²/O process on energy consumption of Licunhe and Tuandao WWTP in one year. The original designed process of Licunhe WWTP is VIP and UCT combined process, and the original designed process of Tuandao WWTP is conventional A²/O process. The comparison is of the same wastewater flow treatment.

The energy consumption of original designed process in Licunhe WWTP was 0.596 kWh/m³, whereas the energy...
consumption was merely 0.348 kW h/m³ when reversed A²/O process was adopted. The reversed process economized about 12%. Meanwhile, in terms of the energy consumption of aeration system, which is the biochemical treatment nucleus of the wastewater treatment plant, the energy consumption of reversed A²/O process was reduced by 12.3% compared to the VIP and UCT combined process.

According to the analysis of long-term operation data of Tuandao WWTP, the energy consumption of the original designed process (conventional A²/O process) was 0.570 kW h/m³ and the energy consumption was merely 0.460 kW h/m³ when reversed A²/O process was adopted. The reversed process economized about 19%. Meanwhile, in terms of the energy consumption of aeration system, the energy consumption of reversed A²/O process was reduced by 19.4% compared to improved A²/O process.

Application of reversed A²/O process in newly-built wastewater treatment plant

Eliminating the mixed liquid internal circulation system of conventional A²/O process, the reversed A²/O process is simpler. PAOs enter the aerobic zone directly after anaerobic environment and the biochemical efficiency of the aerobic zone is relatively high. The infrastructure and installation investment are decreased compared to the conventional A²/O process on the same scale. Yunchen WWTP is a good example which had been designed using reversed A²/O process as its main process originally. Yuncheng WWTP locates in south bank of Beisha River and the east north of Yuncheng city in Shandong province with a service area of 21.9 km² and serves a population of 110 thousand. The design scale was 40,000 m³/d. A detailed analysis and calculation on infrastructure and equipment investment was done when the WWTP was built. The results shows infrastructure

![Figure 3](https://iwaponline.com/wst/article-pdf/63/10/2138/443556/2138.pdf)

**Table 2** | Treatment effect of reversed A²/O process in Tuandao WWTP

<table>
<thead>
<tr>
<th>Water-quality index</th>
<th>CODc</th>
<th>Treatment effect</th>
<th>Influent (mg/L)</th>
<th>Effluent (mg/L)</th>
<th>Average removing rate (%)</th>
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<td>790 ~ 1380</td>
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<td>380 ~ 690</td>
<td>7.5 ~ 23</td>
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<td>Water-quality index</td>
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<td>Treatment effect</td>
<td>Influent (mg/L)</td>
<td>Effluent (mg/L)</td>
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<td>89 ~ 135</td>
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<td>82.6</td>
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<td>Water-quality index</td>
<td>TP</td>
<td>Treatment effect</td>
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<td>0.7 ~ 1.0</td>
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Figure 3 | Aircscape of Tuandao WWTP.
and equipment investment were economized 15% and 10% respectively, compared to conventional A2/O process.

CONCLUSIONS

The main conclusions obtained from this paper are as follows:

1. Reversed A2/O process has advantages over the currently prevalent A2/O process in terms of nitrogen and phosphorus removal efficiencies, operation energy consumption, construction cost, reliability, etc. This new process is simple, high-efficient and suitable for the practical situation of wastewater treatment in China.

2. The practical application results of reversed A2/O process indicated that the process has a pretty good adaptability toward wastewater of different quality. Reversed A2/O process can be used in newly-built municipal wastewater treatment plant, the industrial wastewater treatment plant of similar water quality, and the rebuilding of municipal wastewater treatment plant without nitrogen and phosphorus removal system.

3. With regard to typical municipal wastewater, various treatment indexes of reversed A2/O process can meet the discharge requirements of GB18918-2002 first class Level B completely.

REFERENCES


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