Effect of exposure time ratio on Intermittent Aerated Moving Bed Biofilm Reactor

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Abstract. This study combined the IA craft, and the goal is to achieve aerobic, anoxic and even anaerobic alternating cycles in the same reactor to enhance biological nitrogen and phosphorus removal. At present, there are many studies on the IA process, but less research on the IAMBBR craft. The IAMBBR craft combines intermittent aeration with a biofilm process, which can further improve the processing capacity of a continuous-flow biofilm reactor. Therefore, it is necessary to conduct a detailed study of the IAMBBR craft. In addition, the exposure time ratio is an important parameter for the operation of the IA craft. By adjusting the exposure time ratio, the DO concentration in the reactor can be controlled, which affects the operation effect of the reactor. Therefore, this chapter mainly explores the effect of exposure time ratio on the operating effect of IAMBBR. Six operating stages were connected: the ratio of CA and exposure time are 3h/3h, 1h/1h, 30min/30min, 15min/15min, and 5min/5min, respectively, to study the removal effect of pollutants.

1 Introduction

In recent years, with the increasingly strict discharge standards for municipal wastewater treatment plant, a large number of municipal wastewater treatment plants are in urgent need of upgrading [1, 2]. In addition, most of the plants have problems of high energy consumption and high operating costs, and energy conservation. And consumption reduction of sewage treatment process is also imperative [3]. Therefore, how to improve nitrogen and phosphorus removal efficiency and reduce energy consumption in municipal wastewater treatment plants is a hot spot in wastewater treatment field. Moving bed biofilm reactor (MBBR) has the same structure as the activated sludge process, and it has the characteristics of lower cost, shorter time-consuming during the upgradation [4]. Moreover, MBBR process can improve the treatment load and effluent water quality after upgrading, and lower the operating cost [5]. Therefore, MBBR is one of the preferred processes for the upgrading of wastewater treatment plants. However, slow biofilm formation rate during startup stage is one of the stumbling blocks of MBBR, and there is space for improvement of nitrogen and phosphorus removal efficiency. The combination of MBBR technology and intermittent aeration (IA) technology can not only improve the nitrogen and phosphorus removal efficiency, but also promote the energy saving and consumption reduction of the sewage treatment plant. There have been a lot of researches on MBBR, but few research and application on IAMBBR or similar process. Singh et al. [6] used a biofilm / activated sludge mixing process to study the effect of exposure time ratio on pollutant removal under high aeration. The results show that IA craft has an important effect on the removal of nitrogen, and has a smaller effect on phosphorus and organic carbon. Luostarinen et al. [7] used an MBBR reactor to treat the mixture of anaerobic pre-treated dairy wastewater, kitchen wastewater and black water at low temperature. The effect of continuous flow and sequential batch on the sewage treatment effect under IA condition and CA condition were compared. The results showed that all the reactors could achieve complete nitrification, with the removal of TN and COD reaching 50% ~ 60% and 40% ~ 70%. The denitrification effect in IA was slightly higher than that in CA.

From the current research, IAMBBR and similar crafts can achieve high-efficiency denitrification in many cases. However, most of its current researches use sequential batch method (ie, IASBBR), and there is less research on IAMBBR treatment of domestic sewage. Therefore, it is necessary to carry out systematic research on the treatment of domestic sewage by IAMBBR to provide strong support for its engineering application.

2 Material and methods

The reactor is made of plexiglass with a size of 30×10×30 cm and an effective volume of 8.20 L. Water inlets and outlets are provided at the lower left and upper right of the reactor, respectively. Simulated wastewater enters the reactor from the lower left, and overflows out of the reactor after the treatment. The filler chooses K1 type biological filler, its size is Φ 10×10 mm, density is 0.96 ~ 0.98 g/cm^3, and specific surface area is about 1200 m^2/m^3 with 30% biofiller fill rate. During the experiment, a thermostat was used to control the reactor temperature to 25±2 °C, and a

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time relay was used to control intermittent aeration at regular intervals. The aeration amount during the aeration period was 0.2 m^3/h. This experiment uses artificial simulated wastewater which contained glucose (300 mg/L), ammonium chloride (125 mg/L), sodium bicarbonate (100 mg/L), urea (40 mg/L), sodium dihydrogen phosphate (20 mg/L), potassium dihydrogen phosphate (2 mg/L) and trace elements (1 ml/L). To optimize the exposure time ratio, the optimal exposure time ratio group is selected and the optimization of the exposure time ratio is performed, based on the study of the startup process. HRT is 8 h at this stage. Study the differences in pollutant removal effect under different exposure time ratios: 3h/3h, 1h/1h, 30min/30min, 15min/15min, 5min/5min, and CA stage.

3 Results

3.1 Analysis of pollutant removal effect

The COD, NH_4^+-N, TN and TP concentrations of the influent in this study were 315 ± 10 mg/L, 31 ± 2 mg/L, 51 ± 1 mg/L, and 5.7 ± 0.2 mg/L, and the HRT was 8 h, temperature is 25 ± 2 °C. It mainly examines the removal effect of pollutants under six stages, among which stage 1 is the exposure stopping time ratio 3h/3h, stage 2 is the exposure stopping time ratio 1h/1h, stage 3 is the exposure stopping time 30min/30min, stage 4 is the exposure time ratio 15min/15min, stage 5 is the exposure time ratio 5min/5min, and stage 6 is the CA stage.

3.1.1 Analysis of DO concentration change trend

The change in DO concentration has an important effect on the activity and metabolic pathways of microorganisms. Fig.1 shows the change trend of DO concentration in the reactor under different exposure time ratios. It can be seen from the figure that with the change of the exposure time ratio, the DO concentration in the reactor has a large difference. In stage 1, the DO concentration in the reactor varied between 0.1 and 3.5 mg/L, where the DO concentration was greater than 2 mg/L for 180 minutes. In stage 2, the DO concentration in the reactor varied between 0.1 and 3.7 mg/L, where the DO concentration was greater than 2 mg/L and shortened to 75 minutes. In stage 3, the DO concentration in the reactor varied between 0.1 to 3.2 mg/L, where the DO concentration was greater than 2 mg/L and shortened to 28 minutes. In stage 4, the DO concentration in the reactor varies between 0.1 ~ 3.2 mg/L. In stage 5, the DO concentration in the reactor varies between 1.4 and 2.5 mg/L. In CA stage, the DO concentration of the reactor was maintained at about 4.8 mg/L.

3.1.2 Effect of exposure time ratio on COD concentration in effluent

Fig.2 shows the effect of exposure time ratio on COD effluent concentration. As the exposure time ratio decreased from 3h/3h to continuous aeration, the COD effluent concentration fluctuated between 20-40 mg/L, and was always lower than 50 mg/L. The COD concentration of the effluent in the aeration phase is similar to that in the cessation aeration phase, which indicates that the effect of the aeration time on the removal of organic matter is relatively slight. Previous studies have also shown that under low organic loads, intermittent aeration has less effect on the activity of heterotrophic microorganisms [8].

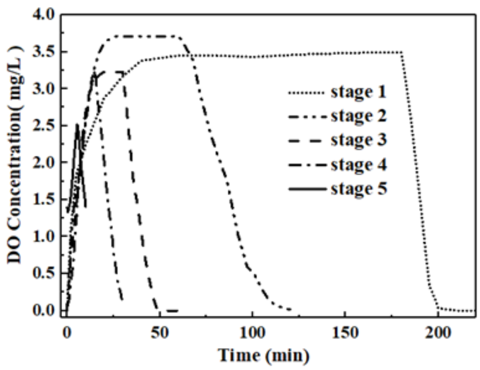

Fig. 1. Effect of oxic/anoxic on DO concentration

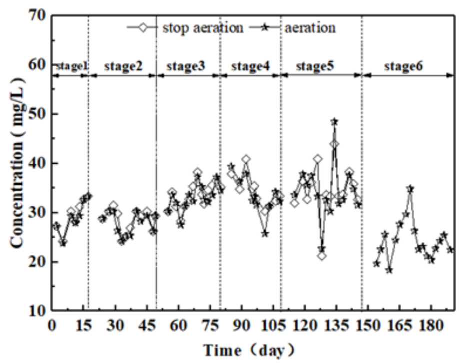

Fig. 2. Effect of oxic/anoxic on COD concentration in effluent

3.1.3 Effect of exposure time ratio on conversion effect of nitrogenous pollutants

Fig.3 shows the changes of NH_4^+-N, NO_3^--N, NO_2^--N and TN concentrations over time at different exposure time ratios. The exposure time ratio has a greater effect on the NH_4^+-N concentration in the effluent. With the shortening of the exposure time ratio, the NH_4^+-N concentration in the effluent increased first and then decreased. When the exposure time ratio was 15min/15min (stage 4), the effluent concentration reached the highest, about 23 mg/L In continuous aeration conditions, the concentration of NH_4^+-N effluent is the lowest, about 10 mg/L. The results show that the exposure time is greater than the removal impact of NH_4^+-N. The removal effect of NH_4^+-N is poor under CA stage due to the fact that the concentration of TN and organic nitrogen in the water is higher, and the HRT is shorter. At 2.5 mg/L, the NH_4^+-N concentration in the effluent is as high as 19.6 mg/L. The removal of NH_4^+-N mainly depends on the nitrifying bacteria to oxidize NH_4^+-N to NO_3^--N under aerobic conditions. The decrease in DO concentration during the aeration period has a greater impact on the nitrification ability, resulting in an increase in NH_4^+-N concentration in the effluent effluent. In addition, it can be clearly seen from Fig.3 that when the exposure time is relatively long, such as stage 1, the difference in NO_3^--N concentration in the effluent during the aeration phase and the aeration phase was 6 mg/L. Therefore, a relatively long exposure time can easily lead to unstable water quality.

With the shortening of the exposure time ratio, the concentration of effluent NO_2^--N showed a downward trend, from about 2 mg/L to about 0.2 mg/L. NO_2^--N is mainly produced by ammonia oxidation and removed by nitrification and denitrification. Compared with NOB, AOB has a stronger affinity for oxygen, and AOB recovers relatively quickly at low DO concentrations. In addition, in the anoxic environment, the decay rate of AOB is also lower than that of NOB. Stopping the aeration stage can greatly reduce the system's oxidation ability to NO_2^--N. Previous studies have also reported that intermittent aeration can effectively inhibit the activity of NOB, thereby achieving the accumulation of NO_2^--N. In IA stage the accumulation of NO_2^--N is greater than that under the CA stage, and as the exposure time ratio is shortened, the NO_2^--N concentration in the effluent is decreasing.

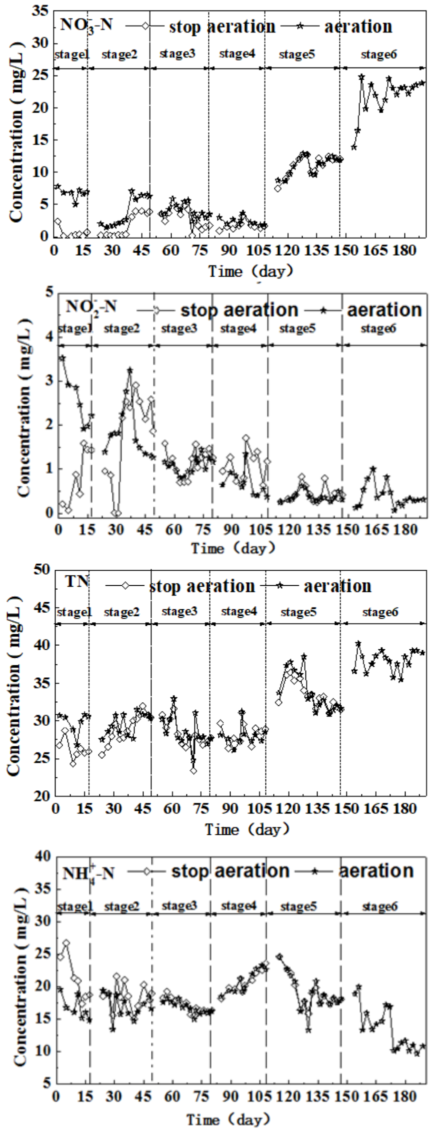

Fig. 3. Effect of oxic/anoxic onNH+ 4-N、NO- 3-N、NO- 2-N and TN concentration in effluent

The TN concentration of the effluent decreases first and then increases with the shortening of the exposure time ratio. Generally, In most sewage treatment systems, the removal of TN mainly depends on the denitrification of denitrifying bacteria. An alternating environment of aerobic and hypoxic conditions is formed in the IA stage. In the aerobic phase, it is beneficial to the nitrification process, and in the anoxic phase, it is beneficial to the denitrification process. In the exposure time ratios of 3h/3h (stage 1) and 1h/1h (stage 2), due to the relatively long exposure stop time, the effluent quality of the aeration phase and the aeration stop phase are unstable, and the TN concentration in the effluent is large different. With the reduction of the exposure time ratio, the actual hypoxic environment duration of the system is shortened, and denitrification is hindered, leading to a reduction in the denitrification effect. Therefore, at CA stage (stage 6), the TN concentration in the effluent rose to 39 mg/L. When the exposure time ratio is 30min/30min (stage 3), the TN effluent concentration reaches the lowest, about 27 mg/L, and the removal rate is about 45%, which is about 24% higher than the total nitrogen removal rate under CA stage. Previous studies on intermittent aeration have also shown that IA stage is more conducive to TN removal than CA stage which is attributed to that in the process of intermittent aeration, the system forms an aerobic and anoxic alternating cycle environment, which provides feasible conditions for simultaneous nitrification and denitrification.

3.1.4 Effect of exposure time ratio on TP concentration in effluent

Fig.4 shows the effect of the exposure time ratio on the TP concentration in the effluent. With the reduction of the exposure time ratio, the TP concentration in the effluent showed a clear upward trend, from 3.26 mg/L to 4.03 mg/L. Biological phosphorus removal is usually enhanced by anaerobic and aerobic processes. Microorganisms decompose their own polyphosphates under anaerobic environment to produce ATP to maintain their own activities. At this stage, microorganisms release phosphorus into the solution. When this part of the microorganisms changes from anaerobic environment to aerobic environment, PAOs will absorb a large amount of phosphorus in solution and store it in the form of polyphosphate in the body, and the amount of phosphorus absorbed in this process is greater than the amount of phosphorus released in anaerobic environment Therefore, intermittent aeration is beneficial for phosphorus removal. It can also be seen from Fig.4 that the effluent phosphorus concentration in the IA stage is lower than that in the CA stage. In the exposure time ratio of 3h/3h (stage 1), the results are similar to previous studies.

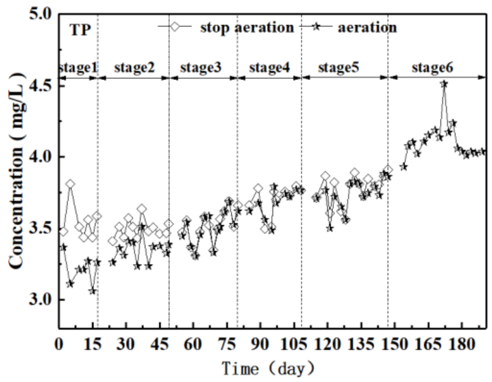

Fig. 4. Effect of oxic/anoxic on TP concentration in effluent

4 Conclusions

The effect of intermittent aeration on the removal of COD is slight, and the COD concentration in the effluent of the CA stage is slightly lower than that in the IA stage. The length of the aeration stop time ratio has an important effect on the stability of the effluent. When the aeration stop time ratio is less than 1h/1h, the difference between the effluent quality of the aeration phase and the aeration stop phase is small. With the reduction of the exposure time ratio, the NH_4^+-N concentration in the effluent increased first and then decreased, the TP concentration increased, and the TN concentration decreased first and then increased. When the exposure time ratio is 30min/30min, the TN concentration of the effluent is the lowest, about 27 mg/L, the NH_4^+-N concentration of the effluent is about 16 mg/L, and the TP concentration of the effluent is about 3.6 mg/L. From the comprehensive comparison of effluent water quality, the exposure time ratio of 30min/30min is the optimal stage.

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