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Study on key influencing factors of magnetic autotrophic denitrification reactor

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Abstract. Under the condition of inoculating autotrophic denitrification sludge cultured earlier in the laboratory by constructing a magnetic autotrophic nitrogen removal reactor, the effect of the change in the range of Influent ammonia nitrogen loading at $0.05\text{KgN}\cdot\text{m}^{-3}\text{d}^{-1}$ - $0.2\text{KgN}\cdot\text{m}^{-3}\text{d}^{-1}$, $\text{pH} = 6 \sim 8$, COD concentration in $0\text{-}300\text{mg/L}$ on the treatment efficiency of autotrophic nitrogen removal process was investigated. Research shows that, magnetic autotrophic denitrification reactor has better resistance to ammonia-nitrogen shock load. When the influent ammonia nitrogen concentration was 400mg/L (ammonia nitrogen loading was $0.2\text{KgN}\cdot\text{m}^{-3}\text{d}^{-1}$), the autotrophic nitrogen removal efficiency could be ensured. PH had obvious effects on short-cut nitrification and anaerobic ammonia oxidation in magnetic autotrophic denitrification reactor. Too high or too low pH had great effect on nitrogen removal efficiency of the reactor. At $\text{pH}=8$, the removal efficiency of total nitrogen is up to 60%, and the efficiency of autotrophic nitrogen removal is the best. The presence of appropriate organic carbon source is helpful to improve the efficiency of nitrogen removal. When the influent COD concentration is 100mg/L , the nitrogen removal efficiency of the reactor is the highest, and the removal rate of total nitrogen is 74%.

1. Introduction

The traditional wastewater biological nitrogen removal technology is mainly realized by nitrification-denitrification process. The traditional wastewater biological nitrogen removal technology is mainly realized by nitrification-denitrification process. However, due to the large aeration in the nitrification stage and the high demand for carbon source in the denitrification stage, the operation cost of the traditional wastewater treatment process has been increased [1-2]. The autotrophic denitrification reaction is based on anaerobic ammonia oxidation. The synergetic action of AOB (aerobic ammonia oxidizing bacteria) and ANAOB (anaerobic ammonia oxidizing bacteria) is used to remove nitrogen efficiently [3-6]. Among them, AOB (aerobic ammonia oxidizing bacteria) and (ANAOB) (anaerobic ammonia oxidizing bacteria) are autotrophic bacteria [7]. Compared with the traditional nitrogen removal process, they have the advantages of high nitrogen removal efficiency, low oxygen demand and less residual sludge [8]. However, the long generation cycle of Anammox bacteria is sensitive to environmental conditions [9], resulting in a long start-up period of Anammox process, which seriously restricts the wide application of this process [2;10-13]. The results show that magnetic field can affect the activity of microbial enzymes and increase the activities of catalase, peroxidase and three kinds of phosphatases [14]. Zhu Lingli [15] studied the effect of magnetic field on anaerobic ammonia oxidation process by adding magnetic powder into conical bottle. It was found that when the magnetic field intensity was in 0.78mT , the magnetic field was helpful to start the anaerobic ammonia oxidation



process quickly, and had better nitrogen removal efficiency. In this paper, magnetic particles were added into the SBR reactor to construct a magnetic autotrophic nitrogen removal reactor. The effects of some key factors such as ammonia-nitrogen loading and pH, COD concentration on the autotrophic nitrogen removal efficiency were investigated under the conditions of high ammonia-nitrogen and low carbon-source influent. The optimal operation condition of magnetic autotrophic nitrogen removal reactor is explored, which provides the theoretical basis for the research and application of self nutrient nitrogen removal process.

2. Materials and methods

2.1. Experimental Equipment

The test reactor is made of polymethyl methacrylate (Fig. 1). The reactor is 1200 mm high and 100 mm in diameter. The reactor is equipped with inlet and outlet, equipped with internal circulation equipment, automatic temperature control equipment, and the reactor is covered with black material to avoid light. Magnetic particles were added into the reactor and the intensity of magnetic field in the reactor was 0.85 mT. The internal circulation of the reactor was stirred by circulating pump.

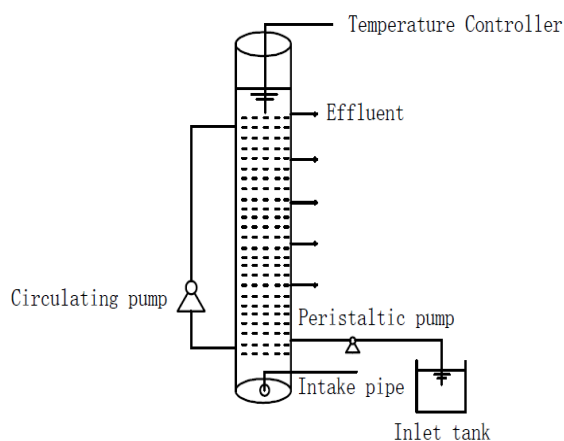


Figure 1. Micro magnetic autotrophic denitrification reactor diagram

2.2. Influent water quality and inoculated sludge

The experimental influent is a simulated sewage prepared with NaNO_2 and NH_4Cl , and other components include: KH_2PO_4 , $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, NaHCO_3 , etc. Trace elements supplied by garden leachate. The pH value was adjusted by adding NaOH and HCl during the experiment. The experimental inoculation sludge is the autotrophic nitrogen removal sludge cultivated in the study of magnetic field enhanced self-nitrogen removal. The concentration of the inoculation sludge is 3500mg/L.

2.3. Operation method

The experiment is carried out in three magnetic autotrophic nitrogen removal reactors, which are shown in figure 1. Autotrophic nitrogen removal sludge cultured in a magnetic field enhanced autotrophic denitrification reactor. The temperature of the reactor is controlled at 30 °C, the pH is between 7.5 and 8.5, the hydraulic retention time of the reactor is 48 hours, and the drainage rate is 50% per time. On the basis of the successful start-up of the autotrophic denitrification reactor, the different operating parameters are changed under the same conditions as mentioned above. The influent ammonia nitrogen concentration in the No. 1 magnetic autotrophic nitrogen removal reactor is 4 gradients 100mg/L, 200mg/L, 300mg/L, 400mg/L gradually increasing. In the No. 2 magnetic autotrophic denitrification reactor, the ammonia nitrogen concentration is 200 mg / L, and the pH

value is adjusted to 9,8,7,6 step by step. In the No. 3 magnetic autotrophic denitrification reactor, the ammonia nitrogen concentration was maintained at 200 mg/L, the concentration of COD in the influent is 0mg/L, 100mg/L, 200mg/L, 300mg/L four gradients. The operating time of three groups of magnetic autotrophic nitrogen removal reactors in each working condition was 20 days. The concentrations of $\text{NH}_4^+\text{-N}$, $\text{NO}_2^-\text{-N}$, $\text{NO}_3^-\text{-N}$ and TN in and out of water were measured in the experiment.

2.4. Analytical method

The test methods for the influent and effluent water quality of the reactor are as follows: $\text{NH}_4^+\text{-N}$ is determined by Nessler's reagent spectrophotometry (Shimadzu, UV-2700), and $\text{NO}_2^-\text{-N}$ is determined by N-(1 naphthyl)- Determination of ethylenediamine by spectrophotometry (Shimadzu, UV-2700), $\text{NO}_3^-\text{-N}$ was determined by ion chromatography (Dionex, ICS-1000). The TN concentration is expressed as the sum of the concentrations of $\text{NH}_4^+\text{-N}$, $\text{NO}_2^-\text{-N}$, $\text{NO}_3^-\text{-N}$, and pH is determined by portable multi-parameter analyzer (Hach, HQ40d).

3. Results and discussion

3.1. Effect of influent ammonia nitrogen loading on autotrophic nitrogen removal

Effect of influent ammonia-nitrogen loading on magnetic autotrophic denitrification reactor test results are shown in Fig. 2 below. In the diagram, a figure shows the effect of influent ammonia nitrogen loading on ammonia nitrogen and nitrate nitrogen removal. b Chart shows the effect of influent ammonia nitrogen loading on total nitrogen removal. 80-day test process, 1 to 20 days influent ammonia nitrogen concentration is 100mg/L (ammonia nitrogen load= $0.05 \text{ KgN}\cdot\text{m}^{-3} \text{ d}^{-1}$). 21 to 41 days influent ammonia nitrogen concentration is 200mg/L (ammonia nitrogen load= $0.10 \text{ KgN}\cdot\text{m}^{-3} \text{ d}^{-1}$). 41 to 61 days influent ammonia nitrogen concentration is 300mg/L (ammonia nitrogen load= $0.15 \text{ KgN}\cdot\text{m}^{-3} \text{ d}^{-1}$). 61 to 81 days influent ammonia nitrogen concentration is 400mg/L (ammonia nitrogen load= $0.20 \text{ KgN}\cdot\text{m}^{-3} \text{ d}^{-1}$).

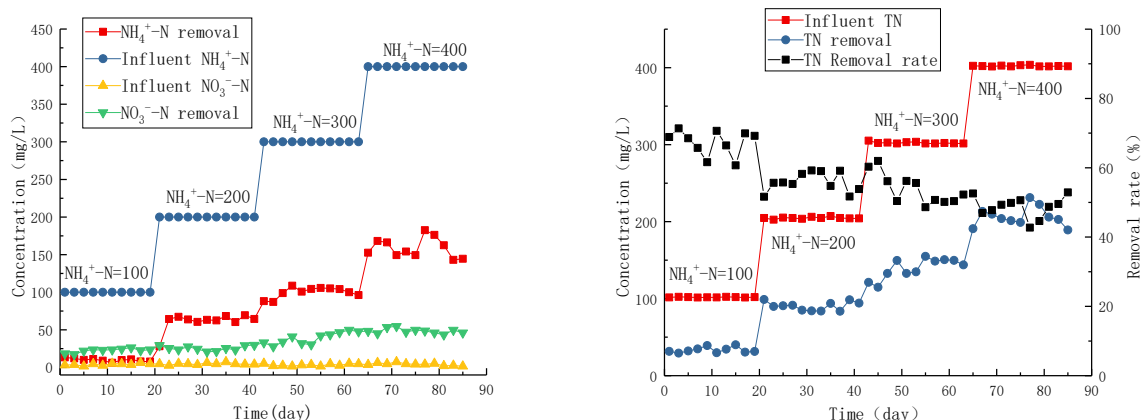


Figure 2. Effect of influent ammonia-nitrogen load on nitrogen removal efficiency

With the increase of influent ammonia nitrogen load, effluent ammonia nitrogen gradually increased from 13mg/L to 182 mg / L, nitrate nitrogen from 18mg/L to 50 mg / L, total nitrogen from 31mg/L to 231 mg/L. With the increase of the influent ammonia nitrogen load, the autotrophic denitrification reactor can maintain a certain nitrogen removal efficiency, and the reactor does not collapse due to the high ammonia nitrogen load. However, the ammonia-nitrogen concentration in the effluent increased gradually, and the removal rate of total nitrogen continued to decrease. Reduced from 70% at $0.05 \text{ KgN}\cdot\text{m}^{-3} \text{ d}^{-1}$ to 55 percent. When the influent concentration is 100mg/L in the influent ammonia nitrogen concentration (ammonia nitrogen load $0.05 \text{ KgN}\cdot\text{m}^{-3} \text{ d}^{-1}$), the total nitrogen removal rate is

up to 69% at 19d, possibly due to microbial activity in the reactor under low ammonia nitrogen loading conditions. It has not been greatly affected, so the removal effect is good. Therefore, under the impact of high ammonia nitrogen load, when the influent ammonia nitrogen concentration is 400 mg/L (ammonia nitrogen load 0.1 KgN·m⁻³ d⁻¹), stable operation efficiency can be ensured.

3.2. Effect of pH on autotrophic nitrogen removal

The experimental results of influent pH on nitrogen removal efficiency of magnetic autotrophic nitrogen removal reactor are shown in figure 3 below. In the figure, a diagram shows the effect of pH on the removal of ammonia nitrogen and nitrate nitrogen. The b diagram shows the effect of pH on the removal efficiency of total nitrogen. During the experiment, maintain influent ammonia nitrogen concentration is 200 mg/L. The influent pH was adjusted to 9, 8, 7, and 6 for 1-20d, 21-40d, 41-60d, and 61-80d, respectively.

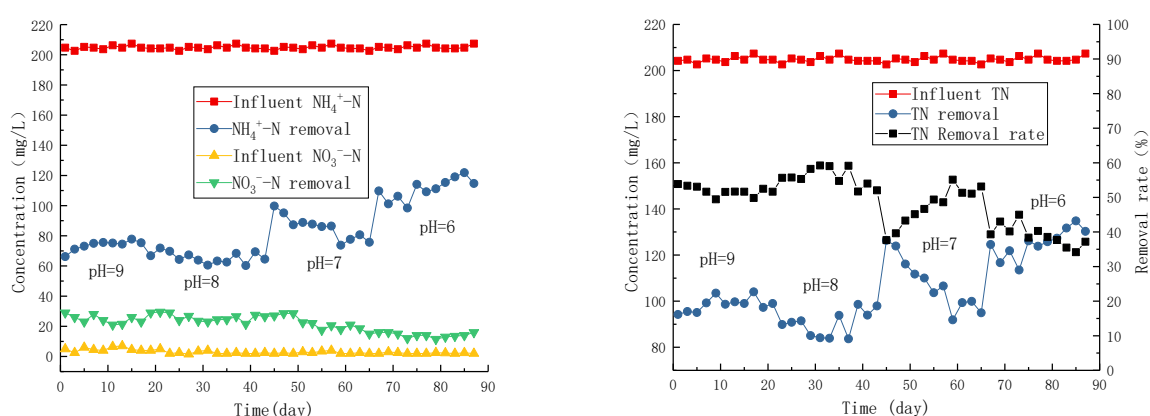


Figure 3. Effect of pH on ammonia nitrogen, nitrate nitrogen and Total nitrogen

With the gradual decrease of pH, the effluent ammonia nitrogen concentration gradually increased from 66mg/L to 200mg / L, and the effluent nitrate nitrogen concentration decreased slowly from 29mg/L to 13mg / L. The removal rate of total nitrogen showed a decreasing trend as a whole. When pH=9 is used, the removal rate of total nitrogen was stable at about 50%. When pH=8 was used, the removal efficiency of total nitrogen was up to 60% at 31 days. When pH=7 was used, the removal rate of total nitrogen increased gradually. The removal rate of total nitrogen in the reactor was up to 49% at 57d, because the microorganism in the reactor was worth adapting to the environment gradually under the condition of decreasing pH. The removal rate of total nitrogen was up to 49% at 57d. When the pH value was reduced to the minimum of 6, the total nitrogen removal rate decreased to the lowest of 34%. It can be seen that pH has a significant effect on the process of short-cut nitrification and anaerobic ammonia oxidation. Too high or too low pH has a greater effect on the denitrification efficiency of the reactor, and the activity of anaerobic ammonia-oxidizing bacteria is inhibited. In pH=8, the removal efficiency of magnetic autotrophic nitrogen removal reactor is the best.

3.3. Effect of Organic compounds on Autotrophic nitrogen denitrification

The experimental results of influent COD concentration on nitrogen removal efficiency of magnetic autotrophic nitrogen removal reactor are shown in figure 4 below. In the diagram, (a) chart shows the effect of influent COD concentration on the removal of ammonia nitrogen and nitrate nitrogen. (b) chart shows the effect of influent COD concentration on total nitrogen removal. During the experiment, the influent ammonia nitrogen concentration was maintained at 200 mg/L. In 1 to 20 days, 21 to 40 days, 41 to 60 days, 61 to 80 days, the influent COD concentration was adjusted to 0 mg / L, 100 mg / L, 200 mg / L, 300 mg / L, respectively.

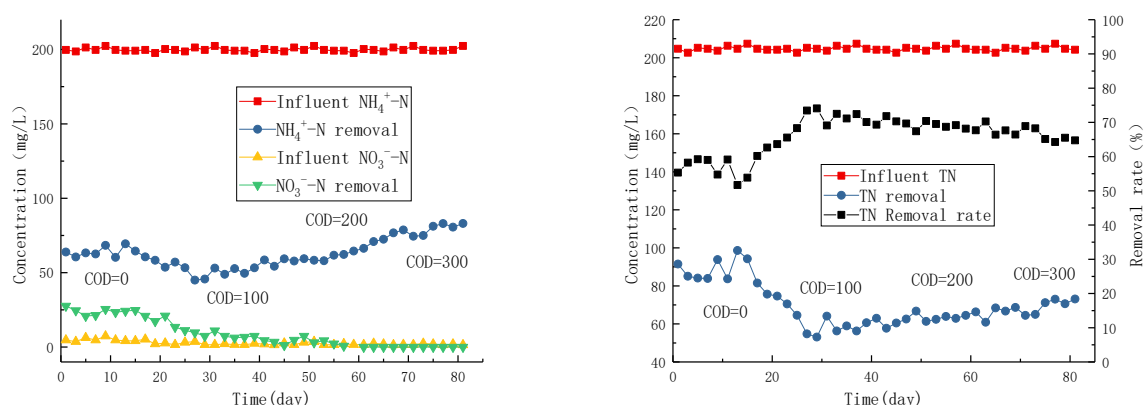


Figure 4. Effect of influent COD concentration on nitrogen removal efficiency

With the increase of the influent COD concentration, the ammonia nitrogen concentration in the effluent decreased at first, and the concentration of ammonia and nitrogen in the effluent decreased at the same time. At 27 days, the lowest ammonia nitrogen concentration was 45 mg / L, the nitrate nitrogen decreased continuously from 27mg/L, the total nitrogen removal rate increased first and then decreased, and the maximum removal rate was 74% at 29 days. These phenomena indicate that the existence of appropriate organic carbon source can co-exist autotrophic nitrogen removal process and denitrification process, which is helpful to enhance the nitrogen removal efficiency of the reactor. However, with the increase of influent COD concentration, carbon source increased, denitrification reaction gradually dominated, and the structure of dominant bacteria in the reactor changed, which would inhibit the process of autotrophic nitrogen removal. In this experiment, when the influent COD concentration is 100mg/L, the removal efficiency of ammonia nitrogen and total nitrogen is the best.

4. Conclusions

- (1) The magnetic autotrophic nitrogen removal reactor has better resistance to ammonia-nitrogen impact load. With the increase of influent ammonia-nitrogen load, the autotrophic nitrogen removal reaction can maintain a certain nitrogen removal efficiency, and the removal rate of total nitrogen gradually decreased. But it didn't show the trend of reactor collapse. When the influent ammonia nitrogen concentration was 400mg/L (ammonia nitrogen loading 0.1 KgN·m⁻³ d⁻¹), the autotrophic nitrogen removal efficiency could be ensured.
- (2) PH had obvious effects on short-cut nitrification and anaerobic ammonia oxidation in magnetic autotrophic denitrification reactor. Too high or too low pH had great effect on nitrogen removal efficiency of the reactor. Weak acid environment or strong alkaline environment can inhibit the activity of anaerobic ammonia oxidizing bacteria and decrease the removal rate of total nitrogen. When pH=8 was used in this experiment, the removal efficiency of total nitrogen was up to 60%, and the efficiency of self-nutrient nitrogen removal was the best.
- (3) The existence of appropriate organic carbon source can make the autotrophic nitrogen removal and denitrification co-exist and improve the denitrification efficiency of the reactor. However, with the increase of carbon source, the structure of dominant bacteria in the reactor changed, which could inhibit the process of autotrophic denitrification. In this experiment, when the influent COD concentration is 100mg/L, the nitrogen removal efficiency of the reactor is the highest, and the removal rate of total nitrogen is 74%.

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