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IOP Conf. Series: Materials Science and Engineering **592** (2019) 012096 doi:10.1088/1757-899X/592/1/012096

Effect of magnetic field on denitrification of anaerobic ammonia oxidation

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Abstract. In this experiment, the effect of magnetic field on the denitrification efficiency of anammox reactor was studied to solve the problems such as slow start-up of anammox process and environmental sensitivity by adding magnetic particles (adding amount 0 20 60 100g/L) in the reactor. It was found that the addition of magnetic field could improve the activity of partial nitrification bacteria, accelerate the accumulation of nitrite and promote the anaerobic ammonia oxidation reaction, especially when the magnetic particle dosage was 60 g/L. The presence of magnetic field can enhance the activity of anaerobic ammonia oxidizing bacteria, increase the impact load resistance of anaerobic ammonia oxidizing system, improve denitrification efficiency and shorten hydraulic retention time.

1. Introduction

Anammox bacteria can use carbon dioxide as the carbon source and nitrite as the electron acceptor to oxidize ammonia nitrogen. Compared with the traditional wastewater denitrification treatment process, Anammox greatly reduces the energy consumption of aeration and the investment cost of carbon source in the wastewater treatment plant. Anammox bacteria have slow growth rate and high sensitivity to the environment, which is one of the bottlenecks in the application of anammox process [1]. In order to shorten the start-up time of anammox and improve the denitrification effect, researchers have done a lot of work: Abstract: Lv [2] investigated the rapid start-up performance of anaerobic ammonia oxidation in a fully mixed membrane bioreactor (MBR) and a push-flow anaerobic baffled reactor (ABR). It was found that the start-up period of MBR (90 days) was 20% shorter than that of ABR (111 days). An anaerobic sludge blanket (UASB) aerobic; activated sludge ammonium oxidation reactor being seeded (ANAMMOX) reactor was successfully started up in 17 days with mixed anaerobic; sludge from laboratory cultures with a from a municipal sewage treatment plant in a volume ratio of 1:2[3]. Cao [4] developed a new ANAMMOX combined with partial denitrification process (ANAMMOX-PD), and the removal rate of total nitrogen (TN) was up to 97.8%. Magnetic field is also a new technology, through the introduction of magnetic technology can improve the activity of enzymes in microorganisms, improve the treatment effect of wastewater [5]. Geng [6] found that the magnetic significantly improve the Sludge dehydrogenase activity in SBR (Sequencing Batch Reactor Activated Sludge Process) system, and thus having a positive role to eliminate the various pollutants; When Leng [7] used magnetic technology to enhance the oil removal efficiency of oil-degrading bacteria, he found that under the magnetic field intensity of 25m T (millitesla), the cell morphology remained intact, the activity of the bacterial strain was the highest, which was 25.2% higher than that of untreated, and the activity of intracellular enzyme (SOD) was increased by 12.3%, the ability to resist the harsh environment was enhanced. According to Wang [8], when the external magnetic field intensity is 150 mT, the removal rate of nitrate nitrogen is increased by 7.2 %, and the activity of dehydrogenase is also increased by 2.38 times .Wang et al. [9] found that the effect of external magnetic field on short-range nitrification was well enhanced by 5 mT magnetic field on the activity of AOB in short-range nitrifying bacteria. The magnetic field can enhance the activity of microorganisms adapted to the magnetic environment and promote the population succession. The useless microorganisms with poor magnetic adaptability in the system are eliminated, and the dominant microorganisms are more obvious. The treatment effect of wastewater is improved [10]: Wen [11] used a static magnetic field with strength of 15 mT to study the influence of microbial characteristics in the short-range nitrification (PN) process, and found that the static magnetic field significantly reduced the start-up time of PN process at ambient temperature and improved the richness of AOB. Wang Qiang concluded through experiments that the removal of ammonia nitrogen was promoted when the magnetic field strength was between 30 and 90 mT, and the removal effect was the best when the magnetic field strength was 60mT. Geng [12] found that the effect of external magnetic field on the removal of total nitrogen in SBR reaction system was significant. At 700GS, the removal rate of total nitrogen increased from 65.69% without magnetic field to 85.98%, and the microbial abundance and diversity of activated sludge reached the highest level.

Based on the enhancement effect of magnetic field on biological treatment process, a magnetic anaerobic ammonia oxidation reactor was constructed, and the start-up law of the anaerobic ammonia oxidation reactor under magnetic field was studied. The degradation and transformation law of ammonia nitrogen, nitrite and nitrate under magnetic field was explored, which provided theoretical reference for the application of anaerobic ammonia oxidation technology.

2. Materials and methods

2.1. The experiment of device

The reactor is refitted with 250mL conical flask. Rubber stopper is used at the bottle mouth to isolate the gas, and Vaseline is used at the junction to ensure the sealing. The inlet and outlet and the air outlet are respectively set, and rubber tube and clamp are used during the operation (Figure.1). Activated sludge collected from AAO activated sludge concentration pool of municipal wastewater treatment plant of Jinan city is used as the seed in this study. And sludge concentration are 3000 ± 50 mg/L, the test device is placed in a thermostatic oscillator, control temperature 35 ℃, the oscillation frequency of 150 r/min. The hydraulic retention time (HRT) is 72h, including 0.5h in the influent phase, 69h in the reaction phase, 2h in the precipitation phase, and 0.5h in the effluent phase.

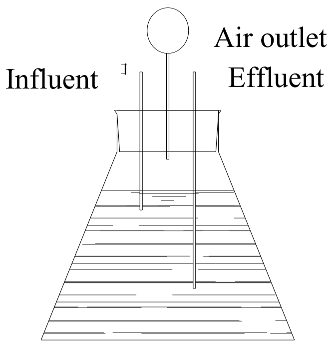


Figure 1. Reactor diagram

2.2. The experiment of water

In order to ensure that the inlet water quality fluctuates within a controllable range, the water we use in the experiment is simulated wastewater, in which NH_4^+-N and PO_4^{3-}-P are provided by ammonium chloride and potassium dihydrogen phosphate respectively, and the carbon source is provided by sodium bicarbonate. The specific water quality is shown in table 1. The pH value was adjusted by adding NaOH. Before water distribution, tap water should be boiled and cooled in an airtight environment to reduce dissolved oxygen and keep the dissolved oxygen content within 0.5-0.9mg/L. The magnetic particles are the magnetic particles of Fe_3O_4 prepared in the early stage of laboratory, and the particle size is 11.68-54.74 micron.

Table 1. Water quality of simulated wastewater

Item	Concentration(mg/L)
NH_4Cl	ND*
$NaNO_2$	ND*
KH_2PO_4	27
$NaHCO_3$	1250
$MgSO_4.7H_2O$	300
$CaCl_2$	170
Trace element solution	2.5mL/L wastewater
NaOH	ND*

Attention：ND* Means the concentration is not fixed.

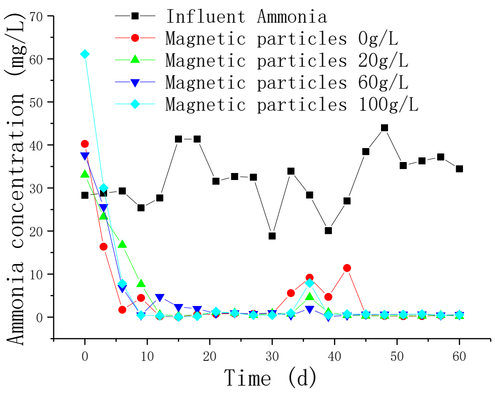
2.3. Analytical methods

The analysis of NH_4^+-N, NO_2^--N, NO_3^--N was carried out in accordance with the standard methods [13]. DO and pH were monitored using a DO meter and a pH meter, respectively.

3. Results and discussion

3.1. Effect of magnetic field on the start-up phase of anammox

The magnetic particles of 0.00g, 5.00g, 15.00g and 25.00g were added in four reactors in turn. The contents of magnetic particles were 0 g/L, 20 g/L, 60 g/L and 100 g/L in turn. The four reactors were placed in a constant temperature oscillating incubator with 0.00g magnetic particles as the control group. The influent ammonia nitrogen concentration was 20-45 mg/L, nitrite nitrogen concentration was 50-65 mg/L, HRT=72 h, and pH value was 7.1-7.4. In the experiment, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen were detected every three days the results are as follows: Figure. 2.



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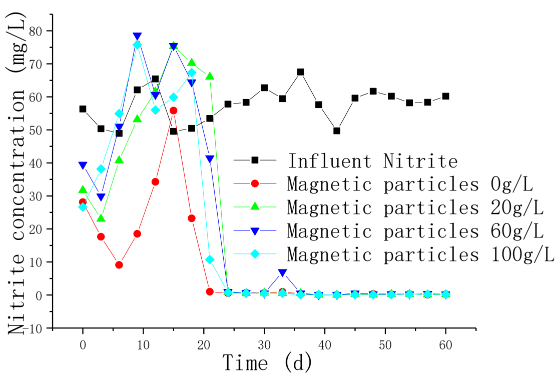

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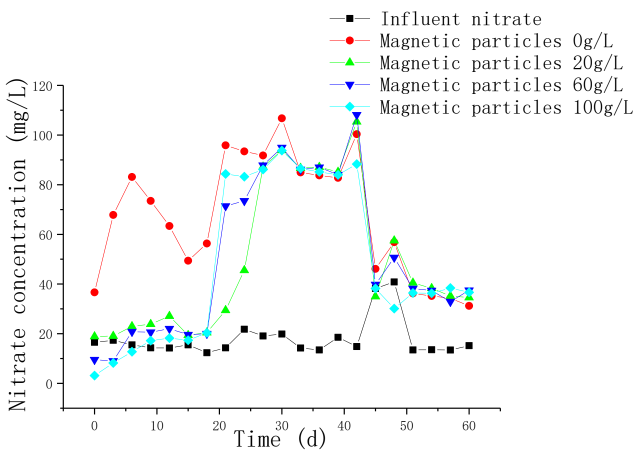

(3)

Figure 2. The changes of ammonia nitrogen, nitrite nitrogen and nitrite nitrogen under the action of different magnetic particle amount

In the initial stage of start-up (1-3 days), the concentration of ammonia nitrogen in effluent was significantly higher than that in influent. This may be due to the autolysis of bacteria cells in the reactor, which released a large amount of organic matter and NH_4^+-N. In this stage, heterotrophic bacteria use organic nitrogen released by autolysis bacteria and NO_2^--N in influent to denitrify, the concentration of NO_2^--N in effluent decreases, and heterotrophic bacteria multiply rapidly as the dominant strain.

On the 4th to 17th day, the effluent concentration of NH_4^+-N decreased gradually, while the effluent concentration of NO_2^--N increased slowly. The increase of the effluent concentration of this order of NH_4^+-N may be due to the presence of ammonia oxidizing bacteria (AOB). AOB converts NH_4^+-N into NO_2^--N by using trace dissolved oxygen in the influent.

During 18-35 days, the average removal rate of NH_4^+-N reached 95%, and NO_2^--N reached high removal efficiency. At this time, the content of degradable organic carbon source was low in the small-scale device, and the heterotrophic microorganisms competing with anammox bacteria were significantly reduced. The ratio of nitrite nitrogen to ammonia nitrogen was 1.7, which was close to the theoretical value of 1.32. It can be inferred that anaerobic ammonia oxidation was the main process of nitrogen removal in the reactor.

Compared with the effluent concentration of the reactor with different magnetic powder dosage in Fig. 2, when the ammonia nitrogen concentration in the effluent of Fig. 2 (1) changed greatly, the reactor with magnetic field was more resistant to load than that of the control group; the nitrite nitrogen concentration in the effluent of the three magnetic powder dosage groups in Fig. 2 (2) began to rise earlier than that of the control group, and the NO2-N concentration was higher at the magnetic powder dosage of 60 g/L, with a larger decrease, and NO2-N concentration was higher at the magnetic powder dosage The process of N effluent concentration from high to low is the process of anaerobic ammonia oxidizing bacteria activity from weak to strong, and also the process of anaerobic ammonia oxidizing bacteria gradually washing out heterotrophic denitrifying bacteria [9]. By contrast, the magnetic field can promote the activity of AOB, and the rapid accumulation of nitrite nitrogen is helpful to shorten the start-up period of anaerobic ammonia oxidizing reaction.

3.2. Effect of magnetic field on denitrification

After 60 days of successful start-up and operation of the reactor, the anaerobic ammonia oxidation reaction has become stable. At this time, water is collected at 36h and 72h time points in one operation cycle for detection, respectively. The results are shown in Figure 3.

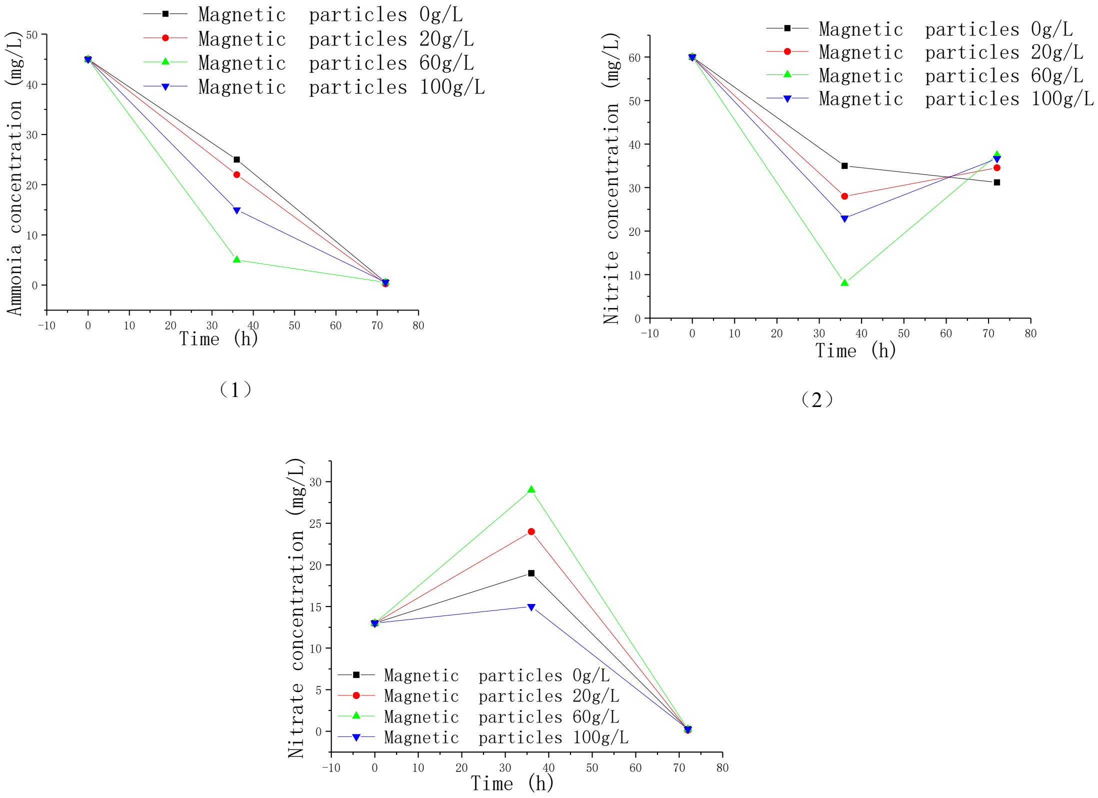

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Figure 3. Changes of nitrogen removal with time with different amounts of magnetic powder

The results show that the removal rates of ammonia nitrogen and nitrite nitrogen increase with the increase of magnetic powder content in the 0-36 h period. The removal rates of ammonia nitrogen and nitrite nitrogen in the device with 60 g/L magnetic powder dosage are the most, followed by 100 g/L magnetic powder dosage. Similarly, in 0-36 h, the nitrate nitrogen production was the highest in the device with 60 g/L magnetic powder, followed by 100 g/L. All of them show that the presence of magnetic field can help to increase the rate of short-cut nitrification and anaerobic ammonia oxidation reaction, and improve the efficiency of nitrogen removal in the reactor, thus shortening the hydraulic retention time.

When running to 72 hours, the difference of ammonia nitrogen and nitrite nitrogen in effluent under different magnetic field intensity is not obvious. The concentration of nitrate nitrogen decreases at 72 h, which indicates that there are some heterotrophic bacteria in the reactor, and denitrification can take place under anaerobic conditions. However, the growth of heterotrophic bacteria was inhibited due to the limited carbon sources in the system, and anaerobic ammonia oxidation was the main denitrification process in the reactor.

4. Conclusions

The above results showed that the addition of magnetic field was helpful to improve the activity of partial nitrifying bacteria, accelerate the accumulation of nitrite, promote the anammox reaction, and shorten the start-up cycle of anammox. The presence of magnetic field can enhance the activity of anammox bacteria, increase the impact load resistance of anammox system, improve the efficiency of nitrogen removal and shorten the hydraulic retention time.

Acknowledgments

This work was supported by the Higher Education Science and Technology Plan of Shandong Province (J17KA198).

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