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Research Article

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Effects of salinity on nitrogen removal in high salinity wastewater treatment

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ABSTRACT

Aiming at the influence to municipal sewage treatment in the utilization of seawater, effects of salinity on nitrogen removal were studied using A/O process. The experiment indicated that the salinity of 20g/L was the tolerance limit for the nitrogen removal of the system. The salinity within 10g/L had little effect on the removal efficiency of ammonia nitrogen. At 20g/L salinity, the removal rate still kept high value and above 80% after the sludge being domesticated. The treatment efficiency plunged and the ammonia nitrogen removal rate dropped to 50% under 25g/L salinity condition. The nitrification rate decreased with the increase of salinity and changed little at the salinity from 5 g/L to 15 g/L. Under the salinity above 20 g/L conditions, it decreased evidently. Otherwise, the proper salinity was beneficial to shortcut nitrification-denitrification. The shortcut nitrification-denitrification was realized at the salinity above 15 g/L. The nitrite-nitrification rate was 97% at 20 g/L salinity.

Keywords: salinity; A/O process; biological nitrogen removal

INTRODUCTION

Utilization of seawater has become one of the important ways to solve the shortage of water resource with development for coastal city. Large quantities of high salinity wastewater produced by seawater utilization must bring certain influence on municipal wastewater treatment system. At present, most studies focus on the effects of salinity on the organic matter removal. But there are few researches on effects of salinity on biological nitrogen removal and the conclusions are very inconsistent. Some research shows that high salinity can obviously inhibit nitrification-denitrification and the nitrification rate can be reduced to zero [1,2]. But some papers indicated that microorganisms can adapt to changes of salinity in certain range and the ammonia nitrogen removal was affected little [3-5]. Some researchers believe that the removal rates of ammonia nitrogen drop somewhat, but still maintain at a certain level as salinity increase [6,7]. Therefore, to study effects of salinity on biological nitrogen removal in high salt wastewater treatment is very necessary. In this paper, effects of salinity on biological nitrogen removal were studied in high salinity wastewater using anoxic-aerobic biological treatment process (A/O process).

EXPERIMENTAL SECTION

2.1 Apparatus

Fig.1 shows anoxic-aerobic biological treatment system. The A/O reactor of total volume 80L was divided into six chambers. The volume of two anoxic chambers is 20L. The volume of four aerobic chambers is 60L. The secondary sedimentation basin is a flow vertical basin of 20L volume. The reactor was operated by hydraulic retention time 12~13h, aerobic area DO 2~3mg/L, MLSS 4000~5000 mg/L and the return sludge ratio is 0.8~1. The inoculated sludge was cultured and acclimated using a continuous flow of freshwater in early experiment. Until the sludge activity recovered and the removal efficiency reached approximately stable, different salinity wastewater began to be treated by stages. The experiments were carried out by gradual increase in salinity from 5 g/L to 25g/L. Each salinity condition was still maintained for a period of time after the removal efficiency remained constant. During this time, the nitrogen removal efficiency was studied continuously.

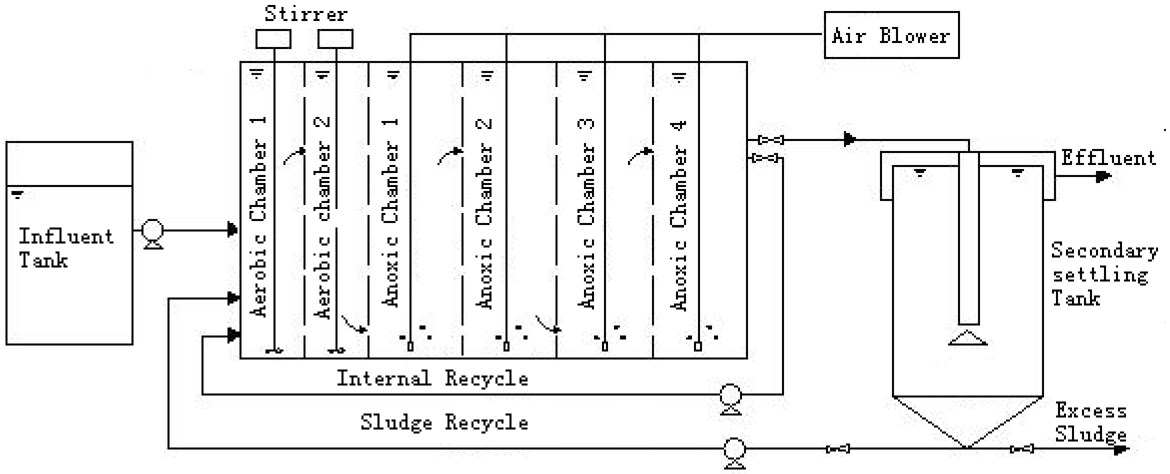

Fig.1 anoxic-aerobic biological treatment system

2.2 Inoculation and acclimation of sludge

The inoculated sludge for experiment was from the two sedimentation sludge pool in the city sewage treatment plant, which contained abundant microorganism easy to culture. The inoculated sludge was domesticated under freshwater condition using continuous flow mode. The influent conditions during the acclimatization period were the following. The COD, ammonia nitrogen and pH concentrations were 500 ~ 600mg/L, 80 ~ 90mg/L and 7 ~ 8. The water temperature was 20～25 ℃. The COD and ammonia nitrogen concentration of influent and effluent during the acclimatization period were measured and the removal rate of COD and ammonia nitrogen were calculated every day.

2.3 Procedures

The effects of salinity on nitrogen removal in the A/O biological system were researched after the sludge acclimation. The synthetic wastewaters with different salinities were prepared by the addition of various amount of coarse salt to domestic sewage. The salinity of wastewater was gradually increased. The COD concentration of influent was in a range of 800~1000 mg/L and the ammonia nitrogen concentration was in a range of 80~100 mg/L. The pH value of influent was determined as 7.0~8.5. The salinity levels of influent were set at 0 g/L, 5 g/L, 10 g/L, 15 g/L, 20 g/L, and 25g/L. Ammonia nitrogen concentration is determined by the Nessler’s reagent colorimetric method. Nitrate nitrogen concentration is determined by the thymol colorimetric method. Nitrite nitrogen concentration is determined by the N-(1-naphthyl)-diethylamine colorimetric method.

RESULTS AND DISCUSSION

3.1 Sludge acclimation

The removal rate of COD and ammonia nitrogen during the acclimatization period were presented in Fig.2 and Fig.3. After the acclimation of over a month, the COD and ammonia nitrogen removal rate reached high levels and remained steady (95% and 91% respectively). The sludge changed from black to taupe with good settle-ability. This showed that the sludge had recovered its activity and the acclimation period ended. By comparing Fig.2 with Fig.3, it can be seen that the removal rate of COD reached stable earlier than the removal rate of ammonia nitrogen. When the removal rate of COD achieved stable, the removal rate of ammonia nitrogen continued to rise. This shows that the stable removal rate of COD is a prerequisite for the rapid growth and reproduction of nitrification bacteria.

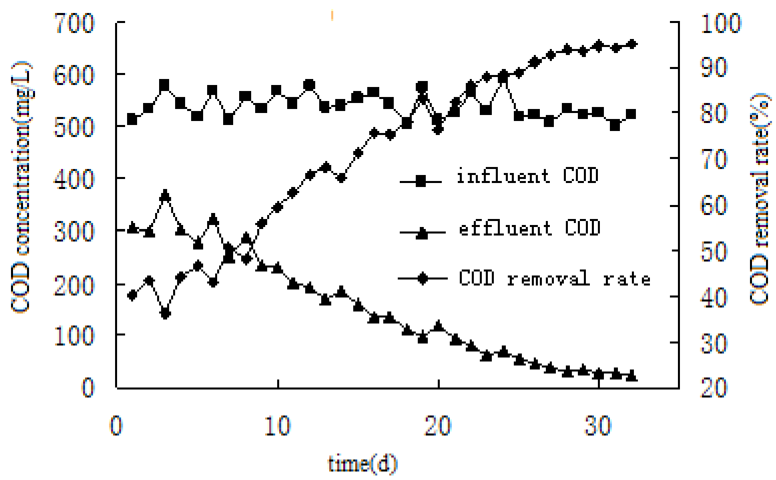

Fig.2 COD removal rate during the acclimatization period

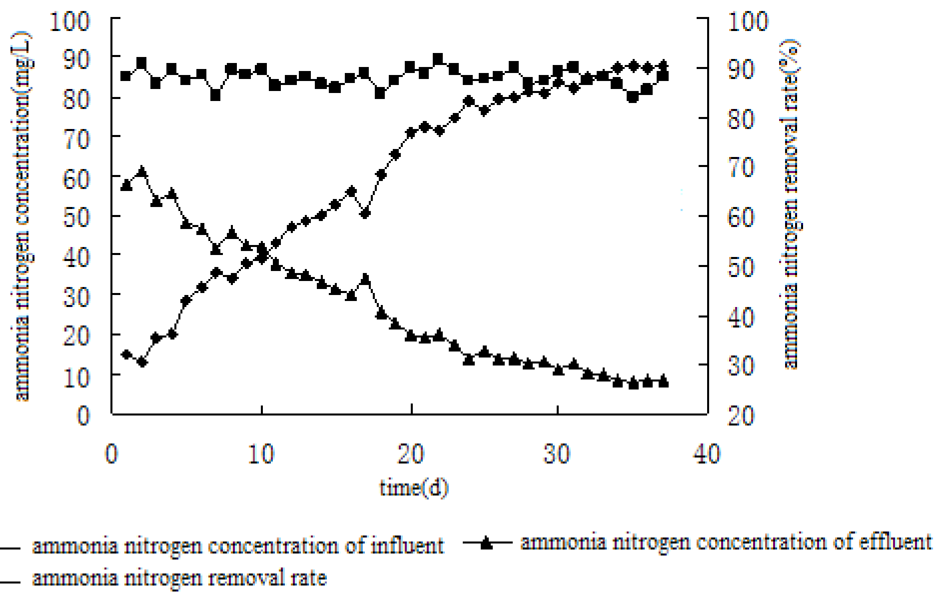

Fig.3 ammonia nitrogen removal rate during the acclimatization period

3.2 Effects of Salinity on ammonia nitrogen removal efficiency

To research the effect of salinity on the ammonia nitrogen removal rate, the A/O system ran continuously for 40 days under each salinity condition. The ammonia nitrogen removal rate was investigated every three or four days. The experimental results are shown in Fig.4.

The removal efficiency of ammonia nitrogen decreased with the increased wastewater salinity. Salinity within 20g/L has a small effect on the removal rate, which can keep at more than 85%. When the salinity was 25g/L, ammonia nitrogen removal rate dropped to about 50%. The water quality of effluent deteriorated rapidly and the concentration of ammonia nitrogen was beyond the second grade of national wastewater effluent standards. At 10g/L salinity, the removal efficiency of ammonia nitrogen was basically not affected and still maintained about 85%. When the salinity was increased to 20g/L, the removal rate dropped evidently. It recovered again two weeks later and reached stable about 80%. The ammonia concentration of effluent remained about 10mg/L. This showed that some salt-tolerant nitrobacteria had become dominant species adapted to high salinity environment and made the system removal rate able to reach a higher level once again. When the salinity was raised further to 25g/L, the system was subject to a significant impact, ammonia nitrogen removal rate declined sharply. Nitrobacteria were severely inhibited and couldn’t recover even after the domestication. Thus, when the salinity was below 20g/L, sludge could adapt well to high salinity environment after a certain period of acclimatization and the treatment system still kept high ammonia nitrogen removal efficiency.

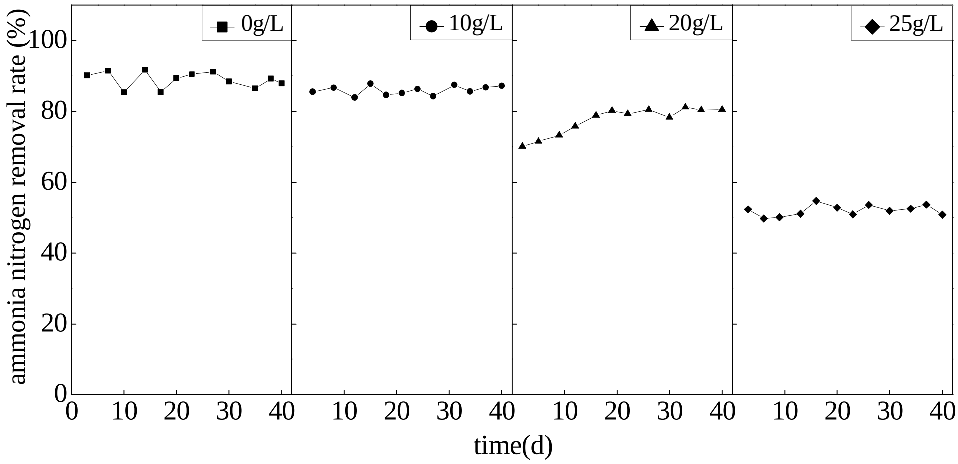

Fig.4 ammonia nitrogen removal rate variation at different salinity

3.3 Effects of salinity on activated sludge nitrification

After the ammonia nitrogen removal efficiency remained stable, an intermittent operation was taken to explore the effects of high salinity on ammonia nitrogen removal under each salinity conditions. The ammonia nitrogen concentration was determined every 2 hours and the nitrification rate of sludge at different salinity was also studied. Fig.5 shows the ammonia nitrogen degradation curve under different salinity conditions.

The slope of curves gradually decreased with the increase of salinity, when the salinity is 25g/L, this decline was most significant. This shows that nitrobacteria degradation rate of ammonia nitrogen declined with the increase of salinity. In addition, it still can be seen from Fig.5 that the sludge nitrification rate decreased gradually with the reaction time under each salinity condition. With the nitration reaction going on, the concentration of ammonia as a nutrients source in the system became lower and resulted in the declined metabolic rate of nitrobacteria.

The specific nitrification rates under different salinity conditions were shown in Fig.6. When the salinity was increased from 5mg/L to 15mg/L, the specific nitrification rate changed little. The activity of acclimated nitrobacteria was unaffected within the salinity of 15 g/L and still maintained high ammonia nitrogen degradation ability. When the salinity was increased to 20g/L, the nitrification rate decreased obviously. To meet the nitrogen removal demands, the nitrification need to be properly prolonged. At the salinity of 25mg/L, the nitrification rate dropped significantly. It need more time to complete the nitrification.

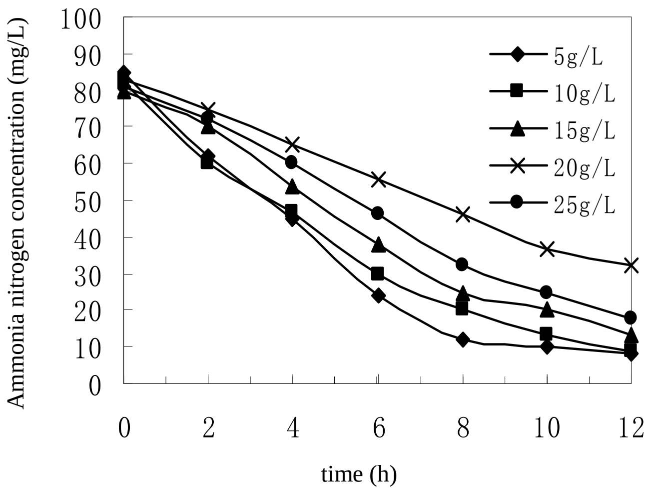

Fig. 5 Variation of Ammonia nitrogen concentration with different salinities

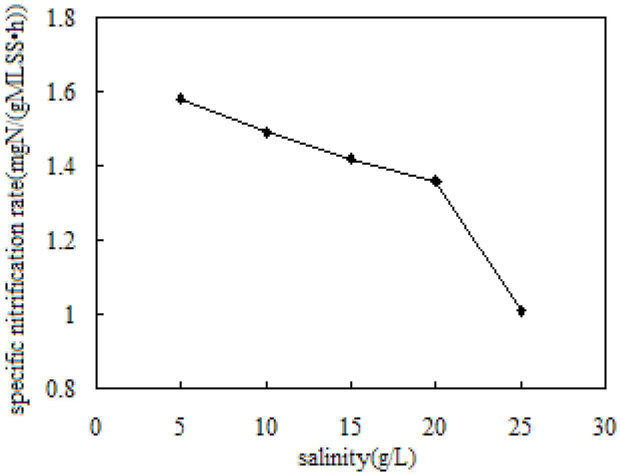

Fig.6 Specific nitrification rate under different salinity conditions

The above results show that salinity within a certain range has no obvious effects on nitrobacteria and the ammonia nitrogen biodegradation rate of system changes a little. But the higher salinity can change nitrobacteria and inhibit the activity of cells by osmotic pressure. So the metabolic rate decreased, which led to the ammonia nitrogen degradation rate reducing [8].

3.4 Effects of salinity on shortcut nitrification and denitrification

Shortcut nitrification denitrification was marked by stable and high nitrite accumulation rate in nitrification process[9]. It means that nitrite accumulation rate is more than 50%. Biological nitrogen removal process of nitrification is fulfilled by nitrosomonas and nitrobacteria [10]. Studies show that salinity has more obvious inhibition on nitrobacteria than nitrosomonas [11,12]. Nitrite accumulation can be achieved by controlling certain system salinity. This experiment studied the effects of salinity on shortcut nitrification and denitrification and measured nitrite accumulation rate at different salinity. The results were shown in Fig.7.

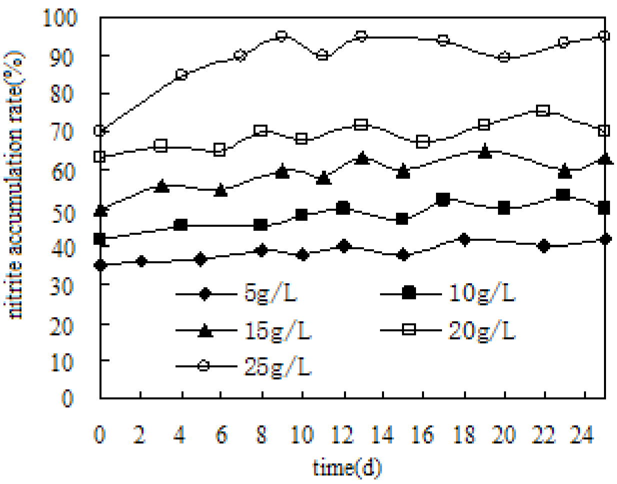

Fig. 7 Nitrite accumulation rate at different salinities

With the increase of salinity, the nitrite accumulation rate and the nitrite concentration of effluent were rising. When the salinity was raised to 15g/L, the nitrite accumulation rate started more than 50% and the concentration of nitrite was higher than the nitrate. As the wastewater salinity was raised to 25g/L continuously, the increasing trend of nitrite accumulation rate was getting stronger and its value kept stable around 90%. It showed that the system had completely entered into the shortcut nitrification process. Nitrifying bacteria has longer generation cycle and slower growth rate than the nitrifying bacteria. It is more susceptible to the increased salinity. Therefore, the effluent nitrate concentration decreased sharply with the increased salinity while nitrite concentrations rose rapidly. These resulted in a continuous rise in nitrification. Subsequently, the activity of nitrifying bacteria recovered gradually after a period of domestication. The nitrate concentration began to pick up and the rising tend of nitrite accumulation rate slowed down. When the system entered a high salinity stage of 20g/L, the activity of nitrifying bacteria was inhibited severely and its growth rate came down to zero. Although the activity of nitrite bacteria was also affected, it still maintained a certain growth rate. The measured average growth rate of nitrite was about 2.67mg/ (L • h), while nitrate average growth rate was only 0.12mg/ (L • h). When the salinity rose to 25g/L, the nitrification rate was very high. But the nitrite concentration of effluent was reduced greatly and the ammonia nitrogen concentration had exceeded the second grade of national wastewater effluent standards. It showed that the activity of nitrite bacteria was also significantly reduced at such a high salinity. So the A/O system could realize the nitrite accumulation at salinity above 15g/L. When the salinity was 20g/L, nitrification rate was the highest and the system could achieve a stable shortcut nitrification.

CONCLUSION

The ammonia nitrogen removal rate of A/O system remained at around 85% and basically not affected by salinity within 10g/L. The removal rate of ammonia nitrogen decreased early at 20g/L salinity. After the bacteria had been domesticated stable, it could reach a high level about 80% or more. When salinity was increased to 25g/L, the removal rate of ammonia nitrogen dropped to about 50% and the treatment efficiency was sharply reduced. This showed that 20g/L salinity was the salt tolerance limit for A/O system. With the increase of water salinity, nitrification rate of the nitrifying bacteria decreased continuously. Nitrification rate changed little within 15g/L salinity. Nitrification rate decreased greatly as the salinity continued to improve. Nitrification time must be extended to meet the requirements of nitrogen removal. Salinity has different inhibition on activities of nitromonas and nitrosomas. It is conducive to realize shortcut nitrification and denitrification by increasing the salinity properly. The experiment shows that the nitrite accumulation phenomenon appeared and the shortcut nitrification and denitrification was realized when the salinity exceeded 15g/L. When the salinity reached 20g/L, the nitrification rate was the highest and reached 97% more stable.

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