

Effect of temperature and $\text{NH}_4^+\text{-N}$ influent concentration on the nitrogen removal effect of luffa cylindrical sponge carrier sequencing batch biofilm reactor

Yafeng Li¹, JianboWu^{1,*}, Yuemeng Bai¹ and Ning Feng²

¹School of Municipal and Environmental Engineering, Shenyang Jianzhu University, Shenyang110000, China

²China Architecture Northeast Design and Research Institute Co., Ltd, Shenyang, China

Abstract. In order to improve the efficiency of biological nitrogen removal, the experiment used the luffa cylindrical sponge carrier sequencing batch biofilm reactor to treat domestic sewage, and it studied the temperature on the removal effect of TN in the sewage in the reactor and the changes of various types of nitrogen. The results showed that the TN treatment rate of the luffa cylindrical sponge carrier SBBR reached the peak at 30 °C, the removal rate was 82.25%, indicating that the luffa cylindrical sponge carrier SBBR is very suitable for the removal of nitrogen from domestic sewage.

1 Instruction

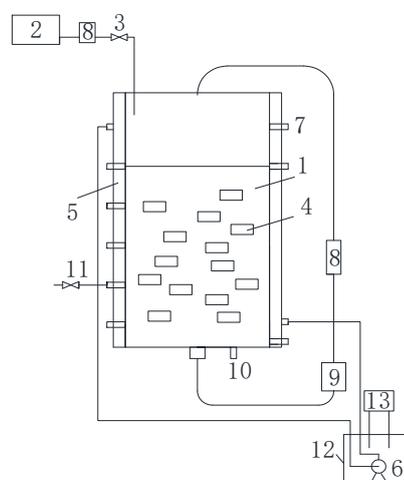
Rapid urbanization has led to excessive nitrogen in urban sewage in China, Most of the sewage treatment plants use traditional processes such as A/O and SBR. When dealing with low C/N sewage, they cannot meet the carbon source requirements of traditional processes for denitrification, which makes the effect of denitrification unsatisfactory and makes it difficult to meet emission standards [1]. Therefore, it is urgent to improve and develop the sewage treatment process. Sequential batch biofilm reactor as a new process produced by the combination of SBR process and biofilm method [2], in addition to the basic advantages of SBR and biofilm method, it also has its own unique advantages such as simple process, high removal rate, low cost [3]. It has certain application prospects [4]. Luffa, also called Luffa tendons, is hollow and has a dense network structure formed by interweaving natural fibers [5], which is widely used in many aspects such as environmental protection, chemical industry, and medical treatment.

2 Materials and Methods

2.1 Test Device

The SBBR reactor is made of plexiglass, with a height of 45cm and an effective volume of 25L. The reactor adopts a double-layer cuboid structure, the inner layer is the reaction zone, and the outer layer is the water bath heating zone. There is a water outlet and a sludge outlet at the bottom; the aeration is performed by a microporous aerator, and the aeration amount is adjusted by a gas flow meter; the hot water heated by the water bath is provided

by the hot water circulation system. It is shown in Figure 1.



1-Reactor 2-High water tank 3-Inlet solenoid valve 4-Packing
5-Outer water bath 6-Submersible pump 7-Overflow port 8-
Rotor flow meter 9-Water pump 10-Drain outlet 11-Drain
solenoid valve 12-Hot water tank 13-Heating and temperature
control device

Fig1. test device

2.2 Test Water

The artificial sewage is adopted to simulate the domestic sewage. The water quality is shown in Table 1. The prepared sewage uses anhydrous sodium acetate as the carbon source, NH_4Cl as the nitrogen source, NaHCO_3 to adjust the pH of the water sample.

* Corresponding author: 627311308@qq.com

Table 1. Test water quality

Water quality index	concentration (mg/L)
COD	300-400
NH ₄ ⁺ -N	19-70
TN	21-74
TP	3-5

2.3 Test Method

Before the reactor is operated, the luffa is processed first. We select the luffa with similar shape, cut off the narrow parts of the two ends, cut the remaining mid-thick luffa into a small section with an average diameter of 7cm and a height of 3.5cm, soak them in distilled water for 3 days, rinse once a day and change add fresh distilled water to reduce the effect of luffa itself on the experiment. According to the 30% filling ratio, the treated luffafiller was added, 5L of inoculated sludge was added, the reactor operating temperature was 17°C ~ 25°C, and the pH was 6.5~ 7.3. Run 2 cycles every day, each cycle includes 5 stages: instantaneous water inflow, anaerobic (3h), aerobic (8h), sedimentation (0.5h), and drainage (20min). Control the aeration volume to 100L/h, and start film hanging. Through the observation of the effect of the film hanging on the appearance of the filler and the microscopic observation of the microorganisms in the biofilm, organisms such as bellworms, barkworms, and paramecium were found, and a complex food chain consisting of bacteria, protozoa, and metazoans was formed. Subsequently, the working conditions of the reactor were adjusted to inflow for 10 minutes, anaerobic 2.5 hours, aerobic 6 hours, precipitation for 45 minutes, drainage for 20 minutes, and idle for 135 minutes. After the reactor effluent is stable, the national standard is used for water quality analysis.

3 Results and discussion

3.1. The effect of temperature change on the removal effect of TN

The test sets the temperature change range to 5°C, 10°C, 15°C, 20°C, 25°C, 30°C, and 35°C, and achieves the set requirements through the combined control of the temperature control device and the heating device. The changes of TN influent and effluent concentration and TN removal rate in the system are shown in Figure 2.

It can be seen from Figure 2 that as the temperature increases, the TN effluent concentration decreases and the removal rate increases. Under the conditions of 5°C and 10°C, the TN effluent concentration is 20.21mg/L and 10.52mg/L respectively, and the removal rate of TN is 34.20% and 42.58%, which is 82.25% of TN removal at 30 °C. The rate was reduced by 48.05% and 39.67% respectively, and the removal effect was poor. This is because under low temperature conditions, the two

bacteria involved in the reaction in the system-nitrifying bacteria and denitrifying bacteria have low activity, the nitrification and denitrification process is slow, and the slow nitrification process leads to the lack of electron acceptors in the denitrification process. It make the denitrification process more difficult. The overall performance is that the effluent TN concentration is very high, unable to meet the effluent discharge standard of 15mg/L. At 15°C, the removal rate of TN reached 62.89%, which was significantly higher than that under low temperature conditions. Under the condition of 20°C ~ 35°C, the TN effluent concentration range is between 5.58mg/L ~ 8.44mg/L, which has achieved good effluent effect. The TN removal rate reached a maximum of 82.25% at 30°C. This shows that this temperature range is suitable for simultaneous nitrification and denitrification by the system.

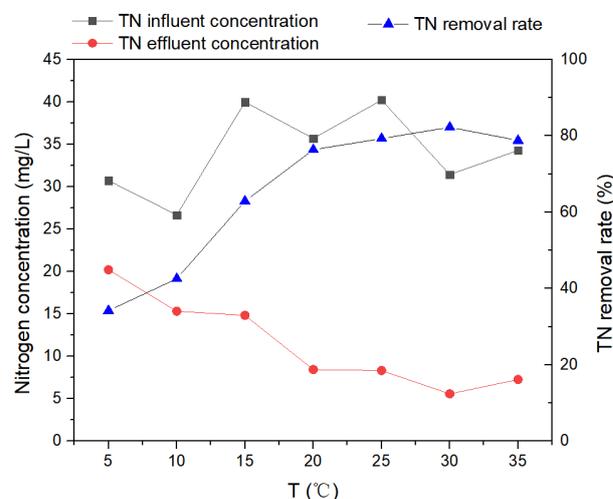


Fig2. Effect of temperature change on TN removal effect

It can be seen from Figure 3 that under the temperature condition of 5°C ~ 25°C, the main form of effluent nitrogen is NO₃⁻-N, and the concentration range of NO₃⁻-N in the effluent is 5.97mg/L ~ 10.33mg/L. As the temperature increases, the activity of denitrifying bacteria increases, the rate of denitrifying increases, and the concentration of NO₃⁻-N in the effluent decreases. At 30°C and 35°C, NO₃⁻-N concentration in the effluent is low, and the effluent concentrations are 2.21mg/L and 3.14mg/L, respectively. Under low temperature conditions of 5°C and 10°C, NH₄⁺-N effluent concentration is relatively large. At 5°C, NH₄⁺-N effluent concentration is as high as 10.36mg/L. A large amount of ammonia nitrogen has not been converted, indicating that the activity of nitrifying bacteria is low at this time, the denitrification process therefore lacks electron acceptors, and the simultaneous nitrification and denitrification process is less effective, with a removal rate of only 34.20%. However, as the temperature rises, NH₄⁺-N effluent concentration gradually decreases. NH₄⁺-N concentration in the effluent from 20°C to 35°C ranges from 0.10mg/L to 1.87mg/L. At this time, the nitrification reaction effect is very good. The effluent concentration of NO₂⁻-N under low

temperature conditions is low, ranging from 0.46mg/L to 1.98mg/L. When the temperature rises to 25°C, NO₂⁻-N concentration of the effluent begins to increase. At 30°C and 35°C, NO₂⁻-N concentration in the effluent is even greater than NO₃⁻-N effluent concentration, reaching a maximum of 3.72mg/L. It shows that under higher temperature conditions, nitrite bacteria are more sensitive to temperature changes than nitrate bacteria [6], while under low temperature conditions, the activity of nitrifying bacteria is significantly suppressed. Studies have also shown that in the range of 15~30°C, nitrite may be completely converted into nitrate, nitrite accumulation may occur above 30°C [7]. Therefore, controlling the temperature can affect the form of nitrogen in the effluent. In order to control the nitrate nitrogen in the effluent and achieve the effect of simultaneous nitrification and denitrification, the temperature should be controlled at less than 30°C.

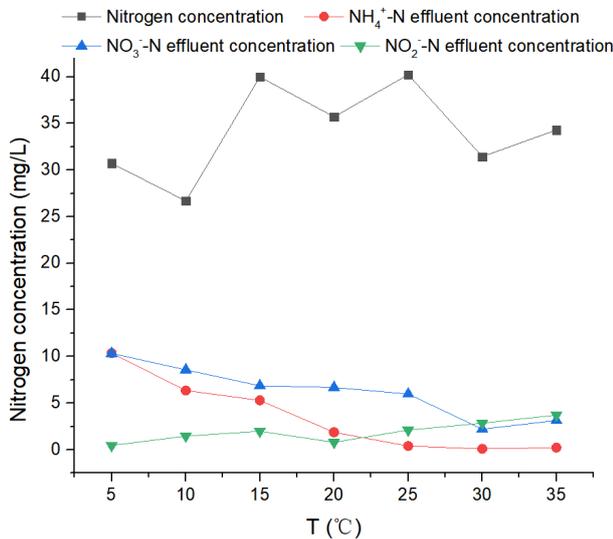


Fig3. Effect of temperature changes on various types of nitrogen changes

3.2. The effect of NH₄⁺-N influent concentration change on the removal effect of TN

Figure 4 and Figure 5 respectively reflect the changes in the TN concentration of the inlet and outlet water and the changes of various nitrogen concentrations in the loofah filler SBBR system under the conditions of the NH₄⁺-N influent change. When the NH₄⁺-N influent concentration increases from 19.11mg/L to 40.50mg/L, the TN removal rate increases, from 77.90% to 84.80%; When the concentration of ammonia nitrogen is low, the growth of denitrifying bacteria in the system will be competed by other heterotrophic bacteria. The effect of TN treatment is poor at the beginning, but gradually becomes better. When the NH₄⁺-N influent concentration is between 28.62mg/L~59.52mg/L, the TN effluent concentration is lower, the TN removal rate is higher than 80%, and the denitrification performance of the system is good. When the NH₄⁺-N influent concentration is greater than 59.52mg/L, the TN removal rate drops to 74.26%. Due to the large ammonia nitrogen concentration in the system at

this time, the influent COD is relatively insufficient, the growth of heterotrophic denitrifying bacteria is limited, and a large amount of nitrate nitrogen cannot be used and converted into nitrogen gas to be discharged from the reactor, and the denitrification performance of the system is reduced.

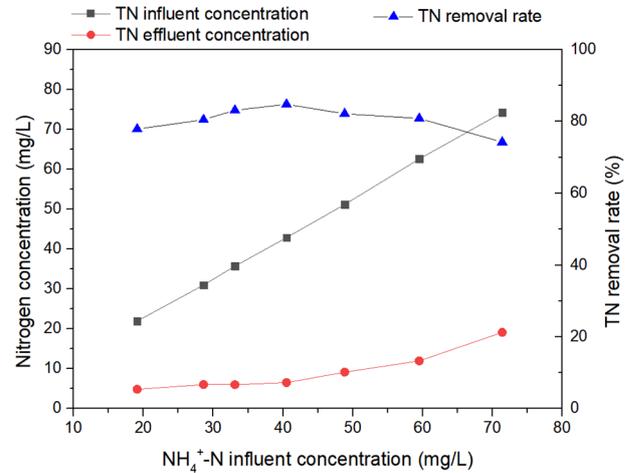


Fig4. Effect of NH₄⁺-N influent concentration change on TN removal effect

It can be seen from Figure 5 that the nitrogen form of the effluent is mainly nitrate nitrogen. As the concentration of NH₄⁺-N influent increases, the concentration of ammonia nitrogen in the effluent has been low. The concentration of effluent is in the range of 0.35mg/L-3.19mg/L, and ammonia nitrogen is removed. The rate is between 94.64% and 99.16%, indicating that the nitrification process in the system is proceeding well. When the influent NH₄⁺-N concentration is large, the ammonia nitrogen removal rate drops slightly. The concentration of nitrite nitrogen in the effluent of the system is 0.31 mg/L~2.48 mg/L. When NH₄⁺-N concentration is large, the amount of dissolved oxygen in the system is not enough to completely convert nitrite nitrogen into nitrate nitrogen. Nitrate nitrogen has increased. The concentration of nitrate nitrogen in effluent rose from 4.11mg/L to 6.31mg/L. The analysis suggests that as the volumetric load of ammonia nitrogen in the system increases, the amount of carbon source in the reactor becomes relatively insufficient, resulting in the weakening of the inhibitory effect of heterotrophic bacteria on nitrifying bacteria, increasing the reproduction of nitrifying bacteria to form a dominant population [8], and increasing the speed of nitrification. The ammonia nitrogen is effectively removed and converted into a large amount of nitrate nitrogen. However, as the concentration of influent NH₄⁺-N increases, the lack of carbon source reduces the growth and reproduction speed of denitrifying bacteria, and the nitrification reaction needs to consume the alkalinity in the system, thereby further inhibiting the progress of the denitrification reaction. A large amount of nitrate nitrogen generated by the nitrification reaction is not converted, which leads to an increase in the concentration of nitrate nitrogen in the effluent.

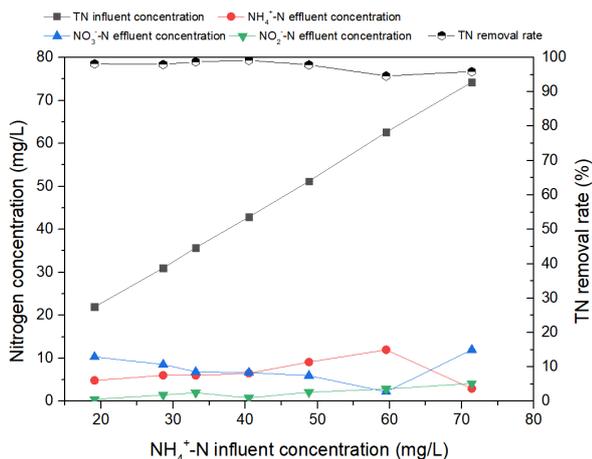


Fig5. Effect of NH₄⁺-N influent concentration changes on various types of nitrogen changes

4 Conclusions

The temperature change has a significant influence on the processing effect of the luffa cylindrical sponge carrier sequencing batch biofilm reactor. When the control temperature range is 20°C ~ 30°C, the system achieves a good treatment effect and when the temperature is 30°C, the removal rate of TN is 82.25%, and the concentration of TN in the effluent is 12.46mg/L. Under the premise that the NH₄⁺-N influent concentration is not high, the change of NH₄⁺-N influent affects the denitrification performance of the SBBR system to a certain extent. When the NH₄⁺-N concentration is 40.50mg/L, the SBBR system has the best treatment effect. In addition, as a natural and cheap biological carrier, luffa fillers have a faster film-hanging speed, a better nitrogen removal treatment effect, and have good development prospects.

Acknowledgments

This research was funded by the China National Critical Project for Science and Technology on Water Pollution Prevention and Control (2018ZX07601001), and thank you for the help of all the teachers and students on the paper.

References

1. Xue Jun, RenZhaoning. Suspended Filler SBBR Treatment of Low C/N Ratio Study on Nitrogen Removal of Domestic Sewage [J]. Environmental Science & Technology,2015,38 (S1):153-156.
2. Qin L,Liu Y. Aerobic granulation for organic carbon andnitrogen removal in alternating aerobic-anaerobic sequencingbatch reactor[J]. Chemosphere, 2006, 63(6):926 – 933 .
3. Matos M, Alves C, Campos J L, et al. Sequencing batch biofilm reactor: from support design to reactor operation. [J]. Environmental Technology, 2011,32(9-10).
4. Tang Kaifeng, WangHua, ZhaoLejun. Application of

SBBR with Filled Suspended InUpgrading of a Wastewater Treatment Plant [J]. China Water &Wastewater.2018,34(12):90-94

5. Kong Lingwei, Wang Lu, He Feng,et al.Research on the interface coupling modification of water treatment used luffa sponge [J]. Technology of WaterTreatment, 2014,40(05):73-78.
6. LingZongyong, Zhang Liqiu, Dong Jiaju. Effect of Temperature on Simultaneous Nitrification and Denitrification via Nitrite in Sequencing Batch Biofilm Reactor[J]. China Water & Wastewater. 2009,25(13):27-30.
7. HuGuoshan, ZhangJianmei, CaiHuijun. Effect of Carbon Source,C/N Ratio and Temperature on Biological Denitrification Process [J]. Science Technology and Engineering,2016,16(14): 74-77.
8. Zhang Liang,Zhang Shujun,Peng Yongzhen.Study on the influence of free ammonia on the inhibition of nitrification in sewage treatment[J].Journal of Harbin Institute of Technology,2012,02:75-79.