E3S Web of Conferences **218**, 03027 (2020) https://doi.org/10.1051/e3sconf/202021803027
ISEESE 2020

Experimental research on the treatment of low C/N wastewater by SBBR-UASB combined process

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Abstract. The research takes low C/N ratio and high ammonia nitrogen sewage as the treatment object, connects the SBBR reactor and UASB reactor after stable operation in series, and studies the PN-ANAMMOX coupling mechanism. The research analyze the effect of the influencing factors of the nitrification process on the subsequent anaerobic ammonia oxidation stage. The two stages adapt to each other that constantly debug and run. The research investigate its denitrification effect, analyze the biological denitrification mechanism and determine the optimal working conditions.

1 Introduction

The characteristics of high ammonia nitrogen content, high COD_{Cr} content but low C/N are currently one of the hot issues in sewage treatment at home and abroad[1]. After anaerobic treatment, organic matter is generally effectively removed, but the effluent ammonia nitrogen content is still relatively high, and the effluent water quality is not ideal, and most of them are still low C/N wastewater. When the traditional process treats high ammonia nitrogen and low C/N wastewater, additional organic carbon sources need to be added, resulting in a large amount of sludge, and the treatment project is likely to cause secondary pollution, which does not conform to the concept of sustainable wastewater treatment in my country[2]. The population of new denitrification microorganisms and the denitrification mechanism have been revealed, and some new denitrification and phosphorus removal processes have been revealed to the world. Partial nitrosation-anaerobic ammonia oxidation process cultivates domesticated AOB and AnAOB in two independent reactors. Firstly, 53% of $NH4^+$-N is oxidized to $NO2^-$-N through AOB, and then the device is connected in series, and the remaining $NH4^+$-N is continuously reacted with NO_2^--N to generate N_2 in the ANAMMOX reactor. Compared with the traditional biological denitrification treatment process, the aeration capacity of this process is greatly reduced, no additional carbon source is added, sludge expansion is avoided, and COD and TN are removed separately.

2 Materials and Methods

2.1 Experimental equipment

2.1.1 System experiment device

The test instruments involved in this test include air compressors, ultraviolet-visible spectrophotometers, temperature controllers, electric heating constant temperature blast drying oven, AC contactors and heating rods. This experiment uses two sets of SBBR and UASB reactors, which are numbered R1, R2, R3, R4 in sequence, to carry out the experimental study of the combined process. The combined system is composed of SBBR and UASB reactors connected in series. Part of the nitrosated effluent will be directly used as the feed water for the anaerobic ammonia oxidation reaction. R1 and R3 are connected in series, and R2 and R4 are connected in series to form two combined processes. Investigate its mutual adaptability debugging operation, and deal with actual domestic sewage. SBBR reactor, UASB reactor and PN/ANAMMOX system are shown in Figure 1, Figure 2 and Figure 3.

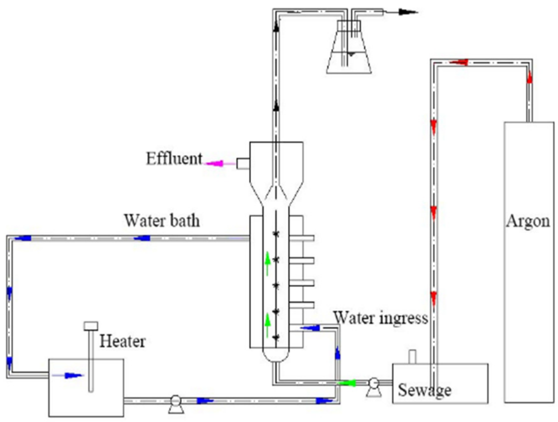

Fig1. Device diagram of SBBR reactor

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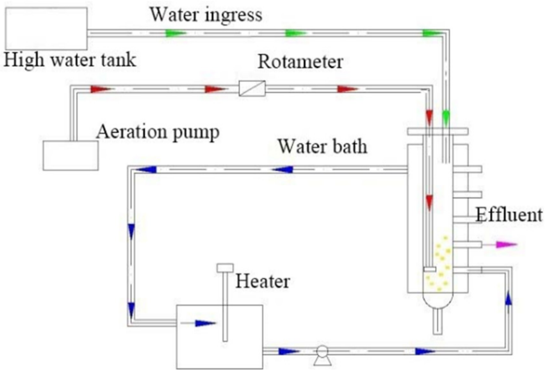

Fig2. Device diagram of UASB reactor

Fig3. Device diagram of SBBR-UASB reactor

Both the SBBR reactor and the UASB reactor are composed of double-layer cylindrical organic glass. The parameters of SBBR reactor and UASB reactor are shown in Table 1 and Table 2.

Table 1. SBBR reactor device parameters

Height/cm	90	Mud bucket diameter/cm	8
Outer diameter/cm	20	Mud bucket height/cm	5
Inner diameter/cm	15	Sampling port/piece	5
Total volume/L	10	Effective volume/L	9

Table 2. UASB reactor device parameters

Height/cm	60	Mud bucket diameter/cm	8
Precipitation zone diameter/cm	15	Reaction zone diameter /cm	8
Precipitation zone height/cm	40	Reaction zone height/cm	60
Total volume/L	9	Effective volume/L	7

2.1.2 Test water and inoculation sludge

Treat artificially simulated wastewater with low C/N ratio and high ammonia nitrogen in the SBBR process and the UASB process, achieve the domestication and enrichment of AOB and AnAOB. The experiment wastewater quality indicators are shown in Table 3 and Table 4.

Table 3. Experiment wastewater quality of the SBBR

Substance	Concentration /mg·L^{-1}	Substance	Concentration/ mg·L^{-1}
NH_4Cl	ND*	$CaCl_2·2H_2O$	200
$NaHCO_3$	ND*	KH_2PO_4	40
COD_{cr}	ND*	$MgSO_4·7H_2O$	30
Trace element solution	0.3 mL·L^{-1}	$NaClO_3$	ND*

Table 4. Experiment wastewater quality of the UASB

Substance	Concentration /mg·L^{-1}	Substance	Concentration/ mg·L^{-1}
NH_4Cl	ND*	$CaCl_2·2H_2O$	136
$NaHCO_3$	ND*	KH_2PO_4	30
COD_{cr}	-	$MgSO_4·7H_2O$	300
$NaNO_2$	ND*	Trace element solution	1mL·L^{-1}

R1, R2, R3, and R4 are all inoculated with 2L sludge. The physical and chemical properties of inoculated sludge are as follows. First, physical and chemical characteristics of sludge inoculated in SBR reactor are loose structure and dark brown. MLSS is 0.5361g·L^{-1}, SVI is 110mL·g^{-1}. Moisture content is more than 99%.The proportion is 1.002.Second,physical and chemical characteristics of sludge inoculated in UASB reactor are yellowish brown and flocculent. MLSS is 0.5122g·L^{-1}, MLVSS is 0.4046g·L^{-1}, MLVSS/MLSS is 0.79, pH is 6.8.

2.2 Test method and analysis method

(1) The effluent from R1 is sent to the inlet tank of R3, and the effluent from R2 is sent to the inlet tank of R4 for continuous operation of the partial nitrosation-anaerobic ammonia oxidation process.

(2) By adjusting the various influencing factors of the nitrification process, such as the effect of the optimal DO amount of nitrosation on the anaerobic ammonia oxidation stage, the water quality is observed, and the two are adapted to each other and continuously debugged. After the system runs stably, the water quality is detected and the denitrification mechanism is analyzed.

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2.3 Start-up of the reactor

2.3.1 Start of SBBR nitrosation reaction

The inoculation sludge adopts the sludge from the secondary settling tank of the sewage treatment plant. In a low oxygen and low matrix environment, the reactor is started by adding $NaClO_3$ inhibitor and traditional starting. Through electron microscopy, it is found that the polyurethane sponge bio-filler used is rich in microorganisms and possesses extremely rich biological phases.

2.3.2 Start of UASB anaerobic ammonia oxidation reaction

The inoculation sludge adopts anaerobic digestion sludge, the environmental temperature is controlled at 30℃, and the pH value is controlled between 7.5 and 8.0 to ensure that the concentration of influent NH_4^+-N and NO_2^--N is 50mg·L^{-1} and 66mg·L^{-1}. The HRT was set to 48h at the beginning, and gradually increased to 12h after a period of reaction time. After reaching 112h, the ANAMMOX reactor started successfully. The inoculated sludge changed from the initial dark brown flocculent to reddish-brown fine granule, and the Gram staining result was negative. At this time, AnAOB was enriched in the reactor.

3 Results & Discussion

The SBBR partial nitrosation reactor and UASB anaerobic ammonia oxidation reactor are coupled in series for the research purpose. First, the partial nitrosation that matches the anaerobic ammonia oxidation is realized in the SBBR reactor, that is, $\rho(NO_2^-\text{-N})_{out}/\rho(NH_4^+\text{-N})_{out}$ is about 1.32, and then the effluent of the SBBR reactor is used as the inlet of the UASB reactor. Water, under the action of AnAOB, simultaneously removes NH_4^+-N and NO_2^--N, and finally converts to N_2 and a small amount of NO_3^--N to realize the effective removal of nitrogen. The operating conditions of the SBBR partial nitrosation reactor are set as: water inlet (instantaneous)-aeration (195min) - precipitation (165min)-drainage (instantaneous)-idle (120min), the temperature is controlled at about 30℃, and the pH value is 7.5~8.0, using continuous aeration mode, adjust the gas flow meter to make the DO concentration 1.0mg·L^{-1}, the dosing concentration of $NaClO_3$ 1.0mol·L^{-1}. The operating conditions of the UASB anaerobic ammonia oxidation reactor are that the temperature is controlled at about 30°C and the HRT is 12h.

3.1 Adaptive debugging of the combined process

Considering that the operation mode of SBBR reactor R1 is batch mode, while the operation mode of UASB reactor R2 is continuous, if the two are directly connected, a small amount of nitrosated sludge may flow out and enter the UASB reaction during the drainage stage of the SBBR reactor. The device affects the activity of AnAOB. In addition, the effluent flow rate will increase significantly during the drainage stage, impacting the reactor and destabilizing microorganisms. Therefore, a bucket is added between the SBBR reactor and the UASB reactor, and the effluent of the SBBR reactor is pumped into the UASB reactor by a constant flow peristaltic pump after precipitation. From this we can see that the bucket not only plays the role of a settling tank, but also as a regulating tank to control water quality and quantity during the experiment.

3.2 Research on denitrification performance of combined process

The test water is artificially configured to simulate wastewater, in which the concentration of NH_4^+-N is 250mg·L^{-1} and the concentration of COD_{Cr} is 150mg·L^{-1}. The system has been running continuously for 35 days, sampling regularly every day to check the influent NH_4^+-N concentration, influent COD_{Cr} concentration and final effluent NH_4^+-N concentration, effluent NO_2^--N concentration, effluent NO_3^--N concentration and effluent COD_{Cr} concentration. Treatment effect of low C/N high ammonia nitrogen wastewater. The test results are shown in Figure 4 and Figure 5.

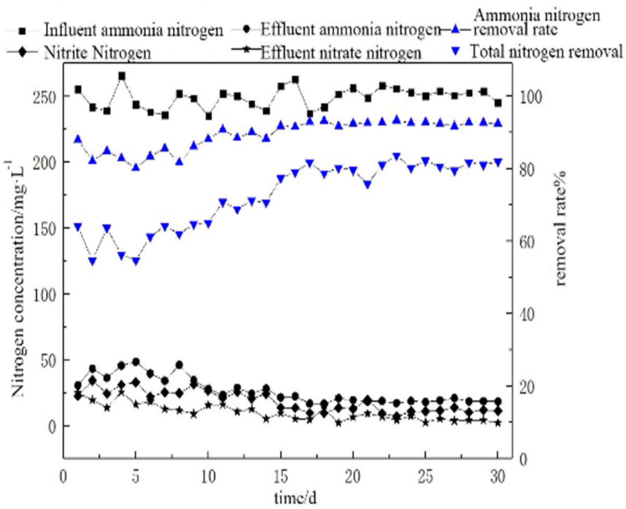

Fig4. Nitrogen removal during combined process operation

It can be seen from Figure 4 that in the initial stage of operation of the combined process, the removal effect of NH_4^+-N is better, but the removal effect of TN is not good. The analysis found that the average removal rate of TN in the first 6 days of the system was only 59.10%. It is speculated that AnAOB was suppressed to a certain extent because the UASB influent was not deoxidized. Therefore, starting from the 7th day, adjust the gas flowmeter of the SBBR reactor to reduce the aeration rate to 0.3L/min, thereby reducing the DO concentration in the SBBR effluent. The denitrification performance of the system is steadily improved within 7 to 15 days, and the TN removal rate increases from 64.15% to 77.38%. The NH_4^+-N removal gradually stabilizes at this stage, the average removal rate is 87.85%. The average concentration of effluent NH_4^+-N, the average concentration of effluent NO_2^--N and NO_3^--N in effluent are 29.85 mg·L^{-1}, 23.6 mg·L^{-1} and 11.45 mg·L^{-1}, respectively.In the middle and late stages of the test, the system runs efficiently and stably.

The average removal rates of NH_4^+-N and TN at this stage are 92.48% and 80.26%, respectively. The nitrogen concentration of various types of effluents is relatively low. The average concentration of NO_2^--N in the effluent and the average concentration of NO_3^--N in the effluent were 18.96mg·L^{-1}, 11.81mg·L^{-1} and 5.72 mg·L^{-1}. It can be seen that the combined process has higher nitrogen removal performance.

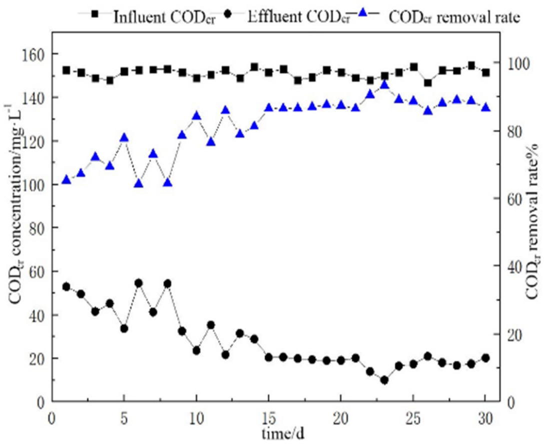

Fig5. COD_{Cr} removal during combined process operation

It can be seen from Figure 5 that after an adaptation period, the combined process has a good removal effect on COD_{Cr}. Similar to the nitrogen removal rule, the COD_{Cr} removal rate in the early stage of the test was average. The average COD_{Cr} concentration of the effluent in the first 5 days was 44.64mg·L^{-1}. The aeration rate in the SBBR reactor decreased from the 7th day, and the COD_{Cr} concentration of the effluent fluctuated significantly after 8 days. After time adaptation, it recovered to 20.38mg·L^{-1}, at this time the COD_{Cr} removal rate was 86.56% . The system was operating stably in the middle and late stages of the test, the average concentration of COD_{Cr} in the effluent was only 17.95 mg·L^{-1}, the corresponding average removal rate at this time had got 88.12%, the treatment effect was good at the same time. The test results show that the SBBR-UASB combined process after adaptive debugging can effectively treat C/N wastewater. G. Anjali[3] et al. used SHARON-ANAMMOX process to treat landfill leachate and found that the TN removal rate was between 85% and 87%.

4 Conclusions

(1) Refer to the stable operating parameters of the two single-stage processes respectively, and add a bucket between the SBBR reactor and the UASB reactor, which can be used as a sedimentation tank or a regulating tank. After adaptive debugging, the two reactors can be adjusted Coupled in series. In addition, AOB and AnAOB have been enriched in the two reactors, which provides a guarantee for the stable operation of the subsequent combined process.

(2) Using artificially configured low-C/N simulated wastewater as the research object to explore the feasibility of the combined process, the bacteria in the two reactors quickly recovered after a short adaptation period, NH_4^+-N and TN were removed during stable operation. The rates were 92.48% and 80.26%, and the average removal rate of COD_{Cr} was 88.12%. It shows that the SBBR-UASB combined process can effectively remove ammonia nitrogen and organic matter.

Part of the nitrosation-anaerobic ammonia oxidation process plays an important role that the essential advantages of not requiring an external carbon source, low sludge production and saving aeration energy consumption when treating low-C/N wastewater. It is favored by many domestic and foreign scholars and has a very high application value and application prospects have gradually become the research hotspot of biological nitrogen removal [4].

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.

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