Activated Carbon Promotes Sulfide to Promote Short-range Nitrification and Denitrification Sludge Granulation

Rui Zhang^{1,2}; Jingyu Li¹; Yanhui Liu^{1,2}; Guangping Wu¹; Xianqiu Li¹; Yanqing Yang¹; Jing Wang^{*1,2}

¹Yunnan Agricultural University, Kunming, 650201, China

²Yunnan Key Laboratory of Water Security, Conservation and Sewage Reduction in Urban and Rural Area, Kunming, 650201, China

*Corresponding author: Jing Wang

Abstract: This article analyzes the factors affecting the nitrification and denitrification sludge granulation, including carbon source abundance, environmental pH, electron acceptors, SRT conditions, reaction temperature, etc. In this paper, the content of impurities in sewage is clarified, and the entire treatment process, COD removal, sludge denitrification and sedimentation, and sludge formation process analysis are analyzed. The purpose is to improve the application value of activated carbon and improve the treatment effect of sewage.

1 Introduction

Granular sludge can effectively improve the processing capacity of the system due to its good structure compactness, strong biological ability, impact load resistance and resistance to complex environments. However, using the traditional granular sludge process, by inoculating different types of nitrified granular sludge into short-range nitrification and denitrification granular sludge, a complete and long start-up process is still required. In this study, the introduction of granular activated carbon provides a platform for sulfide to promote short-range nitrification and denitrification bacteria, and granulate the domesticated mature sludge to form biological granular activated carbon. Under the condition of low C/N sewage, observe the long-term operation and study the effect of the addition of granular activated carbon on the efficiency of sulfide to promote short-range nitrification and denitrification and the mechanism of flocculated sludge granulation.

2 Factors Affecting the Granulation of Nitrification and Denitrification Sludge

2.1 Carbon Source Richness

The carbon source is a nutrient necessary for the growth of microorganisms. In the process of sewage treatment, microbial phosphorus release, denitrification and normal metabolism of heterotrophic bacteria will consume a large amount of carbon source. Different types of carbon sources have a great influence on the efficiency and amount of denitrifying phosphorus accumulating bacteria. When volatile fatty acids (VFA) are used as the carbon source, the effect of system nitrogen and sulfur removal

is better than other carbon sources. The main reason for this kind of situation is that when the microorganism is in the anaerobic stage, the microorganism will absorb the VFA and produce the secondary product poly-β-hydroxybutyric acid (hereinafter referred to as PHB), the content of the substance in the microorganism or cell. The more in metabolic activities, the faster the rate of product formation. Combined with previous experimental data, we can find that if glucose is used as a carbon source, its stability is relatively low. Therefore, we can choose propionate as the carbon source, under this condition, the removal efficiency of sulfide can reach 90.35%, and the proportion of denitrifying sulfur removal bacteria in the stable period, the mass fraction will also exceed 40.5%. We can also choose propionate as the nitrogen source to improve the orderliness of the entire reaction process.

2.2 Environmental pH

In different links of denitrification and desulfurization processes, the pH of the reaction environment has always been one of the more influential factors. However, for microorganisms and desulfurization bacteria, different pH levels have different effects on cell membrane permeability, which also affects the bacteria's absorption of nutrients. After exceeding a certain value, the enzymes that we can use to decompose nutrients will deteriorate, thus affecting the smooth progress of the entire processing activity. In the specific analysis process, we can use the formula to show the relationship between the pH and the potential difference between the inside and outside of the cell membrane, that is, $F_{pm} = \Delta\phi + KRT(A1-A2)$, where F_{pm} represents the proton driving force (that is, the amount of organic matter transported per unit time); $\Delta\phi$ represents the potential difference between the inside and outside of the cell membrane; K represents the

reaction constant, which can be selected in combination with the actual reaction; R represents the gas constant in an ideal state; T represents the ambient temperature; $A1$ represents the pH within the cell membrane; $A2$ represents the outside of the cell membrane pH. According to the formula, it can be found that when the pH value increases, the potential difference will also increase. At this time, the proton driving force will rise, then more organic matter in the sewage will be decomposed to meet the normal energy supply of metabolic activities. However, after a certain threshold is exceeded, the activity of the enzyme will continue to decrease, and when it reaches the inactive state, it will also affect the progress of the entire reaction process.

2.3 Electron Acceptor

In terms of the influence of the electron acceptor, it can be divided into two aspects: nitrate influence and nitrite influence. Taking the influence of nitrate as an example, in anoxic environments, nitrate will replace oxygen as a new electron acceptor to ensure the smooth progress of desulfurization activities. However, in an anaerobic environment, nitrate will affect the permeability of the cell membrane and affect the smooth progress of microbial desulfurization. This is because in an anaerobic environment, nitrifying bacteria will preferentially decompose nitrate and then carry out desulfurization activities, which affects the final desulfurization effect. It can be seen that when controlling such situations, we need to reasonably control the oxygen environment and nitrate concentration, so as to ensure the smooth progress of desulfurization activities and improve the sewage treatment effect ^[1].

2.4 SRT Situation

The Chinese name of SRT is sludge age, which refers to the time that microorganisms stay in the reactor from the generation to the discharge of the system. This is also an important reference index for sludge activity evaluation, indicating the current growth of the system under working conditions. If the SRT value is too low, the direct feedback result is that the sludge concentration in the system will decrease rapidly. Therefore, the new flora will be discharged from the system before it starts to multiply, but the concentration of microorganisms in the remaining sludge is low. After a few discharges, its activity and concentration will also decrease rapidly, thereby affecting the negative effects of particulate matter. Therefore, in the process of management and control, in addition to ensuring the SRT value, it is also necessary to do a good job in the control of sludge concentration to ensure the treatment effect of sludge ^[2].

2.5 Temperature Reflex

When microorganisms desulfurize sewage, they mainly rely on the decomposition enzymes in the microorganisms to metabolize pollutants so that they can form harmless secondary products. Decomposing

enzyme is essentially a protein. Protein is more sensitive to temperature. When the temperature increases or decreases, the activity of the decomposition enzyme will also be greatly affected. After exceeding a certain threshold, the decomposition enzyme will also deteriorate and affect the decomposition effect. As for this reason, we need to adjust the temperature of the reaction process according to the actual situation. However, in the actual control process, this factor is relatively difficult, and part of the desulfurization bacteria group is mesophilic bacteria, which will "freeze to death" at room temperature. Therefore, we need to do a good job in the selection of microflora, select the more stable colonies, thereby improving the stability of the colonies ^[3].

3 Correlation Study on Activated Carbon Promoting Sulfide Reaction

3.1 Clarify the Impurity Content in Sewage

The main function of activated carbon in this application is to remove sulfide in sewage. In order to improve the reliability of the activated carbon analysis results, it is usually necessary to use a simulation experiment to quantify the impurity content in the sewage. In the specific experiment, the impurities contained in the sewage are as follows: (1) $\text{NH}_3\text{-N}$ impurities, which is also an important guarantee for out-of-stock activities. In the specific application process, the material used is mainly NH_4Cl , and its concentration is configured in accordance with the test requirements; (2) SO_4^{2-} , which is sulfide in simulated sewage, can be replaced by Na_2SO_4 during the configuration stage. The concentration is combined with the test requirements ^[4]; (3) S^{2-} , which is the sulfide in the simulated sewage, which can be replaced by $\text{Na}_2\text{S}\cdot 9\text{H}_2\text{O}$ in the configuration stage, and its concentration is combined with the test requirements; (4) The carbon source is mainly replaced by glucose, Cl^- is replaced by NaCl solution.

3.2 Sort out the Whole Process

When activated carbon is used for sludge particle treatment, it can be divided into the following two application stages: The first stage is the adaptation stage, which is to give the microorganisms the time to reproduce and the time to stay in the water, which is generally controlled at about 12h. At the same time, the SBR is set to 6h as a cycle. And in the circulation process, it will be divided into water supply stage (time 10min), effluent stage (time 10min), anoxic treatment stage (time 150min), anaerobic treatment stage (time 150min) and idle stage (time is 40min), run for ten days in this mode. The second stage is the conventional treatment stage. The time spent in the water is generally controlled at about 10 hours. At the same time, the SBR is set to be set to 5h as a cycle period, and in the cycle process will also be divided into the water supply stage (time 10min), the

water stage (time 10min), anoxic treatment stage (time 120min), anaerobic treatment phase (time is 120min), precipitation treatment phase (time is 2min) and idle

phase (time is 40min), run for 60 days in this mode [5].

3.3 COD Removal

Figure 1 COD Removal at the Processing Stage

In the process of desulfurization evaluation, COD removal analysis is an important analysis index. We usually use the test to complete the specific analysis. For the test establishment parameters, please refer to the contents in chapters 2.1 and 2.2. After configuring the mixed solution 100ml, after the adaptation stage and the conventional processing stage, the data information shown in Figure 1 is obtained. It can be seen from Figure 1 that from the beginning of treatment to the stage of effluent, the concentration of COD has been in a stable state throughout the process, keeping it within 50 mg/L. Moreover, we can see that most of the COD is completed

in the anaerobic treatment stage, the desulfurization and nitrogen removal effect of this stage is higher, and the concentration of the anaerobic stage will be significantly reduced. At this time, the granular sludge has a matrix transfer limitation, so the microorganisms will produce some inert products during the reaction. However, from the overall situation, the concentration has increased in the anaerobic stage (90%), which is also conducive to the decomposition of some complex organic matter and improve the treatment effect [6].

3.4 Sludge Denitrification

Figure 2 Denitrification of Sludge in the Treatment Stage

During the evaluation of the desulfurization effect, the analysis of sludge denitrification is an important analysis index. Usually, a specific analysis will also be completed with the help of the test. For the parameters of the test, refer to the contents in chapters 2.1 and 2.2. After configuring the mixed solution 100ml, after the adaptation stage and the conventional processing stage, the data information shown in Figure 2 is obtained. According to Figure 2, we can see that at about 50 days, the nitrate concentration in the liquid began to rise, and at the same time, NAR also began to gradually decline. This is also because the increase in microbial activity has accelerated the conversion ability of nitrogen and ammonia. In addition, the nitrosation capacity is also rapidly improved in this process, which improves the application performance of the organic nitrogen source, and the system's nitrogen removal performance is also improved. According to Figure 2, we can see that the TN removal efficiency of this link exceeds 70%, which meets the basic application requirements^[7].

Figure 3 Change of Sludge Volume Index

3.6 Analysis of Sludge Formation Process

For the analysis of the sludge formation process, we also need to complete it with specific tests. The main points of the test are the same as above, and the following test results are obtained. At the initial stage of the reaction, the average particle size of the activated carbon particles was 412.335 μm . After the adaptation phase and the conventional application phase, the average particle size of activated carbon particles began to decrease at a rate of 9.514 μm per day. After 10 days, the average particle size of more than 45% of activated carbon has dropped to 400 μm . At this time, dispersible flocculent sludge with poor settling performance has been formed in the solution. Then the particle size of the sludge began to increase again, indicating that the microorganisms began to adhere and eventually remained in a stable state.

3.5 Sludge Settlement

The analysis of sludge settlement also needs to be completed through experiments. The relevant content of the experiment is the same as above, and finally we can get the test results. As shown in Figure 3, it shows the changes of the frontal sludge volume index (SVI) at different concentrations. According to the feedback graph, it can be seen that there are granular sludge with relatively stable performance in the reaction vessel. And the system also has a strong settling capacity, which also provides a good survival basis for the growth and reproduction of microorganisms, thereby improving the sludge treatment effect. In addition, when the concentration of SO_4^{2-} changes, its settling performance has also been greatly improved. This also indicates that at a suitable concentration, particle sedimentation will enter a new application stage^[8].

4 Conclusion

To sum up, granular activated carbon, as the "initial crystal nucleus", has a positive effect on the sulfide to promote the adsorption and aggregation of short-range nitrification and denitrification sludge, and stimulate the action of microorganisms to secrete more EPS, and successfully achieved granulation on the 21st. Granular activated carbon has good adsorption properties, and has the characteristics of high mechanical strength, easy repeated regeneration, and low cost. After the addition of granular activated carbon, it not only improves the effect of sulfide to promote short-range nitrification and denitrification, but also maintains high stability under high-load conditions. It can be used to treat low C/N municipal sewage and high nitrogen content industrial sewage.

Acknowledgment

Fund:1. Yunnan Applied Basic Research Project (2017FD081)

2. Associated Special Project of Agricultural Basic Research in Yunnan Province (2017FG001-057)

3. Yunnan Provincial Key Laboratory Construction Project Support Project (20163709)

References

1. Liu Hui, Chang Ze, Sun Ning. Experimental study on tailing liquid for desulfurization and denitrification by sulfide-driven short-range nitrification and denitrification granular sludge treatment [J]. Southern Energy Construction, 2020, 7(01): 65-69.
2. Li Dong, Liu Bo, Wang Wenqi, Zhang Jie. Simultaneous short-range nitrification and denitrification phosphorus removal granular sludge process induced by phosphorus removal particles[J]. Environmental Science, 2020, 41(02): 867-875.
3. Chang Pun, Sun Ning, Jiang Ran. Research on activated carbon promoting sulfide to promote granulation of short-range nitrification and denitrification sludge[J]. Environmental Engineering, 2019, 37(08): 12-15+26.
4. Yang Xi, Li Yafeng, Wu Li, Yang Jigang, Li Qianqian, Chen Jinnan. Research on the cultivation, characteristics and activity restoration of denitrifying phosphorus-accumulating bacteria granular sludge[J]. Environmental Pollution and Prevention, 2019, 41(07): 793- 797.
5. Ping Jiapeng. Effect of Cr(VI) on denitrifying granular sludge and recovery of its activity[D]. Hebei University of Science and Technology, 2018.
6. Niu Wenyu. Research on the rapid cultivation of denitrifying granular sludge and its characteristics using fluctuating operation strategy [D]. Hebei University of Science and Technology, 2018.
7. Chen Yue, Guo Liang, Sun Mei. Denitrifying effluent treatment effect of aerobic granular sludge on carbon source of sludge[J]. Journal of Ocean University of China (Natural Science Edition), 2017, 47(09): 104 -109.
8. Zhou Feng, Wang Fanfan, Qian Feiyue, Huang Huimin, Shen Yaoliang, Zhou Jianmin. Effect of nano-zero-valent iron on the denitrification performance of upflow granular sludge bed[J]. Environmental Science, 2018, 39(01): 263-268.