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Review on the Development of New Technology of Biological Nitrogen Removal from Sewage

Xiangtian Man[1, 2], Hua Lin[1, 2, *], Jian Sun[1, 2]

[1]Guangxi Key Laboratory of Environmental Pollution Control Theory and Technology, Guilin University of Technology, Guilin, China
[2]Collaborative Innovation Center for Water Pollution Control and Water Safety in Karst Area, Guilin University of Technology, Guilin, China

Email address:

1473084901@qq.com (Xiangtian Man), linhua5894@163.com (Hua Lin), 506972441@qq.com (Jian Sun)
[*]Corresponding author

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Abstract: With the improvement of water treatment technology, the biological nitrogen removal of sewage has also made a great progress. Research economic and efficient denitrification technology has become the hot issues of domestic and foreign scholars. During the long-term operation of wastewater treatment, the differences in physiological and biochemical characteristics of traditional denitrification technologies make various functional microflora interact with each other in the same system, which restricts the efficiency and stability of the process. Therefore, some new treatment technologies emerge. This review introduces the new technology and its development direction of biological nitrogen removal in recent years from two aspects: New technology of the original technology improvement and combination and new technology based on the principle of development, engineering examples in the wastewater treatment industry are enumerated.

Keywords: Sewage, Biological Denitrification, New Technology, Engineering Application

1. Introduction

Water resources is an indispensable natural resource for human production and life, and it is one of the important factors of ecological environment. Nitrogen and phosphorus are important sources of nutrients. With the widespread use of chemical fertilizers and pesticides, the nitrogen and phosphorus contents in natural water bodies increase sharply, which makes the eutrophication of water become more harmful to aquatic organisms and human health. A large number of wastewater containing various forms of nitrogen and phosphorus are produced in our country every year, which can also lead to the eutrophication and the deterioration of water quality. "12th Five-Year" pollutant emission reduction to the ammonia nitrogen index requirements [1], so in the strengthening of operation and management and local facilities at the same time, sewage nitrogen and phosphorus removal technology from simple technological innovation to biological research, process reform direction to achieve high energy and low consumption of the treatment. Controlling the total nitrogen in the tailrace water is crucial importance for solving the surface water pollution. Because of the low C/N ratio of the tail water in the wastewater treatment plant, it is unfavorable for further biological denitrification treatment [2]. With the improvement of the sewage discharge standard, It is more difficult and costly for the treatment plant to remove total nitrogen, so it is imperative to study and analyze the feasible new denitrification process. Controlling the total nitrogen in the tailrace water is crucial importance for solving the surface water pollution. Because of the low C / N ratio of the tail water in the wastewater treatment plant, it is unfavorable for further biological denitrification treatment. With the improvement of the sewage discharge standard, It is more difficult and costly for the treatment plant to remove total nitrogen, so it is imperative to study and analyze the feasible new denitrification process. This work focuses on the simultaneous use of organic carbon source in the raw water to synchronously remove nitrogen and phosphorus, such as Step Feed [3], many scholars at home and abroad have made in-depth studies from the initial mathematical model simulation [4], process control [5—6] to the process design parameters and the influencing factors of operation, and made some progress [7—9]. Biological treatment process to

strengthen the effective regulation of biofilms, by enumerating the actual application of the project, to provide technical support for the selection of sewage treatment plant nitrogen removal process.

2. The Development of Biological Nitrogen Removal

With the development of China's sewage treatment business, a variety of sewage treatment technology has been applied in China's sewage treatment plant to Anaerobic-Anoxic-Oxic (A2/O) and its variant process, oxidation ditch, A/O, Sequencing Batch Reactor and its variant process [10]. The new process of biological denitrification should also be combined with the concept of sustainable sewage treatment, as far as possible to reduce CO_2 emissions, to minimize COD oxidation, reduce excess sludge production. In the new process, Well-type AAOO, Multi-sects and Multi-levels AO and Upflow Anoxic / Aerobic Denitrification Process are the use of the existing advantages of the process, the advantages and disadvantages of the development of complementary. The biological denitrification and dephosphorization processes such as Moving Bed Biofilm Reactor, Anaerobic ammonia (nitrogen) oxidation, Aerobic granular sludge + membrane technology are all developed on the basis of breaking the traditional biological nitrogen and phosphorus removal principle.

2.1. New Technology of the Original Technology Improvement and Combination

Now, the removal of nitrogen in wastewater treatment mainly through the biological nitrogen removal process. In the traditional A2/O process, the pretreated wastewater enters the anaerobic reactor to partially decompose the high-COD material in this section and then enters the anoxic section for denitrification process. Finally, the aerobic degradation of organic matter and Nitrification. In order to ensure the efficiency of denitrification, part of the effluent from the aerobic reactor is circulated into the anoxic section through internal circulation and mixed with the effluent from the anaerobic section in order to make full use of the carbon source in the wastewater. The other part of the water into the second settling tank, after the separation of activated sludge effluent, phosphorus sludge back to the anaerobic section to increase the sludge load. With the widespread use of the A2/O process, its problems have also emerged: nitrifying bacteria, denitrifying bacteria and polyphosphate bacteria existed conflicting and competing in carbon demand, sludge loading and sludge age [11]. And the nitrogen removal performance is greatly affected by dissolved oxygen and anoxic-aerobic zoning proportion, starting from the above two points, to promote the A2/O process improvements and variants.

Table 1. *Process Comparison.*

Process name	AO Process	A^2O Process	AAOO Process	SBR Process
Process flow	Anaerobic-Aerobic	Anaerobic-hypoxia-aerobic	Anaerobic -hypoxia-Micro-oxygen-aerobic	Anaerobic, anoxic and aerobic state run alternately
Advantages	1. High efficiency and simple process 2. High degradation efficiency 3. High volume load 4. Strong ability to withstand load	1. High efficiency of pollutant removal 2. Good sludge settling performance, and the removal of organic matter and nitrogen removal 3. No sludge expansion will occur. 4. High phosphorus content in sludge.	1. Small land and high oxygen utilization. 2. Small odor and stable temperature 3. Strong resistance to stability and impact load 4. Not prone to sludge expansion, it can dispose organic wastewater of high concentrations [12]	1. Stable operation and high efficiency 2. Water quality is good, the process can be adjusted according to water quality and quantity 3. Run flexible, simple process and low cost 4. The removal of nitrogen and phosphorus is good
Disadvantages	The degradation efficiency of refractory material is low, and the nitrogen removal rate is difficult to reach 90%	The reaction pond volume is larger than the AO nitrogen removal process, the energy consumption is higher, the methane recovery and utilization economic benefit is poor, the sludge seepage needs chemical phosphorus removal	Nitrogen removal effect is lower, but pre-treatment can be used to improve the efficiency of nitrogen removal.	The intermittent cycle runs, and the requirement of automatic control is high, the water level runs, the electricity consumption increases, the sludge stability is not as good as the anaerobic nitrification
Applicable conditions	Degradation of organic matter, with some nitrogen and phosphorus removal function, suitable for small and medium-sized water plant	The removal of nitrogen and phosphorus is good, and it is suitable for large and medium-sized water plants which need to dephosphor	Suitable For industrial-intensive cities, construction or expansion of the venue is limited areas [13]	Removal of organic matter and nitrogen and phosphorus removal efficiency, less processing equipment. Suitable for small-sized urban waterworks

2.1.1. Well-Type AAOO Process

The well-type AAOO process is a kind of sewage treatment technology which integrates AAOO and deep well aeration technology, which can effectively deal with organic wastewater and other waste water of different nature. Jinan Iron and Steel coking wastewater using AAOO-Fenton oxidation process [14], the effluent indicators can be stable to the national secondary emission standards, ammonia nitrogen indicators can reach the national level discharge standards, but the best medication The amount of the area, remains to be seen.

2.1.2. Multi-sects and Multi-Levels AO Process (AMAO)

The AMAO process is based on innovation based on the proven theory of activated sludge [15]. Multi-sects and Multi-levels AO process is to divide the sewage into the anaerobic zone, anoxic zone, anoxic zone and aerobic zone in the bio-pool, so that the carbon source in the sewage can be selectively supplied to different functional areas, Phosphorus and denitrification denitrification, which can effectively save carbon sources. At the same time can also increase the sludge concentration, reduce the bio-pool volume. Multi-sects AO series can cancel the internal reflow equipment, the upper level of digestive solution completely into the next level of hypoxic zone for denitrification, enhanced denitrification effect, improve the efficiency of denitrification. This process has been widely used in the construction and renovation of multiple sewage treatment projects [15]: Tianjin Chuangshui Water Co., Ltd. Ji Zhuangzi Sewage Treatment Plant Productivity Test (100,000 m^3/d, original process: AAO process) (38 million m^3/d, the original process: AB method); Fuyang Venture Water Co., Ltd. Yingdong sewage treatment plant a project (30,000 m^3 / d, new).

2.1.3. Upflow Anoxic / Aerobic Denitrification Process (UAO)

Peng Yong-zhen et al [16] showed that the appropriate C/N values favored the removal of total nitrogen. Wang Cuiping et al [17] for the traditional AO process to improve the lack of hypoxia full mixing mode mode. In the stable operation phase, the removal rate of COD in AO system and UAO system is high, and the removal of NH_3-N from the two systems is relatively thorough. When the influent water quality fluctuates greatly, UAO The anti-impact ability of the system is stronger and the operation is more stable. The removal rate of TN in UAO process is 12% higher than that of AO process under the same operating conditions, so as to improve the denitrification efficiency of the system. This provides a reference for the upgrading of traditional AO craft wastewater treatment plants.

2.2. New Technology Based on the Principle of Development

In the biological nitrogen removal process, effective regulation of the biofilm growth is the preconditions for the normal operation of many sewage treatment processes. For example, avoid biofilm membrane fouling on the membrane surface, thereby enhancing the reactor effluent efficiency and reduce operating costs, cultivate biofilms with good structural stability and high metabolic activity also can enhance the removal efficiency of pollutants.

2.2.1. Advances in MBBR and IFAS Systems

MBBR process is based on the biofilm technology, suspended in the filler carrier attached to the growth of biofilm instead of activated sludge and the formation of a composite membrane biological wastewater treatment device [18]. At present, the research of MBBR at home and abroad mainly focuses on the activation of the reactor, the influencing factors (organic load, DO content, C / N, HRT, etc.), the choice of carrier and the change of microbial population structure [19-23]. Scientific research in recent years has shown that the formation of biofilms is controlled by the quorum sensing of intercommunication among microorganisms [24], however, it is still difficult to control the membrane fouling by mass quenching in practical projects. Therefore, a new type of IFAS-MBR was designed, which can reduce the concentration of suspended activated sludge mixture and thus reduce the quorum sensing strength. Most of the studies that compare the pure MBBR-MBR and the IFAS-MBR go in the favour of IFAS-MBR [25] and most of the studies that compare the traditional MBR and the IFAS-MBR also go in the favour of IFAS-MBR [26]. The benefit of IFAS is that nitrification can be obtained at less than half of the SRT than what is required in CAS plants [27]. Moreover, at a lower SRT more carbon will be available for denitrification through hydrolysis of the MLSS. Hence the IFAS MBR-system have the potential of becoming a very competitive alternative as own far more compact and cheaper than the conventional MBR. MBR-based IFAS plants may be used for the same application as MBRR, but are limited in the choice of biomass separation method-to settling or membrane separation.

2.2.2. Anaerobic Ammonia (Nitrogen) Oxidation (ANAMMOX)

Anaerobic ammonium oxidation is a new type of biological nitrogen removal technology in the past 20 years, which can be used to treat high concentration ammonia nitrogen wastewater. It's nitrogen removal rate can be as high as 9.5kgN/m^3/d, much higher than the traditional nitrification and denitrification process [28]. ANAMMOX refers to the process of ammonia nitrogen to nitrous oxide as an electron acceptor directly under anaerobic conditions to oxidize to nitrogen. The decomposition reaction is as follows [29-30]:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$$

The Gibbs free energy produced in this reaction is even higher than the energy produced by oxidation (nitrification) of aerobic ammonia (nitrogen), so it can support the growth of autotrophic bacteria. Anaerobic ammonium oxidation with no need to add organic carbon source, low oxygen consumption, low sludge yield, etc., but anaerobic ammonium oxide growth slow, long doubling time, impact resistance is weak, demanding environmental conditions, DO, temperature, PH, organic matter will affect the anaerobic ammonium oxidation process [31]. The optimum temperature for anaerobic ammonium oxidation should be 31°C [32]; suitable pH is 6.7 to 8.3; carbonate / carbon dioxide is the inorganic carbon source required for the growth of ANAMMOX microorganisms. In 2009, China Tongliao Meihua Group built the world's largest anaerobic ammonium oxidation reactor [33]; After several decades of development, anaerobic ammonium oxidation technology has matured, there have been established about 100 anaerobic ammonium oxidation plant But is still limited to the treatment of medium temperature and high ammonia nitrogen wastewater, mainly used for sludge digestion, landfill leachate or food processing digestion treatment [34]; municipal sewage application

ANAMMOX technology is the biggest difficulty is how to achieve short-range nitrification and stability Run [35].

2.2.3. Aerobic Granular Sludge + Membrane Technology (AG-MBR)

Aerobic granular sludge simultaneous nitrogen and phosphorus removal process as a new type of biological treatment technology, has been widely concerned [36]. This technology has successfully realized the process of denitrification and dephosphorization in a single system because of its own structure. It has the advantages of high microbial activity, good solid-liquid separation effect, strong resistance to organic shock load, Chain length and other unique advantages, it has a broad development and application prospects [37-39]. Zhou et al [40] studied the properties of aerobic granular sludge with different particle ages. The results showed that aerosols with small particle age have better organic degradability, higher microbial activity and better stability. When deal with the problem of the northern autumn and winter low temperature sewage by AG-MBR technology, not only the original water quality is good, and granular sludge simultaneously remove organic matter and nitrogen and phosphorus, while this process also has better control of membrane fouling ability.

3. Conclusion

In the future research and development, new process should improve its principles and operating conditions gradually, simplify the operational process, and strive to put forward new theories and develop new technologies. The combination process should optimize the existing technology, main solution to the existing problems, improve the efficiency of nitrogen and phosphorus removal of wastewater; Secondly, the combination process of nitrogen removal should fully consider the structure and area of existing waterworks structures and reconstruct them on the basis. It will be the main goal and direction in the future to develop and apply the sewage treatment technology with reasonable economy, strong function, flexible operation, high automatization and stable operation.

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