Engineering and Technology Journal e-ISSN: 2456-3358

Volume 10 Issue 04 April-2025, Page No.- 4564-4571

DOI: 10.47191/etj/v10i04.24, I.F. – 8.482

Research Progress and Future Trends of Nitrogen and Phosphorus Removal Technologies in Wastewater Treatment Plants

Hanxiao Zhang

College of Resource and Environment, Henan Polytechnic University, Jiaozuo 454003, China

ABSTRACT: This paper focuses on the nitrogen and phosphorus removal technologies in wastewater treatment plants, elaborating on their research progress, development status, and future trends. Currently, traditional technologies are widely used but have limitations, while new technologies are emerging continuously, and combined processes have also developed. However, these technologies face problems such as high costs, poor stability, difficult sludge treatment, and insufficient water quality adaptability. In the future, the nitrogen and phosphorus removal technologies in wastewater treatment plants will develop towards technological innovation and optimization, intelligence and automation, resource recovery and sustainable development, and standardization and regulation construction, aiming to achieve the goals of efficient nitrogen and phosphorus removal, resource recovery, and the sustainable operation of wastewater treatment systems.

KEYWORDS: Wastewater treatment plants; Nitrogen and phosphorus removal technologies; Research progress

1. INTRODUCTION

With the rapid development of urbanization and industrialization, the discharge of wastewater is continuously increasing. If nutrients such as nitrogen and phosphorus in the wastewater are discharged into water bodies without effective treatment, it will trigger serious environmental problems such as eutrophication of water bodies, such as excessive reproduction of algae, deterioration of water quality, and decrease in dissolved oxygen, which pose a threat to the aquatic ecosystem and human health. Therefore, efficient nitrogen and phosphorus removal technologies for wastewater are crucial for environmental protection and sustainable utilization of water resources. This article will elaborate in detail on the research status, progress, development status, and future trends of nitrogen and phosphorus removal technologies in wastewater treatment plants.

2. RESEARCH STATUS AND PROGRESS OF NITROGEN AND PHOSPHORUS REMOVAL TECHNOLOGIES IN WASTEWATER TREATMENT PLANTS

(1) Biological Nitrogen and Phosphorus Removal Technologies

Traditional Biological Nitrogen and Phosphorus Removal Processes Traditional biological nitrogen removal mainly includes two stages: nitrification and denitrification. Nitrification is the process in which ammonia nitrogen is oxidized to nitrite and nitrate by nitrifying bacteria under aerobic conditions. Denitrification is the process in which denitrifying bacteria use organic matter as an electron donor to reduce nitrate and nitrite to nitrogen gas under anoxic conditions, thus achieving the removal of nitrogen. In terms of biological phosphorus removal, phosphorus-accumulating organisms (PAOs) release phosphorus under anaerobic conditions and absorb volatile fatty acids to synthesize polyhydroxyalkanoates (PHA) and store them in cells. Under aerobic conditions, PAOs decompose PHA and use the released energy to take up phosphorus in the wastewater in excess, and achieve phosphorus removal by discharging excess sludge. Common traditional biological nitrogen and phosphorus removal processes include A2/O (anaerobic-anoxic-aerobic) and oxidation ditch. The A2/O process sets up anaerobic, anoxic, and aerobic zones reasonably, allowing the wastewater to flow through these zones in sequence to complete the nitrogen and phosphorus removal process. It has the advantages of a simple process and low operating costs. However, this process has the problem of carbon source competition. When the influent carbon source is insufficient, the nitrogen and phosphorus removal effects restrict each other, and it is difficult to achieve high-efficiency removal simultaneously. The oxidation ditch process has a strong impact load resistance and can achieve nitrogen and phosphorus removal to a certain extent. However, when treating wastewater with a low carbon source, it also faces the problem of low nitrogen and phosphorus removal efficiency.

Simultaneous Nitrification and Denitrification (SND): Simultaneous nitrification and denitrification refers to the simultaneous occurrence of nitrification and denitrification reactions in the same reactor. Its realization mechanism mainly includes two aspects: from the perspective of microorganisms and the environment. From the perspective of microorganisms, there are special microorganisms such as aerobic denitrifying bacteria and heterotrophic nitrifying bacteria, which can carry out denitrification in an aerobic environment or complete the functions of nitrification and denitrification under different dissolved oxygen conditions[1]. From the perspective of the environment, there is a dissolved oxygen concentration gradient in the reactor. For example, in a biofilm reactor, the dissolved oxygen concentration on the surface of the biofilm is high, which is conducive to the nitrification reaction, while the dissolved oxygen concentration inside is low, creating conditions for denitrification. This technology can reduce the amount of carbon source addition, reduce the sludge production, and improve the treatment efficiency. Some studies have shown that when strengthening SND in a sequencing batch biofilm reactor to treat low C/N wastewater, when the simultaneous nitrification and denitrification rate (SND rate) is greater than 97.3%, effective nitrogen removal can still be achieved. However, currently, the SND technology faces challenges in aspects such as sludge morphology and precise control of dissolved oxygen. Biological nitrification and denitrification have different requirements for the oxygen environment, which is likely to lead to the limitation of one of the processes, and the instability of the SND rate affects the removal effect.

Anaerobic Ammonium Oxidation (ANAMMOX): Anaerobic ammonium oxidation is a process in which ammonia nitrogen is directly oxidized to nitrogen gas using nitrite nitrogen as an electron acceptor under anaerobic or anoxic conditions. Its reaction process is unique and does not require organic matter as an electron donor. It has the advantages of high nitrogen removal efficiency, small sludge production, and low energy consumption. Compared with traditional nitrogen removal methods, the nitrogen removal volume load of anaerobic ammonium oxidation is higher, easily reaching 5 $kg/(m^3 \cdot d)$, while the nitrogen removal volume load of traditional nitrogen removal processes is usually less than 0.5 $kg/(m^3 \cdot d)$. However, anaerobic ammonium oxidation bacteria have a slow growth rate, low cell yield, and are sensitive to environmental factors. For example, low temperature, high alkalinity, and the form of organic matter will all inhibit their reaction performance, and an excessively high substrate concentration (nitrite nitrogen and ammonia nitrogen) will instead inhibit the reaction rate. In practical engineering, it is difficult to precisely control these influencing factors, which limits its large-scale application. Currently, research mainly focuses on optimizing the cultivation conditions of anaerobic ammonium oxidation bacteria, improving their adaptability to environmental changes, and coupling with other processes.

Denitrifying Phosphorus Removal: Denitrifying phosphorus-accumulating bacteria (DPB) can use nitrate or nitrite as an electron acceptor under anoxic conditions to simultaneously achieve denitrification and excessive uptake of phosphorus. Compared with traditional biological nitrogen and phosphorus removal processes, denitrifying phosphorus removal can reduce the demand for carbon sources, reduce the aeration volume, and reduce the production of excess sludge. Studies have found that under specific conditions, the denitrifying phosphorus removal system can effectively improve the nitrogen and phosphorus removal efficiency. However, the key to this technology lies in screening and enriching highly efficient denitrifying phosphorus-accumulating bacteria, as well as optimizing the process operation parameters to ensure the stable operation of the denitrifying phosphorus removal process[2]. Currently, the denitrifying phosphorus removal technology still needs further research in aspects such as the regulation of microbial communities and process stability.

Short-cut Nitrification and Denitrification: In the traditional nitrification process, ammonia nitrogen is converted into nitrite and nitrate through the action of ammonia-oxidizing bacteria and nitrite-oxidizing bacteria in sequence. Short-cut nitrification and denitrification is to control the process conditions to make ammonia nitrogen accumulate nitrite in the ammonia oxidation stage and then directly carry out denitrification, shortening the nitrogen removal reaction process. Compared with the traditional process, it can save about 40% of the carbon source. The key to achieving short-cut nitrification and denitrification lies in creating suitable conditions to make ammonia-oxidizing bacteria become the dominant flora and inhibit the growth of nitrite-oxidizing bacteria, such as controlling the appropriate temperature, pH value, dissolved oxygen, and sludge age. However, in practical applications, it is difficult to precisely control the process conditions, and problems such as unstable nitrite accumulation or excessive nitrification are likely to occur, affecting the nitrogen removal effect.

(2) Physicochemical Nitrogen and Phosphorus Removal Technologies

Chemical Precipitation Method

The chemical precipitation method is to add chemical agents to the wastewater, making nitrogen and phosphorus react chemically with certain ions in the agents to form insoluble precipitates, thus achieving the removal of nitrogen and phosphorus. In terms of phosphorus removal, commonly used precipitants include iron salts (such as ferrous sulfate, ferric chloride), aluminum salts (such as aluminum sulfate, polyaluminum chloride), and lime, etc. Iron salts and aluminum salts react with phosphate radicals to form iron phosphate and aluminum phosphate precipitates, while lime reacts with phosphate radicals to form hydroxyapatite precipitates. In terms of nitrogen removal, for wastewater with a high concentration of ammonia nitrogen, the stripping method can be combined with the chemical precipitation method. For example, adding magnesium salts and phosphates to the wastewater can form magnesium ammonium phosphate (struvite) precipitates to achieve the removal of ammonia nitrogen. The chemical precipitation method has the advantages of simple operation, fast reaction speed, and high removal efficiency. However, it has problems such as high reagent costs, large sludge production, and potential secondary pollution. For example, the subsequent treatment and disposal of a large amount of chemical sludge are difficult, and the use of some chemical agents may lead to an increase in the salinity of the water body, affecting the water quality[3].

Adsorption Method

The adsorption method uses the adsorption effect of adsorbents on nitrogen and phosphorus to adsorb nitrogen and phosphorus in the wastewater onto the surface of the adsorbents, thereby achieving the removal purpose. Commonly used adsorbents include activated carbon, zeolite, biochar, metal oxides, etc. Activated carbon has a large specific surface area and rich pore structure, showing good adsorption performance for nitrogen and phosphorus, and has strong adsorption broad-spectrum properties; Zeolite has a special crystal structure and ion exchange performance, and has a high selective adsorption capacity for ammonia nitrogen; Biochar has good stability and regenerability; Metal oxides have strong oxidizing properties and can remove nitrogen and phosphorus through chemical adsorption. The adsorption method has the advantages of low energy consumption, simple operation, and little secondary pollution. However, the adsorption capacity of the adsorbent is limited. After the adsorbent is saturated with adsorption, regeneration treatment is required, and the regeneration cost is high. Moreover, different adsorbents have different adsorption selectivities for different forms of nitrogen and phosphorus, so it is necessary to select a suitable adsorbent according to the quality of the wastewater.

Membrane Separation Technology

Membrane separation technology uses the selective permeation characteristics of the membrane to separate nitrogen and phosphorus from the water phase in the wastewater. Common membrane separation technologies include reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF), etc. Reverse osmosis and nanofiltration can effectively remove dissolved inorganic salts, small molecular organic matters, and some microorganisms in the wastewater, and have a high removal rate for nitrogen and phosphorus; Ultrafiltration and microfiltration are mainly used to remove colloids, suspended solids, and macromolecular organic matters in the wastewater, and have a certain effect on the removal of phosphorus, but have limited ability to remove dissolved nitrogen[4]. Membrane separation technology has the advantages of small floor space, high treatment efficiency, and stable effluent quality. However, it has problems such as high membrane cost, easy pollution, and the need for regular cleaning and replacement. Membrane pollution will lead to a decrease in membrane flux, increase operating costs, and affect the treatment effect. Therefore, the control of membrane pollution and the cleaning and regeneration technology of the membrane are the key research directions for the application of membrane separation technology.

(3) Combined Processes

Due to the certain limitations of a single nitrogen and phosphorus removal technology, in order to improve the nitrogen and phosphorus removal efficiency and meet the increasingly stringent discharge standards, combined processes have been widely studied and applied[5]. Common combined processes include combinations of biological and physicochemical processes, combinations of different biological processes, etc.

Biological and Physicochemical Combined Processes

For example, the combination of biological treatment and chemical precipitation. First, most of the organic matters and part of the nitrogen and phosphorus are removed through biological treatment, and then the remaining nitrogen and phosphorus are further removed by the chemical precipitation method, which can effectively improve the removal rates of total nitrogen and total phosphorus, and can reduce the amount of chemical agents used, and lower the sludge production and treatment costs. The combination of biological treatment and adsorption uses adsorbents to deeply adsorb the residual nitrogen and phosphorus in the effluent of biological treatment to improve the effluent quality. For example, combining activated carbon adsorption with the biological treatment process can effectively remove trace organic pollutants and nitrogen and phosphorus in the wastewater. The combination of biological treatment and membrane separation, that is, the membrane bioreactor (MBR), combines biological treatment with membrane separation technology. Using the high-efficiency interception effect of the membrane, microorganisms are completely retained in the reactor, increasing the sludge concentration and biomass, thereby enhancing the nitrogen and phosphorus removal effects, and at the same time, high-quality effluent can be obtained. However, the MBR process has problems such as serious membrane pollution and high operating costs, and effective membrane pollution control measures need to be taken.

Combinations of Different Biological Processes

For example, combining the anaerobic ammonium oxidation process with the traditional nitrification and denitrification process. The anaerobic ammonium oxidation process is used to treat wastewater with a high concentration of ammonia nitrogen, and then the effluent of anaerobic ammonium oxidation is further treated by the traditional nitrification and denitrification process, which can improve the overall nitrogen removal efficiency and reduce energy consumption and operating costs. Combining the simultaneous nitrification and denitrification process with the denitrifying phosphorus removal process gives full play to the advantages of the two processes to achieve the efficient synergistic removal of nitrogen and phosphorus. For combinations of different biological processes, it is necessary to rationally design the process flow and operating parameters according to the characteristics of the wastewater quality and treatment requirements to ensure the synergistic effect of each process link and improve the treatment effect.

3 DEVELOPMENT STATUS OF NITROGEN AND PHOSPHORUS REMOVAL TECHNOLOGIES IN WASTEWATER TREATMENT PLANTS

(1) Application Status

Globally, traditional biological nitrogen and phosphorus removal processes (such as A2/O, oxidation ditch, etc.) and physicochemical processes like the chemical precipitation method are still the most widely applied nitrogen and phosphorus removal technologies in wastewater treatment plants. After long-term practice, these technologies have relatively mature processes and rich experience in operation and management. However, with the continuous improvement of the requirements for effluent water quality, especially in some regions with strict requirements for water environment quality, the application of new biological nitrogen and phosphorus removal technologies (such as simultaneous nitrification and denitrification, anaerobic ammonium oxidation, denitrifying phosphorus removal, short-cut nitrification and denitrification) and combined processes is gradually increasing. For example, in some European countries, the anaerobic ammonium oxidation technology has been successfully applied in some wastewater treatment plants, achieving efficient and energy-saving nitrogen removal treatment. In China, with the implementation of environmental protection policies such as the "Water Ten Articles", many wastewater treatment plants face the demand for upgrading and reconstruction. More and more wastewater treatment plants are beginning to try to adopt new technologies and combined processes to improve their nitrogen and phosphorus removal capabilities and meet stricter discharge standards. However, overall, the application proportion of new technologies and combined processes is still relatively low. The main reasons include higher technical costs, the need to improve operation stability, and a shortage of professional technical talents[6].

(2) Challenges Faced

Cost Issues

Whether it is new biological nitrogen and phosphorus removal technologies or combined processes, their construction and operation costs are usually high. New biological nitrogen and phosphorus removal technologies such as anaerobic ammonium oxidation require special equipment and precise control due to the harsh requirements for reaction conditions, resulting in large construction investments. During the operation process, in order to maintain suitable reaction conditions, costs such as energy consumption and reagent consumption are also high. Combined processes, due to the integration of multiple technologies, have relatively high costs for equipment procurement, installation and commissioning, as well as operation and management. The high costs limit the promotion and application of these technologies in some economically underdeveloped regions or small wastewater treatment plants[7].

Technical Stability

The stability of some new biological nitrogen and phosphorus removal technologies needs to be further improved. For example, anaerobic ammonium oxidation bacteria are sensitive to environmental changes. During the actual operation of wastewater treatment plants, fluctuations in water quality and quantity, and changes in environmental conditions such as temperature and pH value may all lead to a decrease in the reaction performance of anaerobic ammonium oxidation, and even cause the reactor to collapse. In the simultaneous nitrification and denitrification technology, it is difficult to precisely control the dissolved oxygen, and it is easy to have incomplete nitrification or denitrification, affecting the nitrogen removal effect. The insufficient technical stability increases the difficulty and risk of the operation and management of wastewater treatment plants, and it is necessary to further strengthen technical research and development and optimization to improve the reliability and adaptability of the technology.

Sludge Treatment and Disposal

With the application of nitrogen and phosphorus removal technologies, the properties and output of the generated sludge have also changed, bringing new challenges to sludge treatment and disposal. For example, using the chemical precipitation method for phosphorus removal will produce a large amount of chemical sludge, which has a complex composition and contains heavy metals and residues of chemical agents, making subsequent treatment and disposal difficult. The sludge generated by some new biological nitrogen and phosphorus removal processes has a different microbial composition and metabolic products from traditional processes, which affects the treatment processes such as anaerobic digestion and dewatering of the sludge, and corresponding sludge treatment technologies and processes need to be developed.

Adaptability to Water Quality Changes

The quality of wastewater is complex and changeable, and the contents, forms of nitrogen and phosphorus, as well as the components of organic matters in the wastewater generated by different regions and industries vary greatly. The existing nitrogen and phosphorus removal technologies are often designed and optimized for specific water quality conditions, and have insufficient adaptability to water quality changes. When there are large fluctuations in the water quality of wastewater, the treatment effect may be significantly affected. For example, wastewater with a low carbon source poses a challenge to the carbon source supply of biological nitrogen and phosphorus removal technologies, and traditional processes are difficult to meet the treatment requirements, so targeted enhanced nitrogen and phosphorus removal technologies need to be developed. Therefore, how to improve the adaptability of technologies to different water quality changes is an important issue facing the development of nitrogen and phosphorus removal technologies in wastewater treatment plants.

4. FUTURE TRENDS OF NITROGEN AND PHOSPHORUS REMOVAL TECHNOLOGIES IN WASTEWATER TREATMENT PLANTS

Innovation in Microbial Technologies

Conduct in-depth research on the metabolic mechanisms and functions of microorganisms. Through technical means such as genetic engineering and synthetic biology, carry out directional transformation and optimization of microorganisms, and cultivate highly efficient and stable nitrogen and phosphorus removal microbial strains. For example, construct genetically engineered bacteria with stronger impact load resistance and higher nitrogen and phosphorus removal efficiency, or screen and enrich native microbial communities that are adapted to specific wastewater quality to improve the performance of the biological nitrogen and phosphorus removal system. Study the synergistic action mechanism among microorganisms, and develop new technologies and processes based on the synergistic pollution removal of multiple microbial communities, giving full play to the advantages of different microorganisms in the nitrogen and phosphorus removal process to achieve more efficient nitrogen and phosphorus removal[8].

Process Optimization and Integration

Further optimize the existing nitrogen and phosphorus removal processes. Improve the treatment efficiency and stability of the processes by improving the reactor structure and optimizing the operation parameters. For example, upgrade and transform traditional processes such as A2/O, and adopt technologies such as precise aeration and intelligent control to achieve precise regulation of key parameters such as dissolved oxygen and carbon source distribution, and improve the nitrogen and phosphorus removal effect. Strengthen the integration and innovation among different processes, and develop more efficient, energy-saving, and economical combined processes[9]. For example, deeply integrate the anaerobic ammonium oxidation process with the short-cut nitrification and denitrification process, and use the complementary advantages of the two to achieve efficient treatment of wastewater with a high ammonia nitrogen concentration. Combine biological treatment with physical and chemical technologies such as advanced oxidation and adsorption to develop new advanced treatment combined processes to meet the increasingly strict effluent water quality requirements.

Application of New Materials and Technologies

Research and develop new adsorbents, membrane materials, etc. for nitrogen and phosphorus removal. New adsorbents should have a higher adsorption capacity, selectivity, and regeneration performance, and reduce the cost of adsorbents. New membrane materials should have better anti-pollution performance, high flux, and a long service life, and reduce the operation cost of membrane separation technology. Explore the application of emerging technologies in the removal of nitrogen and phosphorus in wastewater, such as photocatalysis technology and electrocatalysis technology. Photocatalysis technology can use light energy to excite the catalyst to generate active species with strong oxidizing properties, degrade organic matters and nitrogen and phosphorus pollutants in the wastewater. Electrocatalysis technology can achieve the removal and conversion of nitrogen and phosphorus through electrode reactions. These emerging technologies have the advantages of mild reaction conditions and little secondary pollution, and are expected to provide new ways for the removal of nitrogen and phosphorus in wastewater[10].

(2) Development towards Intelligence and Automation

With the rapid development of information technology, the nitrogen and phosphorus removal technologies in wastewater treatment plants will develop towards intelligence and automation. By installing various sensors, real-time monitoring of information such as wastewater quality, quantity, and process parameters is carried out, and technologies such as big data, artificial intelligence, and the Internet of Things are used to analyze and process the data to achieve intelligent control and optimized operation of the wastewater treatment process. For example, a precise aeration system based on artificial intelligence algorithms can automatically adjust the aeration volume according to the real-time dissolved oxygen concentration and the oxygen demand of microorganisms, reducing energy consumption while ensuring the treatment effect. An intelligent chemical dosing system can accurately control the dosage of chemical agents according to the changes in the nitrogen and phosphorus concentrations in the wastewater, improve the treatment efficiency, and reduce the waste of reagents. The application of intelligent and automated technologies will improve the fine management level of wastewater treatment plants, reduce labor costs, reduce human operation errors, and ensure the stable and efficient operation of the nitrogen and phosphorus removal system[11].

(3) Resource Recovery and Sustainable Development

In the future, the nitrogen and phosphorus removal technologies in wastewater treatment plants will pay more attention to resource recovery and sustainable development. Recover nutrients such as nitrogen and phosphorus from the wastewater and convert them into valuable products, such as recovering phosphorus to prepare slow-release fertilizers like magnesium ammonium phosphate, realizing the resource utilization of nitrogen and phosphorus. This can not only reduce environmental pollution but also lower the cost of wastewater treatment, having good economic and environmental benefits. At the same time, in the process of technology research and development and application, fully consider the issues of energy consumption and carbon emissions, and adopt energy-saving and consumption-reducing technologies, such as optimizing the aeration system and using the biogas generated by anaerobic fermentation as an energy source, to achieve low-carbon and sustainable development of wastewater treatment[12]. Promote the transformation of wastewater treatment plants from simple pollutant treatment facilities to comprehensive facilities for resource recovery and energy production, and promote the green development of the wastewater treatment industry.

(4) Standardization and Standardization Construction

With the continuous development and application of nitrogen and phosphorus removal technologies in wastewater, it is crucial to formulate unified technical standards and specifications. Relevant departments and industry associations should strengthen the evaluation and certification of new technologies and combined processes, formulate technical standards, design specifications, operation and management regulations, etc., clarify the applicable scope, performance indicators, quality requirements, etc. of the technologies, and provide guidance and basis for the promotion and application of the technologies. At the same time, establish and improve the technical supervision system, strengthen the supervision and management of the construction and operation of wastewater treatment plants, ensure that various technologies are implemented in accordance with standards and specifications, and guarantee the wastewater treatment effect and environmental safety[13]. Standardization and standardization construction will promote the healthy development of the market for nitrogen and phosphorus removal technologies in wastewater, and improve the overall level and application effect of the technologies.

5. CONCLUSION

The nitrogen and phosphorus removal technologies in wastewater treatment plants have made remarkable progress in research and application. Traditional technologies are constantly being improved, new technologies are emerging continuously, and combined processes have also been widely applied. However, currently, these technologies still face many challenges in terms of cost, stability, sludge treatment and disposal, and adaptability to water quality changes. In the future, the nitrogen and phosphorus removal technologies in wastewater treatment plants will develop towards technological innovation and optimization, intelligence and automation, resource recovery and sustainable development, as well as standardization and standardization construction. Through continuous technological research and development, process optimization, and improvement of the management model, it is expected to achieve efficient removal of nitrogen and phosphorus in wastewater, resource recycling, and the sustainable operation of the wastewater treatment system, making greater contributions to protecting the water environment quality and promoting the recycling of water resources.

6. PROSPECT

With the increasingly stringent environmental protection requirements and the emphasis on the sustainable utilization of water resources, the development of nitrogen and phosphorus removal technologies in wastewater treatment plants will continue to be a research hotspot and focus. In the future, it is necessary to further strengthen basic research, deeply explore the metabolic pathways of microorganisms, reaction mechanisms, and the laws of substance transformation, etc., to provide a solid theoretical support for technological innovation. In terms of technological research and development, efforts should be made to break through the existing technical bottlenecks, improve the stability, reliability, and adaptability of new technologies, reduce costs, and promote their large-scale engineering applications. At the same time, attention should be paid to interdisciplinary integration, and draw on the advanced achievements of multiple disciplines such as materials science, information technology, and automatic control to inject new vitality into the nitrogen and phosphorus removal technologies for wastewater. In addition, in engineering practice, according to the characteristics of wastewater quality and quantity in different regions and the level of economic development, the nitrogen and phosphorus removal technologies and processes should be selected and optimized according to local conditions, and the intelligent management, operation, and maintenance of wastewater treatment plants should be strengthened to improve the treatment efficiency and the compliance rate of water quality. Through the joint efforts of the whole society, continuously promote the progress and development of nitrogen and phosphorus removal technologies in wastewater treatment plants, and lay a solid foundation for achieving the goals of improving the water ecological environment and sustainable development.

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