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Research on Innovation of Wastewater Treatment Technology in Water Environment Restoration

Zhipeng Cheng*

School of Civil Engineering, Wanjiang University of Technology, Ma'anshan, China
987968279@qq.com
**corresponding author*

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Abstract: With the rapid development of global industrialization and urbanization, the problem of water environment pollution is becoming increasingly serious. Water resources shortage and water quality deterioration have become important factors restricting human survival and development. As a key link of water environment restoration, the technological innovation and research of wastewater treatment is of great significance to improve the efficiency of water resources utilization and the quality of water environment. Traditional wastewater treatment technology has many limitations in treatment efficiency, energy consumption, land area and so on, and it is difficult to meet the current complex water pollution treatment needs. Under this background, the innovation research of wastewater treatment technology has become a hot spot in the field of water environment restoration. In this study, a variety of new wastewater treatment technologies were discussed, including membrane separation technology, electrochemical technology, advanced oxidation technology, biological treatment technology and automatic control system. These technologies have their own characteristics, such as membrane separation technology can achieve efficient substance separation, electrochemical technology uses the principle of electrochemical reaction to remove pollutants, advanced oxidation technology decomposes organic matter through strong oxidants, biological treatment technology uses microorganisms to degrade organic waste, and automatic control system improves the intelligent level of sewage treatment. By comparing and analyzing the principles, advantages and application scope of various technologies, this study aims to provide scientific basis for the selection of wastewater treatment technology in water environment restoration, and promote the innovation and development of wastewater treatment technology.

1. Introduction

Water is the source of life, and the quality of water environment is directly related to the survival

and development of human beings. However, with the acceleration of industrialization and urbanization, a large amount of sewage discharge has brought serious pollution to the water supply environment, resulting in water resource shortage and water quality deterioration. As a key technology of water environment restoration, the efficiency and quality of wastewater treatment directly affect the reuse of water resources and the improvement of the environment. In the face of increasingly complex water pollution problems, traditional wastewater treatment processes have gradually exposed problems such as low treatment efficiency, high energy consumption, and large footprint[1]. Therefore, the innovation research of sewage treatment technology has become the key to the restoration of water environment.

2. Innovative research on sewage treatment technology

2.1 Membrane separation technology

Membrane technology is an efficient wastewater treatment process, the core of which is to use membrane materials with different pore sizes to separate and concentrate substances in wastewater[2]. According to the size of membrane pore size, membrane technology can be divided into microfiltration, ultrafiltration, nanofiltration and reverse osmosis. The pore size of the microfiltration membrane is usually between 0.1-10μm, which can effectively trap large particles and microorganisms[3]. The pore size of the ultrafiltration membrane is between 0.01 and 0.1μm, which can further remove colloids, proteins and viruses. Microfiltration and ultrafiltration technology has the advantages of simple operation, low energy consumption and small footprint. Nanofiltration and reverse osmosis technologies are mainly used to remove dissolved salts, organic matter and heavy metal ions in sewage. The pore size of the nanofiltration membrane is between 0.001 and 0.01μm, and the pore size of the reverse osmosis membrane is less than 0.001μm. Nanofiltration and reverse osmosis technology has the advantages of good treatment effect and high effluent quality, but the operation cost is high, and it is suitable for occasions with high effluent quality requirements (Table 1).

Table 1 Classification and characteristics of membrane separation technology

Technology type	Aperture range	Main removal substance	Application field
Microfiltration	0.1-10 μm	Suspended solids, colloids, bacteria, viruses	Urban sewage treatment, industrial wastewater treatment
Ultrafiltration	0.01-0.1 μm	Colloid, protein, virus	Drinking water purification, pharmaceutical industry
Nanofiltration	0.001-0.01 μm	Polyvalent ions, small molecules of organic matter, viruses	Industrial wastewater treatment, seawater desalination
Reverse osmosis	< 0.001 μm	Dissolved salts, organics, heavy metal ions	Drinking water purification, electronics industry

2.2 Electrochemical Technology

Electrochemical technology is a technology that uses the principle of electrochemical reaction to treat sewage. By applying voltage or current, the pollutants in the sewage can undergo REDOX reaction on the electrode, thus achieving the purpose of purifying the sewage[4]. Electrolysis is the use of electrolytic cell anode and cathode electrolytic treatment of sewage. The oxidation reaction

occurs on the anode, so that the organic matter and heavy metal ions in the sewage are oxidized and decomposed. Reduction reaction occurs on the cathode, producing hydrogen, etc.[5]. The electrolysis method has the advantages of good treatment effect and simple operation, but it has high energy consumption and is suitable for the occasions with high effluent quality requirements. The electrochemical oxidation method uses strong oxidants such as hydroxyl radical (OH) produced by the anode to oxidize and decompose organic matter in sewage. The method has the advantages of strong oxidation capacity and wide application range, and can effectively remove refractory organic matter and heavy metal ions. However, the electrochemical oxidation method also has some problems, such as high energy consumption and easy corrosion of electrode materials.

2.3 Advanced oxidation technology

Advanced oxidation technology is a technology that uses strong oxidant to decompose organic matter in sewage. Common advanced oxidation technologies include ozone oxidation, Fenton oxidation, photocatalytic oxidation and so on. Ozone oxidation is to use the strong oxidation of ozone to decompose organic matter in sewage. Ozone can react directly with organic matter, and can also react with water to produce hydroxyl radical (OH) and other strong oxidant, which has the advantages of good treatment effect and no secondary pollution, but the operation cost is high. Fenton oxidation is the oxidative breakdown of organic matter in sewage using strong oxidants such as ferrous ions (Fe^{2+}) and hydrogen peroxide (H_2O_2) to form hydroxyl radicals (OH) [6]. The method has the advantages of strong oxidation capacity and wide application range, but the amount of ferrous ion and hydrogen peroxide is large, and the operation cost is high. Photocatalytic oxidation is the use of photocatalyst to generate electrons and holes under light conditions, and then generate hydroxyl radical (OH) and other strong oxidants to oxidize and decompose organic matter in sewage[7]. Photocatalytic oxidation technology has the advantages of good treatment effect and low energy consumption, but the problem of recovery and regeneration of photocatalyst still needs further research.

2.4 Biological treatment technology

Biological treatment technology is a kind of technology using microorganisms to degrade and transform organic waste, which has the advantages of low cost, stable operation and simple operation. Traditional biological treatment technologies include activated sludge method and biofilm method, etc. However, with the progress of science and technology, some new biological treatment technologies such as anaerobic biological filter and biological contact oxidation method have gradually been applied (Table 2).

Table 2 Classification and characteristics of biological treatment technologies

Technology type	Working principle	Advantage
Activated sludge process	Microbial degradation of organic matter in activated sludge	The technology is mature and widely used
Biofilm method	Microorganisms attach to the carrier to form biofilms and degrade organic matter	Low cost, stable operation, simple operation
Anaerobic biological filter	Anaerobic microorganisms degrade organic matter in the fixed bed layer to produce biogas	No energy consumption, low cost, simple management, no noise, no smell
Biological contact oxidation method	Microorganisms form biofilms on the fillers and degrade organic matter	Strong purification function, less sludge generation

2.5 Automatic control system

With the maturity and development of computer and automatic control technology, the application of automatic control system in sewage treatment is more and more extensive. The automatic control system can realize the functions of real-time monitoring, dynamic management and data processing of sewage treatment, and improve the efficiency and stability of sewage treatment[8].

PLC (Programmable Logic Controller) control system is a commonly used automatic control system. The control and regulation of various links in the sewage treatment process are realized through programming, such as the start and stop of pumping station, control of dosage, adjustment of aeration, etc.[9]. PLC control system has the advantages of stable operation and high reliability, but the programming and debugging work is more complicated. SCADA (Supervisory Control and Data Acquisition) system is an automatic control system which integrates data acquisition, transmission, processing and control. Data is collected by various sensors and meters installed at the sewage treatment site and transmitted via the network to the central control room for processing and display. SCADA system has the advantages of real-time monitoring and remote control, but the cost of construction and operation is high. The application of artificial intelligence algorithm in sewage treatment is more and more extensive. Through machine learning, deep learning and other algorithms to analyze and predict the data in the sewage treatment process, the optimal control of the sewage treatment process can be achieved. For example, by predicting changes in pollutant concentration and flow in sewage, parameters such as dosage and aeration rate can be automatically adjusted to improve treatment efficiency and water quality stability[10].

3. Conclusion

Research on innovation of wastewater treatment technology in water environment restoration is of great significance for improving wastewater treatment efficiency, reducing environmental pollution and promoting recycling of water resources. This paper discusses the innovative direction of wastewater treatment technology, including membrane technology, electrochemical technology, advanced oxidation technology, biological treatment technology and automatic control technology, through the implementation of innovative technology, can better protect the environment and improve the sustainable use of water resources. In the future, we should continue to explore new technologies, materials and equipment, optimize the process flow and management mode, achieve more efficient, environmentally friendly and sustainable sewage treatment and water resource recycling, and make greater contributions to the construction of a beautiful China and the construction of global ecological civilization.

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