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Research Progress of Chemical Wastewater Treatment Technology

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Abstract:

The rapid development of the chemical industry has caused serious environmental problems, among which chemical wastewater discharge has become a key problem that needs to be solved urgently. Compared with traditional treatment technologies, emerging technologies such as advanced oxidation and bioelectrochemical systems have been widely adopted due to their advantages of low energy consumption and high efficiency. This article aims to briefly analyze the principles, advantages, disadvantages and application scenarios of emerging treatment technologies, and points out a series of challenges facing the development of chemical wastewater treatment technology. This paper concludes that traditional water treatment methods face the challenge of energy conservation and consumption reduction. Compared with traditional technologies, emerging technologies have the advantages of being energy-saving and efficient, and are suitable for meeting increasingly stringent environmental protection standards. In the future, innovation and integration of a variety of technologies can be carried out, and combined processing technology not only reduces equipment costs but also improves processing efficiency and quality. The analysis in this article can provide some reference and inspiration for the selection and improvement of chemical wastewater treatment technologies in related industries.

Keywords: chemical wastewater, water treatment technology, sustainable development

1. Introduction

The chemical industry is one of the important pillar industries in my country and has made important contributions to the national economic development. In recent years, with the continuous expansion of the scale of the chemical industry, environmental problems caused by chemical wastewater have become increasingly serious. Unlike domestic wastewater that is easily degraded, chemical wastewater contains a variety of pollutants such as organic matter, heavy metals, and harmful microorganisms. Most of these pollutants are difficult to decompose, have high toxicity and high content, so how to efficiently

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treat chemical wastewater has become a hot topic in water treatment in recent years [1].

Traditional chemical wastewater treatment technology mainly focuses on physical and chemical technologies, and the main physical technologies include: precipitation method, air float method, centrifugal method, etc. Chemical technology is mainly divided into oxidation methods and reduction methods, and strong oxidation agents are used for redox reduction. Although these methods can meet the general requirements of wastewater treatment, they all have the disadvantages of high equipment costs, high energy consumption, and low efficiency.

Compared with traditional wastewater treatment technology, emerging treatment technologies such as advanced oxidation technology, bioelectrochemical technology, etc. have been widely used for their low energy consumption and high efficiency advantages. Xiao Xu et al. analyzed the research progress of electrochemical technology in wastewater treatment in recent years, pointing out that electrochemical technology has the advantages of simple equipment and mild reaction conditions, but has the limitation of large energy consumption and may produce by-products[2]. Chen Yeping analyzed the research progress of ozone oxidation technology in wastewater treatment, pointed out the characteristics of simple equipment and the good treatment effect of ozone oxidation technology [3]. It is suitable for fine chemical industries such as pharmaceuticals, printing and dyeing, coal chemical industry, which produces large wastewater and complex composition. Zhang Xia et al. analyzed the challenges in applying algae-bacteria symbiotic systems to practical wastewater treatment, highlighting their high tolerance to recalcitrant chemicals (e.g., pharmaceuticals and personal care products) and their potential for such applications [4]. This article aims to sort out the progress of chemical wastewater treatment technology. By briefly describing the source, classification and hazards of chemical wastewater, we will introduce emerging chemical wastewater treatment technologies, and mainly analyze the principles, applications and advantages and disadvantages of advanced oxidation technology and bioelectrochemical technology. Then, compared with traditional treatment technologies, we will obtain the challenges and development trends facing chemical wastewater treatment technology.

2. Source, classification and hazards of chemical wastewater

Chemical wastewater refers to polluted wastewater generated in chemical industry production and related links, mainly including the use of raw materials, product manufacturing and material transportation. According to the characteristics of different links, their sources can be divided into raw material wastewater, production wastewater and storage and transportation wastewater [5]. Raw material wastewater refers to the water contained in raw materials, catalysts, etc. required for chemical production, which will produce a small amount of wastewater after being discharged; production wastewater refers to the unreacted raw materials and side reaction products that are separated from the product during the purification process; storage and transportation wastewater refers to the loss of chemicals during transportation and storage, rainwater erosion, and the cleaning of production and transportation equipment.

There are many classification methods for chemical wastewater, and common classification methods include classification by source and classification by main pollutants. Taking wastewater generated by coal chemical technology as an example, its wastewater can be divided into gasification wastewater, liquefied wastewater and coking wastewater according to its source. Gasification wastewater is the wastewater formed by dissolving tar, gasifier and organic impurities in the gasification process by the gas-making furnace outlet circulating water spray system. Liquefied wastewater is the wastewater generated during the conversion of coal carbon into oil products, and its main components are sulfur and phenol. Coking wastewater is the wastewater generated by the process of coal insulation air decomposition into tar and gas, and its main components are ammonia and nitrogen [6]. The above chemical production process wastewater can also be classified according to the main pollutants, that is, according to the pollutants with the highest content in the wastewater. For example: phenol-containing wastewater, cyanide-containing wastewater, sulfur-containing wastewater, etc.

If chemical wastewater is improperly treated and discharged into the environment, there are many hazards, which can be summarized into the following three aspects: (1) Sensory hazards. Chemical wastewater is usually relatively turbid and accompanied by a foul odor, which will cause great damage to the human body's senses. Some wastewater is even highly corrosive, such as strong acid wastewater, which may burn the skin if it is accidentally exposed to it; (2) Harm to water. If the inorganic acid alkaline substances in chemical wastewater are discharged directly into natural water bodies, it may cause changes in the overall pH of the water body, affecting the metabolism of aquatic organisms and coastal organisms. Among them, organic substances will consume a large amount of dissolved oxygen during the degradation process, resulting in the death of aerobic organisms and anaerobic microor-

ganisms; (3) Toxic hazards. The highly toxic substances, such as aromatic hydrocarbons and cyanide contained in chemical wastewater may enter the water body organisms and even the human body through enrichment, resulting in serious consequences such as poisoning, deformity, and cancer [7].

3. Analysis on the progress of chemical wastewater treatment technology

3.1 Traditional technology

Traditional wastewater treatment technologies are mainly separate physical, chemical and biotechnology.

Physical treatment technology uses physical methods to separate pollutants in chemical wastewater. Commonly used physical technologies mainly include precipitation, filtration, centrifugation, gas float, etc. [8]. The main principle is to separate the pollutant mass or size difference. These technologies have the advantages of easy operation, low cost and stable operation, but they also have the disadvantages of incomplete separation and can only be used in wastewater pretreatment processes. In addition, the precipitation method, filtration method and centrifugal method each have the disadvantages of slow speed, easy blockage and high energy consumption.

Chemical treatment technology is a treatment technology that uses chemical reactions to convert harmful substances in chemical wastewater into harmless substances. The main chemical reactions include oxidation reaction, reduction reaction and neutralization reaction. Commonly used oxidants include ozone, hydrogen peroxide, hypochlorite, etc., and common reducing agents include sulfate, nitrite, etc. [9]. The advantages of chemical treatment technology lie in its advantages, such as rapid reaction and thorough removal, but since redox agents are generally non-renewable, there are disadvantages of high cost. In addition, unconsumed oxidants in the water must be removed, otherwise it is very easy to cause secondary pollution.

Biological treatment technology is a technology that uses the microorganisms' own life activities to decompose and convert harmful substances in chemical wastewater. It is divided into two categories according to the type of microorganisms: anaerobic and aerobic. The metabolic process of microorganisms in wastewater will oxidize organic matter in the water to provide energy to itself, thereby realizing the removal of harmful substances in the water. This type of treatment method usually uses equipment such as oxidation ponds, biological turntables, biological filters, etc. Most of this equipment can be used multiple times, so it has the advantages of low cost and strong applicability. At the same time, this method has problems such as low treatment efficiency and instability of the system. Changes in water composition may have a great impact on the activities of microorganisms.

3.2 Emerging technologies

Emerging water treatment technology is a new and efficient treatment method formed through technological integration and innovative evolution based on traditional methods. This section mainly analyzes advanced oxidation technology and bioelectrochemical technology.

The principle of advanced oxidation technology is a water treatment technology that uses strong oxidizing organic matter in wastewater into small molecules or inorganic matters. There are many forms of advanced oxidation technology, such as Fenton oxidation technology, photoelectrocatalytic oxidation technology, etc. [10]. Taking photocatalytic oxidation technology as an example, the principle is that photocatalysts can produce active substances after absorbing light energy. This technology uses natural light and has low energy consumption and no pollution, so it has been widely used in recent years [11]. For example, the researchers synthesized polyaniline (PANI) modified SnO_2/Carbon composite, which degraded methyl orange by as much as 98% under visible light irradiation [12]. Wu Dayong made his own photocatalytic oxidation device and studied pollutants in a paper chemical factory. After oxidation time is 50 minutes, the digestion efficiency of total phosphorus and total nitrogen in the wastewater reaches 95%. Ghasemi et al. used Fe-ZSM-5 zeolite as a support to synthesize a supported nano-TiO_2 catalyst to photocatalyze the organic pollutants in the refining wastewater, and the COD removal rate can reach 83% under the optimal conditions [13]. In contrast, the unloaded mixture of TiO_2 and Fe-ZSM-5 reached only 64%, indicating that the catalytic activity of TiO_2 can be significantly improved through support optimization. However, photocatalytic technology also has problems such as the inability to recover catalysts and the easy generation of other by-products, which require further research and resolution.

The principle of electrochemical technology is that the pollutants in wastewater undergo redox reactions at the anode and cathode to be converted into harmless substances. Among them, bioelectrochemical technology is an improvement of the traditional electrochemical technology fusion method. The basic principle is that microorganisms at the anode undergo an electrooxidation reaction, and harmful substances in wastewater at the cathode undergo a reduction reaction. This technology has a wide range of applications and can be used in areas such as energy recovery and environmental monitoring in addition to

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wastewater treatment [14]. Guo Xuefei made a self-made "electro-Fenton+ bioelectrochemical" device to conduct evolutionary research on the production wastewater of a pharmaceutical factory [15]. Using EEMs and GC-MS to measure the degradation effect of inlet and outlet water, it can ensure that the degradation rate of CODCr is 96%. Tang Wanting constructed a bioelectrochemical nitrogen and phosphorus recovery system to study its nitrogen and phosphorus recovery performance on ship domestic sewage [16]. After 72 hours, the removal rates of urea nitrogen (CO(NH2)2-N) and total phosphorus (TP) reached 40.2% and 40.6%, respectively. Meanwhile, 14.7 mg of NH4+-N and 38.3 mg of TP migrated to the recycling chamber, with mobility rates of 39.0% and 94.6%.. FENG et al. used BES to degrade nitrobenzene wastewater, and the removal efficiency of p-fluorinitrobenzene using an electrically enhanced activated sludge system is as high as 62.9% [17].

4. Prospects of chemical wastewater treatment technology

With the continuous development of industry, chemical wastewater discharge is increasing year by year, and environmental protection standards are becoming increasingly stringent. Emerging wastewater treatment technologies will play an increasingly important role. At present, emerging technologies have the following development trends: (1) The wastewater treatment standards have gradually improved. In recent years, my country has entered the era of economic takeoff after reform and opening up, and industry has developed rapidly. The resulting environmental pollution problems and energy consumption problems are becoming more and more serious. Local governments and environmental regulatory departments are increasingly strict in the supervision of pollution emissions in the chemical industry. Sewage discharge pipelines, flue ducts, etc. in chemical plant areas have been installed in the whole day of pollution monitoring devices and data is uploaded to the local environmental protection department in real time. Traditional chemical wastewater treatment technology needs to be further improved to adapt to stricter environmental protection requirements; (2) The integrated development of multiple technological innovations. Compared with the original single treatment technology, the combined development and utilization of multiple treatment technologies can not only reduce equipment costs, but also further improve treatment efficiency and quality. It is a popular direction for the development of water treatment technology in recent years; (3) The utilization rate of energy and resources has gradually increased. With the seriousness of energy shortage and environmental pollution problems, traditional water treatment methods face the challenge of energy conservation and consumption reduction. Energy conservation and consumption reduction are also one of the key issues facing China's industrial transformation, and it is also an inevitable requirement for industry by sustainable development. Compared with traditional technologies, emerging water treatment technology can significantly reduce energy consumption and realize the recycling of substances, meeting higher environmental protection requirements while creating economic benefits for factories.

5. Conclusion

This article introduces the source, classification and harm of chemical wastewater, from traditional physical, chemical, biological methods to emerging advanced oxidation technology and electrochemical technology, and discusses principles, research progress, advantages and disadvantages, and finally predicts the development trend of chemical wastewater treatment technology. Various different methods have certain advantages and limitations. For example, traditional physical methods (such as air floatation) have slow processing speed, a large equipment area, but stable treatment effect, and are still widely used in the initial stage of sewage treatment. Emerging treatment technologies (such as advanced oxidation methods) improve the atomic utilization rate of oxidants compared with traditional chemical oxidation methods (such as using hypochlorites), and have the advantages of energy saving and efficiency, but still face certain challenges (such as stability changes with the composition of sewage), and are still a certain distance from large-scale industrial application. In order to promote the upgrading of the chemical industry to further optimize energy conservation and emission reduction, practitioners should conduct further in-depth research on the water treatment process from the three perspectives of high efficiency, energy conservation and environmental protection. Chemical wastewater is synchronized with other industrial wastewater, and intensive treatment is also the general trend.

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