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Application of Dye Wastewater Treatment Technology Based on High Efficiency

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Abstract. Dye wastewater has features such as high chroma, complex composition and poor biodegradability, which is a significant challenge in the current industrial wastewater treatment. The methods of flocculation, iron-carbon micro electrolysis and carbon material adsorption are widely used in the treatments of dye wastewater. This article systematically analyzes the mechanisms and characteristics of the three processing technologies.The flocculation method mainly removes colloids and some dye molecules from water through mechanisms such as compressing the double layer, electric neutralization, adsorption bridging, and netting and sweeping. The iron-carbon micro electrolysis method uses a microbattery system formed by iron and carbon to destroy the structure of dye molecule and remove color through the synergistic effects of reduction, oxidation and flocculation. The carbon material adsorption depends on its porous structure and surface functional groups to achieve the enrichment and removal of pollutants through mechanisms of physical adsorption and electrostatic interaction.The results show that different treatment methods have different adaptability to dye wastewater. The flocculation method is suitable for primary separation of pollutants in pretreatment stage. The micro electrolysis method has good decolorization ability for dye wastewater, especially for improving the biodegradability of wastewater and the degradation of pollutants. The carbon material adsorption method is outstanding in biochemical treatment and low concentration wastewater treatment, which is suitable for the enrichment and removal of pollutants.

Keywords: Dye wastewater, flocculation, micro electrolysis, carbon material adsorption

1. Introduction

With the rapid development of the textile, dyeing and chemical industries, the application scale of dyes is expanding. Therefore, the discharge of dye wastewater continues to rise. However, when a number of dye wastewater is discharged into natural water without efficient treatment, the transparency of natural water will be reduced [1]. At the same time, the photosynthesis of plants in water will be blocked [1]. Dye wastewater also affects the content of dissolved oxygen in water, thus destroying the ecosystem in water [2]. Meanwhile, there is still a strong toxicity in some dye wastewater after treatment. They can be absorbed by the human body through ingestion, which accumulate in the human organ and increase the risk of disease [3]. For example, dyes ingested by fish and other organisms can form toxic intermediates in their bodies, thus creating a threat to the

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health of fish and their predators. Dye wastewater mainly contains toxic inorganic and organic substances, heavy metal ions [3, 4]. And dye wastewater can be classified according to water solubility. Hydrophilic dyes include acid dyes and basic dyes, while hydrophobic dyes include azo dyes and vat dyes [2]. Different dyes have different molecular structures, functional groups and dissolution characteristics, which lead to different difficulties in wastewater treatment.

At present, dye wastewater treatment methods can be divided into three categories: physical, chemical and biological. Adsorption and membrane separation are two common physical methods, which have the advantages of simple operation and wide application range. Chemical methods include flocculation, electrochemistry and micro electrolysis, which can effectively reduce chromaticity and some refractory organics. Biological methods are energy-saving and environmental protection, but there are limited effects on the treatment of high concentration dye wastewater [2]. Among them, Adedapo O. Adeola and other scholars believe that flocculation method is widely applied due to its mature process, but it can generate massive sludge, which is not friendly to the environment and increases the cost of treatment and transportation [5]. Xiaoxu sun and other scholars believe that micro electrolysis method has obvious advantages in improving the biodegradability of wastewater by using iron carbon primary battery reaction to treat refractory organic pollutants, but its treatment cost is relatively high due to the investments of equipment and materials [6]. Bernice Yram Danu and other scholars believe that carbon material adsorption method has excellent adsorption performance in dye wastewater treatment due to its pore structure and high chemical stability, but it faces the challenges of difficult material regeneration and low efficiency in treating high concentration dye wastewater [7].

In this paper, flocculation, micro electrolysis and carbon material adsorption are three efficient treatment technologies for dye wastewater. Their mechanism, characteristics and practical applications are reviewed, and the similarities and differences of the three technologies in treatment mechanism, applicable objects and treatment capacity are compared. On this basis, the development trend of dye wastewater treatment technology in the future is analyzed and prospected, which provides theoretical reference and technical support for efficient dye wastewater treatment.

2. Three technologies for treating dye wastewater

2.1. Flocculation method

Flocculation is a physical and chemical method commonly used in wastewater treatment. Its basic principle is to add an appropriate amount of flocculant to the wastewater to destabilize the colloidal particles and micro suspended solids that were originally stable. And they form large flocculent aggregates through the interaction between particles. Finally, the pollutants can be separated and removed by sedimentation and filtration [5]. This method has good treatment effect for colloidal substances, suspended particles and some organic pollutants in dye wastewater which are difficult to settle naturally. The flocculation process mainly depends on the flocculant to change the stable state of the particle surface, weaken the repulsion between particles and promote their mutual integration. At present, research shows that flocculation mainly contains the following four mechanisms [8].

2.1.1. Electric double-layer compression

Colloidal particles in wastewater usually have the same charge and maintain stable dispersion due to electrostatic repulsion. When the flocculant is added to the system, the ion concentration in wastewater increases, which makes the diffusion layer around colloidal particles thinner and the

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electrostatic repulsion force on the particle surface decrease. Under the action of van der Waals' gravity, the particles are easier to approach and gather together, thus forming large flocs [8].

2.1.2. Charge neutralization

Clay particles, humus, dye colloids and other substances in wastewater usually have negative charge, and the added metal salt flocculant or cationic polymer can provide positive charge. Therefore, both of them have electrical attraction, which weakens the charge on the particle surface and even reaches electrical neutrality. When electrostatic repulsion between particles is reduced, particles can integrate with each other under the influence of intermolecular force to form large particle flocs [8].

2.1.3. Adsorption bridging

Adsorption bridging mainly occurs in the presence of polymer flocculants. The polymer chain has massive active groups, which can adsorb colloidal particles in wastewater. When a polymer chain connects multiple particles at the same time, it can form a connection structure similar to a bridge, so that the dispersed small particles gradually gather into large flocs [8].

2.1.4. Net trapping and sweeping

When a high concentration of metal salt flocculant is added to the wastewater, the iron salt or aluminum salt can undergo hydrolysis reaction and generate a large number of insoluble metal hydroxide precipitates. During the formation of these sediments, the surrounding colloidal particles and pollutants can be wrapped and adsorbed like a net, so that they can be removed along with the precipitation [8].

Ahmad K. Badawi and other scholars believe that metal ions in inorganic flocculants can reduce the charge repulsion on the surface of contaminated particles and make colloidal particles unstable. The polymer flocculant uses its long molecular chain structure to form a connection between different contaminated particles and promote the continuous growth of flocs [9]. And polyacrylamide (PAM) and other polymer materials are often used as polymer flocculants in wastewater treatment process.

However, the traditional chemical flocculation method has shortcomings. For example, a large amount of sludge containing chemical substances is produced during the treatment process, which increases the subsequent disposal cost. At the same time, some inorganic flocculants may bring potential environmental risks [9]. In order to reduce secondary pollution and improve the sustainability of the treatment process, many researchers began to pay attention to the development of natural flocculants. Natural flocculants mainly come from plants, animals and microorganisms, which have the advantages of degradability, low toxicity and less sludge production. For example, Nurull Muna Daud and other scholars proposed that Moringa oleifera seed could be used to treat wax printing wastewater, and Natural Flocculants could be used to improve the sustainability of the ecosystem [10].

Flocculation method has the advantages of mature process, good economy and wide range of pollutant removal, which is one of the important methods for the treatment of dye wastewater. However, in the future, it is still necessary to achieve the deep removal and resource utilization of pollutants with the development of efficient new flocculants and other treatment technologies.

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2.2. Iron-carbon micro electrolysis

Iron-carbon micro electrolysis technology is a dye wastewater treatment method based on the principle of electrochemistry. It mainly uses the electrode potential difference between iron and carbon materials to create an environment with a lot of tiny primary batteries in the dye wastewater. When the iron carbon filler is in contact with the conductive wastewater, iron acts as an anode to undergo oxidation reaction and release electrons to generate ferrous ions. Carbon material acts as a cathode to promote the reduction reaction, thus forming a continuous oxidation-reduction process in the system. This process can destroy the stable structure of dye molecules and remove refractory organics [11].

Lu Hongxiu and other scholars believe that in the presence of oxygen, the iron-carbon micro electrolysis system can produce hydrogen peroxide, and ferrous ions and hydrogen peroxide further undergo a reaction to produce hydroxyl radicals with strong oxidation ability [11]. These reactive free radicals can oxidize the refractory organics, which improve the removal efficiency of pollutants and achieve decolorization [11]. In the treatment of dye wastewater, iron-carbon micro electrolysis is usually used to deal with refractory organic pollutants. The main function is to reduce the chroma and COD content of wastewater, and improve the B/C ratio, which benefits the biodegradability of wastewater and subsequent biological treatment [6].

In the treatment of dye wastewater of scarlet 4BE, Xiaoxu sun and other scholars found that if only the iron-carbon micro electrolysis method is used to treat the dye wastewater, the relevant conditions are controlled to reach the best decolorization rate, which is nearly 99.03% [6]. However, under other conditions unchanged, the total decolorization rate can be further increased to 99.79% after flocculation sedimentation and Fenton oxidation [6]. This shows that iron-carbon micro electrolysis can be applied with flocculation sedimentation, Fenton oxidation and other processes together to achieve better treatment efficiency of dye wastewater.

Iron-carbon micro electrolysis is an important technology to treat dye molecules and refractory organics with the characteristics of simple operation, strong adaptability and high efficiency on the treatment of refractory organics. However, there are some problems in this method, such as the passivation of iron carbon materials and the generation of iron sludge, which lead to the decline of treatment efficiency over time. Therefore, the researchers tried to improve the treatment effect through the combination of material modification, Fenton oxidation, flocculation and other technologies.

2.3. Iron-carbon micro electrolysis

Carbon material adsorption method mainly uses the developed pore structure and achieves the removal of pollutants in wastewater through the joint action of physical adsorption and chemical adsorption. In the adsorption process, pollutant molecules first enter the internal pores of carbon materials through liquid phase diffusion, and enrich at the adsorption sites, thus reducing the pollutant concentration [12]. Isabel Pestana Da Paix ã o Cansado and other scholars believe that the adsorption properties of carbon materials are mainly affected by their surface structural characteristics and surface chemical properties. Large specific surface area and developed pore structure can provide more effective adsorption sites and improve the removal efficiency of pollutants [12].

Adane Kassa and other scholars believe that one of the main limitations of carbon material adsorption in the treatment of dyes is economic factors. For example, although activated carbon is one of the traditional adsorbents, which has high treatment efficiency, its regeneration cost is high,

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and material loss can lead to efficiency reduction [13]. Therefore, low-cost adsorbents (LCA), such as some natural materials and industrial by-products, have become a new direction of research on the treatment of dye wastewater due to their lower cost and simple treatment compared with traditional adsorbents. Huyi Zhang scholar found in practical application that coke powder activated carbon can effectively remove azo dyes and some cationic dyes from wastewater, and the main mechanism is surface adsorption [14]. Coke powder activated carbon is prepared by activation treatment of coal coking by-products, which has a wide range of materials. So it is widely applied in the pretreatment or auxiliary to treat industrial wastewater. However, the pore structure of the material is unevenly distributed, and the problem of adsorption saturation will occur after long-term use. Therefore, it needs to be replaced or recycled regularly [14].

Porous biochar is a kind of adsorption material prepared by pyrolysis of biomass materials, which has the characteristics of wide sources and environmental friendliness. Bingguo Li scholar used mangosteen shell as raw material to prepare porous biochar and treat methylene blue dye wastewater. Methylene blue is a cationic dye with positive charge in water. The surface of mangosteen shell biochar contains many oxygen-containing functional groups, which makes its surface negatively charged and is conducive to electrostatic adsorption with methylene blue [15]. At the same time, the porous structure can provide a large number of adsorption sites, so that dye molecules can quickly enter the pores and be fixed, and accumulate at the active sites.

The carbon material adsorption method mainly relies on the large specific surface area, rich pore structure and surface active sites of carbon materials to achieve the adsorption and enrichment of pollutants in dye wastewater. It has high adsorption efficiency and wide application range, but there are still some problems such as difficult regeneration of materials, high cost, secondary pollution of recycling to the environment.

3. Comparative analysis

Table 1. Comprehensive comparison of three dye wastewater treatment technologies

Treatment method of dye wastewater	Flocculation	Iron-carbon micro electrolysis	Carbon material adsorption
Main mechanism	Charge neutralization, floc sedimentation	Oxidation reduction, flocculation and sedimentation	Surface adsorption
Major pollutants	Total suspended solids (SS), some dyes	Refractory organics, COD	Dye molecule
COD removal capacity	Medium	High	Medium
Decolorization efficiency	High	High	High
Sludge production	High	Moderate	Low
Running cost	Low	Moderate	High
Industrial maturity	High	Medium	Medium
Pollution control path	Pollutant separation	Pollutant degradation	Pollutant enrichment

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Comprehensive analysis of the three treatment technologies shows that they have their own characteristics and application scope. Flocculation mainly relies on charge neutralization, floc sedimentation and other mechanisms to settle the suspended solids and some dye molecules in dye wastewater, which has low operation cost and high industrial maturity. However, massive sludge is produced in the treatment, and the structure of pollutants is not be damaged. Therefore, flocculation is suitable for primary separation of pollutants in the pretreatment stage of dye wastewater. Iron-carbon micro electrolysis mainly uses oxidation-reduction reaction to destroy the structure of pollutant molecules, and has significant removal effect on refractory organic matter and COD, which can improve the biodegradability of water. However, iron carbon materials are easy to be passivated, which will lead to the decline of long-term operation efficiency. Therefore, it is suitable for the front end of biochemical treatment of dye wastewater to degrade pollutants. The carbon material adsorption method mainly uses the pore structure and active sites on the material to adsorb the dye molecules in the dye wastewater, which has high adsorption efficiency for low concentration pollutants and does not produce a large amount of sludge. But the disadvantage is that the adsorption capacity is limited, and the cost of material regeneration and secondary pollution to the environment need to be considered. Therefore, carbon material adsorption method is suitable for the enrichment and removal of pollutants.

4. Conclusion

In this paper, the application of flocculation method, iron-carbon micro electrolysis method and carbon material adsorption method in the treatment of dye wastewater is systematically analyzed. It is considered that flocculation can effectively reduce the number of suspended solids and some dyes in wastewater through the functions of electric neutralization and adsorption bridging, but the removal ability of dyes with strong solubility or stable structure is limited, so it is more suitable for the primary separation of pollutants in the pretreatment stage of dye wastewater. Through the synergistic effect of oxidation-reduction and flocculation, iron-carbon micro electrolysis can effectively destroy the molecular structure of dyes, achieve rapid decolorization, improve the biodegradability of wastewater, and degrade pollutants in dye wastewater. The carbon material adsorption method with the characteristics of fast reaction is easy to operate, which performs well in the low concentration dye wastewater and biochemical treatment stage. And it is suitable for the enrichment and removal of pollutants. However, the regeneration cost of carbon materials is high and causes secondary pollution to the environment, so it is necessary to develop materials that are easier to regenerate and more efficient. The three methods have their own advantages and limitations, and a single process is hard to achieve the advanced treatment of dye wastewater. This paper believes that the three methods can be reasonably combined. For example, the flocculation method is used to reduce the initial load of wastewater, the iron carbon micro electrolysis method is used to destroy the structure of refractory organic compounds, and the carbon material adsorption method is used to remove the remaining pollutants, thus forming a collaborative system of "separation, degradation and enrichment".

The printing and dyeing industry has made continuous progress in recent years. So the composition of dye wastewater has become more complex, which puts forward higher requirements for the treatment process. This paper suggests that the selective separation ability in the flocculation process can be improved by developing new flocculants in the future. For iron-carbon micro electrolysis, we can try to combine it with advanced oxidation technology to further improve the degradation ability of organic compounds. In terms of carbon material adsorption, high-performance

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renewable carbon materials can be developed and natural materials can be modified to achieve resource utilization and improve environmental friendliness.

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