ISSN: 2414-1895 DOI: 10.6919/ICJE.202112_7(12).0010

Advances in biological treatment of dye wastewater

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Abstract

With the rapid development of the textile industry, resulting in the continuous increase of pollution wastewater discharge, has become one of the highest degree of chemical pollution in the world.It is estimated that nearly two-thirds of the dyes produced in the world each year are used in the textile industry.A large amount of dye wastewater is discharged into the nature, causing damage to the ecological environment, so it is of great significance to study how to treat dye wastewater efficiently.At present, the biological treatment method of dye wastewater is an economic and effective, environmentally friendly environmental treatment method, can be biological adsorption or biodegradation of printing and dyeing wastewater by microbial cells, as well as biological secondary degradation of harmful by-products.Under certain environmental conditions, some microorganisms can degrade printing and dyeing wastewater into colorless decomposition products, partially or even completely mineralize these metabolites.

Keywords

Dye wastewater; Decolorization; Biological methods.

1. Hazard of dye wastewater

Because people growing demand for textile products, the production of textile industrial waste water and pollution emissions continue to increase, make it one of the world chemical industry with high levels of pollution, and nearly two thirds of the dyestuff produced annually around the world by textile industry, it is estimated that up to 50% of the dye wastewater has been released into the environment [1]. It has been reported that 280,000 tons of textile dyes are discharged into textile industry wastewater every year globally due to the low efficiency of dyeing treatment of fiber materials [2]. At the same time, the textile wastewater discharged into rivers and lakes contains complex chemical mixtures with extremely complex chemical characteristics [3]. Due to the use of a large number of chemical printing and dyeing materials in textile processing, printing and dyeing wastewater usually has high organic content and high salinity, especially the stubborn dyes [4]. Untreated or improperly treated printing and dyeing wastewater directly discharged into surface water can affect flora, fauna and microbial communities. For example, even if the printing and dyeing wastewater is discharged at a very low concentration, the visibility of the dye will interfere with sunlight penetration, and it is also resistant to physical chemical/biological degradation. Its degradation products are toxic, mutagenic and carcinogenic, increasing the content of COD or BOD in the water, and eventually leading to eutrophication [5]. The presence of color and suspended matter in water reduces the penetration of sunlight in water and thus inhibits the photosynthetic process, thus disrupting the ecological balance [6]. In addition, some chemicals found in dyeing wastewater may be highly toxic to aquatic organisms [7].

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Therefore, it is urgent to develop an efficient, environmentally friendly and economical treatment scheme for dye wastewater. In general, physical and chemical methods to treat dye wastewater have inherent disadvantages, such as high cost due to excessive energy demand or excessive use of chemicals, insufficient degradation of pollutants to generate a large number of secondary pollutants, inefficient removal of stubborn printing and dyeing wastewater and its metabolites, and the formation of harmful by-products [8]. Biological methods: Biological decolorization can be carried out through biological adsorption or biodegradation of printing and dyeing wastewater by microbial cells, and biological secondary degradation of harmful by-products[9].Under certain environmental conditions, some microorganisms can transform dyeing wastewater into colorless decomposition products partially (biodegradation), or even complete mineralization of these metabolites (full biodegradation)[10].

2. Biological treatment of dye wastewater

2.1 Dye wastewater treatment by fungi

Fungi play an important role in the biological treatment of dyeing wastewater. The degradation process of dyeing wastewater by fungi may include biodegradation of live fungi and adsorption of dead fungi. The efficiency of this process depends largely on the properties of the dye, especially the molecular structure and the linked functional groups. This may ultimately determine the degree to which dyes can be removed from the organic substrates of complex dyeing wastewater [11].

Fungi can produce lignin-degrading enzymes that allow various kinds of chemical resistant polymers to decompose and transform. Therefore, compared with conventional wastewater treatment conditions, fungi can dissolve many target degradants that are insoluble in water [12]. It has been reported that this phenomenon is important for how to degrade dye wastewater processes, including bioadsorption, bioaccumulation and biohealth [13].

A large number of fungi, particularly white rot fungi, have been found to remove various colors from wastewater. Mustafa et al. [13] studied a new method for dye biodegradation using fungal strains. White rot fungus Panus Tigrinus was used as biosorbent to decolorize active blue 19.The kinetic study showed that the selected dyes could be bio-adsorbed under the condition of quasi-second-order kinetic model. Therefore, chemisorption may be a rate-limiting step of biosorption. It is proved that the decolorization rate is about 83% at pH=2.When pH=4, the decolorization rate of active blue 19 is about 23%.The high decolorization rate of dyes at pH=2 is the result of electrostatic attraction between negatively charged dye molecules and positively charged fungal surfaces. At a higher pH value, electrostatic repulsion is generated between the fungal surface and the dye molecules, resulting in a lower decolorization rate of dye wastewater[13].Mishra found that fungi are effective at adsorbing dye wastewater due to their large surface area and their ability to separate the target adsorbent from the dye wastewater. Fungal biosorption has great advantages in the treatment of dyeing wastewater, because the treatment environment has little influence on the adsorption of dead fungal mycelia.

Fungi biodegrade complex dyeing wastewater by extracellular lignin decomposing enzymes, including laccase, manganese peroxidase and lignin peroxidase. Kariminia et al. [14] found that lignin peroxidase produced by fungus Coprinus Cinereus had a good decolorization effect on acid orange 7. When the treatment conditions were: temperature 25°C, pH 9.0, initial AO7 concentration 50 mg·L-1, the decolorization rate reached 100%.Danouche et al.[15] studied the decolorization rate of acid red 14 by laccase produced by fungi at pH = 5.154 and initial concentration of AR14 at 50 mg·L-1, which reached 97%.

Fungi use enzyme action to carry out a good biodegradation of printing and dyeing wastewater, but in order to ensure the efficiency of biological enzyme treatment needs to maintain the enzyme has a high biological activity, that is, to make the fungal treatment of printing and dyeing wastewater in a mild environment, which is a great limit to the efficiency of biological enzyme treatment of printing and dyeing wastewater.

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Table 1: Decolorization of different dyes by different Fung

The dye type	fungi	treatment effect	references
Alizarin tonight	*Trichoderma harziana BsIII*33	adsorbing capacity 247.05mg/g	Rybczynska (2016) [16]
Dye wastewater	*T. versicolor*	decolorization rate 90%	Kim (2004) [17]
Orange II	*Wood rot fungus strain* F29	decolorization rate 99%	Zhang (2000) [18]
Reactive blue 19	*Panus tigrinus*	decolorization rate 83%	Liu (2018) [13]
Acid orange 7	*Coprinus cinereus*	decolorization rate 99%	Yousefi V (2016) [14]
Acid red 14	White-rot fungi	decolorization rate 97%	Danouche M (2021) [15]

2.2 Treatment of dye wastewater by microalgae

In recent years, complex microorganisms including various microalgae have been used as biosorbent materials to degrade dye wastewater. For example, the cell walls of algae are made up of many functional groups, such as hydroxyl, carboxylic acid, amino and phosphate. They can remove dye pollution from water phase and effectively decolorize printing and dyeing wastewater [19]. In addition, some studies have shown that the metabolites produced by microalgae treatment of dyeing wastewater can be used as a source of natural and green chemical biofuel substrates. In general, algal biosorbents are receiving increasing attention due to their unique biochemical activities and ubience in the environment, which is important from an economic point of view (low cost compared to other sorbents and high biosorbilities for target compounds).

Deniz and Ersanli [20] studied the experimental material of biological adsorption performance of a physical composite material. The material is composed of spirogyra, rhizozoa and flame-red green algae and is used to remove alkaline red 46.They investigated the biosorption capacity of the algal symbiotic system, which is determined by key process parameters such as solution pH, biosorbent quality, dye concentration and contact time. They found that the biosorbents of the symbiotic system studied performed best at pH=9, with a maximum biosorption capacity of 56 mg/g.Interestingly, the biomass adsorption capacity of single microalgae was significantly lower than that of the symbiotic system[20].Studies have shown that the adsorption mechanism of algae on dyeing wastewater may be due to the mutual adsorption of dye ions and the further diffusion of the functional groups on the surface of algae from dye molecules in the wastewater to the biological polymerization on the functional group.

The mechanism of algae treatment of dyeing wastewater is not only adsorption, but also biodegradation. Similar to fungi, algae can produce azo reductase to degrade azo dyes to break azo bonds, thus decolorizing dyeing wastewater. Dhaneshwar et al. found that the decolorization rate of malachite green under pH 9.0 was 92.4% when chlorella produced azo reductase. Aravindhan et al. found that Caulerpa degradation pH of alkaline yellow dye was 8.0 and the dye removal efficiency was 95.5%.

Although microalgae play a good role in the treatment of printing and dyeing wastewater through adsorption and degradation, microalgae also has its disadvantages. The efficiency of microalgae in the degradation of macromolecular organic matter is low, and as a source of biomass energy, microalgae is difficult to recycle.

Table 2: Decolorization of different dyes by different microalgae

dyestuff type	different microalgae	treatment effect	references
Simulated textile wastewater	*Spirulinaplatensis*	decolourization ratio 97.1%	Aksu Z (2000) [21]
Basic Yellow	*Caulerpa*	removal efficiency 27 mg/g	Aravind (2007) [22]
Acid red 274	chlorella	decolourization ratio 96%	Özer A (2006) [23]
Direct red 31	green alga NCIM 2738	decolourization ratio 96%	Sinha (2016) [24]
indigo blue	Chlorella PSBDU06	decolourization ratio 93%	Revathi (2017) [25]

3. Conclusion

The cost of biological degradation of dye wastewater is low, it is not easy to produce secondary pollution, in line with the national environmental friendly governance requirements, has good development potential. At present, there are many applications for biological treatment of dye

wastewater, but few researches on mechanism should strengthen the depth of theoretical research, and then guide practice by theory, so as to avoid many problems in practical application.

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