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Research progress on co-cultivation of microorganisms in the treatment of printing and dyeing wastewater

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Abstract

Due to the increasing demand for textile products, a large number of textile industries have emerged. The waste water discharged directly flows into the ground and nature, posing a huge threat to the health of people and the natural environment. Biological treatment is considered to be a more promising means of remediation of pollution, it has the characteristics of not easy to cause secondary pollution, natural decomposition, and green and sustainable. Although biological methods are considered to be a promising remediation method, cultivating microorganisms alone is prone to contamination and high harvest costs. Compared with traditional physical and chemical remediation methods, it lacks competitiveness. The use of microbial co-cultivation can realize self-flocculation to reduce harvesting costs, and the culture system is not easy to be polluted, and has high stability and degradability. Therefore, microbial co-cultivation is an economical, energy-saving, and highly efficient technology with broad application prospects.

Keywords

Dye wastewater;Decolorization;Co-culture system.

1. Current status of co-cultivation microbial treatment

A single microbial strain can decolorize dye wastewater, but it often produces harmful by-products that are more difficult to biodegrade than the original dye target removal, and these single microbial strains are usually specific to a dye for biodegradation. Due to the chemical complexity of textile industry wastewater, some research groups have tried to develop more effective microbial processes. The complete degradation of printing and dyeing wastewater may be due to several enzymatic reactions, which means that it is necessary to establish a symbiotic system [1]. An obvious advantage of the symbiotic system in degrading printing and dyeing wastewater is that different strains can degrade dye molecules at different adsorption sites, or can use metabolites produced by another strain to further degrade, and in some cases can mineralize the printing and dyeing wastewater[2].The symbiosis system can be composed of bacteria, fungi, microalgae or a mixture of the three [3].

Current studies have shown that the symbiosis system microbial treatment of printing and dyeing wastewater has a good degradation effect. Different microbial symbiosis systems and similar microbial symbiosis systems treat printing and dyeing wastewater as shown in Table 1.

Table 1Printing and dyeing wastewater treatment by microorganism of consortium

Similar microorganisms	Dyestuff type	Treatment effect	references
Aspergillus sp. XJ-2	Mixed dyes	Decolorization rate 98%	Huiran Pan (2017)[4]

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Aspergillus sp. XJ-2			
bacterial consortium bacterial consortium	Reactive Blue	Decolorization rate 96%	Khouni (2012)[5]
Different types of microorganisms	Dyestuff type	Treatment effect	references
Providencia sp. P. aeruginosa	Reactive black 5B	Decolorization rate 90%	Patil P S(2010) [6]
Activatedsludge C.sorokiniana XJK	Disperse Blue 2BLN	Decolorization rate 76%	Li Xie(2017) [7]

The microbes in the culture system are macro-regulated through their own interaction mechanism. Therefore, studying the microscopic effects of the microbes in the co-cultivation system is of great significance for understanding the symbiosis system for the treatment of printing and dyeing wastewater. The symbiosis mechanism of microorganisms in the symbiosis system is diverse, and most of the current researches analyze the interaction between microorganisms from the perspective of signal conduction between microorganisms at the metabolic level.

Signal transduction is that microorganisms use their own secreted metabolites to influence the shape and metabolic level of another microorganism. Studies have shown that the phthalyl homoserine lactone and other molecules secreted by the bacteria in the co-culture system will affect the properties and metabolism of green algae. The interaction of bacteria and algae in the co-cultivation process is the main factor for the high efficiency of the bacteria-algae colony system in decolorizing printing and dyeing wastewater. Therefore, the study of the complex interaction in the bacteria-algae colony system has become a current research hotspot.

2. Application of Co-cultivation of Microorganisms in Treatment of Printing and Dyeing Wastewater

2.1. Application of mixed bacteria system in wastewater

The biological enzyme activity of a single strain will be affected by the presence of other microorganisms, while the biological enzyme activity of a symbiotic system is different from that of a single strain. In the symbiosis system, the microorganisms are processed cooperatively to greatly increase the activity of biological enzymes. Pseudomonas sp. SUK1 can decolor the dye, but Pseudomonas sp. LBC2 and LBC3 cannot. However, the co-cultivation of these three microorganisms is more effective in decolorizing printing and dyeing wastewater than the single strain SUK1[8] .Within 15 minutes, the decolorization rate of Orange II by Enterobacter cloacae was 10%, and the decolorization rate of Orange II by Enterococcus was 23%, and the two co-cultured NAR-1 to achieve complete decolorization[9].Using NAR-1 co-cultivation to decolorize purple safflower by 70% within 60 minutes, and the combination formed by adding Citrobacter freundii to NAR-1 completely decolorize purple safflower within 30 minutes, and Increased mineralization rate under oxygen conditions[9]. It takes 14 hours to decolorize Crimson R with Chlorella vulgaris, 20 hours to decolor Crimson R by Micrococcus glutamine, and it takes only 3 hours for the co-cultivation of two microorganisms to decolor Crimson R completely[10]. PMB11 co-cultured with Bacillus odysseyi SUK3, Morganella morganii SUK5 and Proteus sp. SUK7, the decolorization rate of reactive blue reached 59% within 3 hours, while the decolorization of reactive blue by a single strain It takes more than 24 hours for the rate to reach 59% [11]. The SDS co-culture composed of Providencia sp. and P. aeruginosa can effectively decolorize Disperse Red 3B, Reactive Black 5B and Disperse Red 7B within 1 h, with a decolorization rate of more than 90%, but a single strain has a decolorization time of 5 -48 h [6].

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Pseudomonas aeruginosa can decolorize the textile wastewater as high as 92% within 30 h, Providence bacteria achieve 84% decolorization rate within 48 h, and the co-cultivation of these two microorganisms can completely decolorize the dye wastewater within 20 h [12]. In the symbiotic system composed of Sphingomonas paucimobilis SP, Staphylococcus epidermidis SE, and Bacillus SP. COD degradation played a role [13]. In the decolorization process of 6 kinds of reactive azo dyes, the symbiotic system composed of Staphylococcus vulgaris and Micrococcus glutamine has a significantly higher decolorization effect than a single microorganism [14]. The decolorization rate of Pseudomonas sp. SUK1 on reactive navy blue HE2R within 72 hours is 78%, the decolorization rate of HE2R by Aspergillus ochrae NCIM -1146 is 61%, and the decolorization rate of HE2R by the two symbiosis system is 92%[15] . The fungus *Penicillium sp.* QQ has a better decolorization effect on azo dyes than the bacteria Exiguobacterium sp.TL, but their symbiosis system has a higher decolorization effect on the same azo dyes [16] .

2.2. Application of bacteria and algae system in printing and dyeing wastewater

Microalgae have potential applications in the pharmaceutical industry, food and feed production, environmental engineering, wastewater treatment, renewable energy and other fields. However, due to technical and economic constraints, the industrial application of microalgae still needs to be considered. Recent studies have shown that there are three ways to improve the economics of microalgae production: a.cultivating microalgae in wastewater to reduce costs related to nutrition and freshwater demand b.fixing carbon dioxide and using microalgae to produce third-generation biofuels c.using high-efficiency The collection method reduces the collection cost and can reduce the total production cost by 20-30%. Biological flocculation is a chemical-free flocculation method due to the use of biological agents. The use of biological flocculants is non-toxic to microalgae biomass and can be recycled and reused, which can further reduce the overall cost. The biological flocculation of algae is carried out by co-cultivation of suitable microorganisms, such as algae-algae, algae-bacteria and algae-fungi. The fungus-microalgae harvesting method is to co-cultivate microalgae and filamentous fungi, and is convenient for recycling. This is an effective method of algae collection. Filamentous fungi such as Aspergillus, Mucor and Penicillium can be used as biological flocculants because of their high efficiency in spheroidizing and harvesting microalgae. Zhou et al. co-cultured with microalgae, a coccobacterial fungus strain Aspergillus oryzae isolated from urban sewage sludge, to effectively treat urban sewage. After treatment, 100% of Chlorella biomass can be harvested and used as a sustainable hydrothermal gasification. raw material. Bhattacharya et al. harvested microalgae by the fungus-microalgae harvesting method, and co-cultured the microalgae with Aspergillus lanuginosa to obtain 99% of the microalgae biomass within 2.5 h. Under optimized culture conditions, higher biomass yield and harvest efficiency were obtained.

2.3. The role of different microorganisms in wastewater treatment in co-cultivation system

In the construction of the symbiosis system, the ratio of each microorganism is one of the keys to the effective treatment of dye wastewater. For example, when the biomass of Streptococcus lessmobilis, Bacillus sp[17]. Separate the symbiosis system of different dye wastewater treatments. Among them, the decolorization efficiency of Bacillus cereus, P. putida, Pseudomonas fluorescens, and Acidophilus sphaerophaga in equal proportions is 3 times higher than that of other proportions[18]. In the decolorization of Reactive Black 5 and Reactive Red by the symbiosis system of Bjerkandera sp. and forest protozoa, the ratio of the symbiosis system is 2:3 and the decolorization rate is higher than 2:4. When the ratio of Sphingomonas paucimobilis, Bacillus cereus, and B. cereus in the symbiotic system is 1:1:2, the methyl red is completely decolorized and the COD removal rate reaches 98%[18].

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The symbiosis system combined with anaerobic and aerobic in the process of treating printing and dyeing wastewater can effectively improve the decolorization efficiency. The anaerobic step involves the reductive cleavage of the azo bond, resulting in decolorization [20]. It is speculated that fully mineralized aromatic amines can be achieved under aerobic conditions [18]. Taking enterococcus and cloacae symbiotic system (NAR -1) as the research object, orange II was treated aerobic under aerobic conditions to obtain sulfamate. In contrast, a single strain cannot degrade to sulfamic acid even after 5 days[19]. The NAR-2 (NAR-1 + citrate bacillus) symbiosis system can achieve continuous decolorization under aerobic conditions and the mineralization of vat dyes under aerobic conditions. The study observed that the cell density in NAR-2 changes significantly with the oxygen content. Under anaerobic conditions, the cell density of Enterococcus accounted for 82%. Under aerobic conditions, the cell density of Cloacae and Citrobacter increased to 50.24% and 33.69%, respectively, within 48 hours[21]. An anaerobic and aerobic treatment system is used to study the decolorization of Acid Red 18. Anaerobic can make the decolorization rate of dyes reach more than 98%, and the degradation rate of COD can reach more than 80%. HPLC analysis showed that during the aerobic process, more than 80% of the 1-naphthylamine-4-sulfonate produced anaerobic was completely removed [22]. Compared with traditional anaerobic and aerobic processes, improving the efficiency of oxygen transfer during the biodegradation process or using oxygen supply systems can enhance the degradation of amines in the acid orange 7 decolorization process. The anaerobic-aerobic system can not only mineralize the dye, but also if the micro-aerobic treatment of geotechnical mold and Bacillus perisporidium is used after the aerobic treatment, the degradation of the golden yellow dye can be improved [1]. Aerobic particles are a high-density microbial system that contains different types of bacteria. Each gram of aerobic particle biomass usually contains millions of microorganisms. At a concentration of 5 g/L, it will be completely decolorized within 8-12 hours. Reactive Blue [13]， This is very high compared to previous reports. The advantages of using aerobic particles include easier separation of liquids and solids after treatment, higher metabolism and the ability to withstand higher concentrations of dye wastewater. Because of the structure of amines, aerobic systems are not always able to degrade aromatic amines produced by anaerobic process degradation of dye wastewater. Under anaerobic conditions, the decolorization rate of Reactive Yellow RR is 98%. However, in the process of aerobic treatment, because the metabolites of Reactive Yellow RR will automatically oxidize under aerobic conditions, and the product cannot be further degraded, aromatic amines can only be partially degraded [24].

Textile wastewater has the characteristics of high temperature and high salinity, so extremophiles are a good type of microorganisms for treating printing and dyeing wastewater. For example, the decolorization rate of four extremophiles isolated from hot spots exceeds 70% when treated with reactive black 5 within 24 hours at 65°C[25].At 50℃ and pH 9.0, co-cultivation of Bacillus terreus and Bacillus can decolorize methyl red [26]. Microorganisms from semi-arid areas are more resistant to osmotic pressure, pH and salinity. Several extremophiles isolated from these environments can effectively decolorize Reactive Red 198, Reactive Red 141 and Reactive Blue 214 [27]. The co-culture of Penicillium sp. and Exiguobacterium sp. can tolerate high concentrations of NaCl, and the decolorization rate can exceed 70% within 24 hours[16].

When constructing a symbiosis system, it should be considered that the enzyme activity and enzyme induction are not the sum of the individual enzyme activities and induction amounts of individual strains[28]. For example, the activity of veratrol oxidase is not present in Galactas terrestrial bacteria GG but is present in Brevibacterium BL. In the GGBL symbiosis system, the induction rate of this enzyme in the process of golden yellow dye decolorization is 340% higher than that of BL alone[29]. The activities of riboflavin reductase, extracellular tyrosine, NADH-DCIP and azo reductase are lower than those of individuals. Researchers proposed different degradation mechanisms for the symbiosis system of single strains GG and BL and GGBL, and

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observed that the degradation of amine is only completed by the symbiosis system[29]. No azo reductase was detected in Pseudomonas aeruginosa, azo reductase in Providence was 0.127 units, and azo reductase in symbiosis system was 0.192 units. Similarly, there is no veratrol oxidase in Providence, but 0.178 units in Pseudomonas aeruginosa, and 0.211 units in the symbiosis system after textile wastewater decolorization[13]. The LiP activity of the GR symbiosis system with Micrococcus glutamine is almost the same as that of a single strain, while the Lac activity is lower in the GR; however, the riboflavin reductase (26.56 units) of the symbiosis system is higher than that of the glutamine group (3.6 Unit) enhanced [30].

3. Conclusion

Based on the above, most of the current research on symbiosis systems are bacteria-microalgae symbiosis systems, but there are few studies on fungi-microalgae symbiosis systems. Therefore, the study on the interaction of bacteria and algae in the fungus-microalgae consortium system affects the treatment effect of printing and dyeing wastewater. It is necessary and has good prospects.

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