Adverse Impact of Textile Dye Wastewater on Algae and Aquatic Environment

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Abstract: Dye wastewater from the textile industry has many adverse impacts on the environment and is one of the main factors causing pollution of water resources in particular. Due to technical problems in the textile industry, dyes cannot be completely fixed on textiles and hence the dyes are mixed with water and discharged into the water without treatment or with incomplete treatment. Algae has essential functions in aquatic ecosystems and this paper investigates the effects of dye effluents on algae in several ways, focusing on the important role relationship of azo dyes, the most commonly used dyes today, in the effects of algae and the aquatic environment. In addition, azo dyes are structurally very steady and difficult to break down, which can have a lasting impact on the environment. This article takes the Konto River, which is polluted by dye wastewater, as an example to study and analyze that azo dyes will inhibit the growth of algae and reduce their nutritional value. At the same time, the discharge of azo dyes into the water may cause eutrophication and form a dead zone. This paper suggests that in the future, the government needs to set clearer discharge standards and study more comprehensive utilization of dye wastewater treatment methods to achieve the best results.

1 INTRODUCTION

The problem of water environment pollution is a growing and highly publicized problem. Textile industry waste discharge is considered to be one of the primary causes of pollution of water bodies because more than 8000 chemicals such as nitro, sodium hydroxide, azo group etc. are used in the dyeing process which flows into the outside world with the rinsing of water (Sharma et al., 2021). Dyes are one of the most commonly used raw materials in the textile industry and are also a major source of pollutants, with about 15%-20% of the dyes failing to adhere to the fabric during the dyeing process (Adjid et al., 2022). Dyes mixed with water and discharged directly into rivers without treatment can cause serious environmental pollution problems, however, up to 200 thousand tons of dye wastewater is discharged into the aquatic environment annually (Adjid et al., 2022). The most widely used dyes in the textile sector are synthetic dyes, and azo dyes make up approximately seventy percentage of the annual production of synthetic dyes (Berradi et al., 2019). Dye waste can cause ongoing harm to the environment, especially in aquatic environments, as bacteria in the water cannot degrade dye waste (Lim et al., 2010). Dye waste produced in the textile industry contaminates the habitats of aquatic animals, and these organisms occur in more than one food chain, so toxins are passed along trophic levels and accumulated. At the same time, the dye wastewater generated during the production process of the textile industry seriously reduces the light transmission rate of the waters, and the weak sunlight that enters the water hinders the photosynthesis process of aquatic plants to a great extent, leading to a reduction in the production of aquatic plants, and this seriously affects the food source of aquatic animals (Samchetshabam et al., 2017). Therefore, untreated or incompletely treated dye waste will have a serious impact on the aquatic environment and endanger the life of aquatic animals and plants (Kant, 2012). This article analyzes how dye wastewater affects algae production and how dyes and microfibers affect fish, and makes relevant recommendations based on these negative effects.

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2 CASE DESCRIPTION

Indonesia is one of the regions with the most serious dye wastewater pollution in the world. This article uses Konto River as a case to analyze the impact of dye wastewater pollution on the aquatic environment, aquatic plants and aquatic animals.

As the population continues to grow, the demand for clothing is increasing in various regions around the world, which has promoted the expansion of the textile industry in Indonesia (Adjid et al., 2022). At the same time, the increasing investment value drives the development of TPT in Indonesia (Adjid et al., 2022). BPS pointed out that in 2021, the investment amount in Indonesia's textile industry increased from US$238.89 million to US$279.79 million, and the export volume of clothing products reached 5.8565 million tons (Indonesian Statistic Center 2018 & 2021).

Local villagers told researchers they believed the Konto River was polluted by textile waste. After the interview, it was found that some villagers think that the color of the river changes and the river often emits a bad smell. There were also some who believe that crop yields have decreased recently and that more people are getting sick here. To test the idea, the researchers took samples from four different locations along the Konto River, and tested dye concentrations and COD values in the water.

Table 1: Concentration of Dyes in Konto River Flow (Adjid et al., 2022)

Sample Point	Yellow RGB	Yellow HR	Red 3BS	Red RGB	Everzol Black GSP	Reactive Black WNN	Remazol Navy RGB
Point 1	22.42	68.13	5.30	12.68	2.08	5.37	3.70
Point 2	12.99	53.21	0.13	8.40	0.95	2.22	1.63
Point 3	10.67	46.16	0	0	0	0	0
Point 4	10.67	45.34	0	0	0	0	0

Dye pollution was reported in four villages along the river in Table 1. The dye with the highest concentration in water sources is Yellow HR, an azo dye. Because it has a double-bonded nitrogen group, it is difficult to decompose naturally. Azo dyes contain a variety of carcinogens, such as aminobphenyl. At the same time, azo dyes pose ongoing hazards to the environment because they are not easily degraded by light, microorganisms, and processing in related industries (Sweta and Tank, 2019).

Table 2: Results of the COD Parameter Measurement (Adjid et al., 2022)

Sample Point	COD level ($mg.L^{-1}$)	Description
Sample Point1	40	Not above the quality standard
Sample Point2	320	Exceed the quality standard
Sample Point3	40	Not above the quality standard
Sample Point4	200	Exceed the quality standard

The capacity of aquatic microbes to break down organic matter through oxidation, which lowers the amount of dissolved oxygen in a water body, is measured by COD parameter (Estikarini et al., 2016). Owing to the waste products from the textile sector, 150 mg/L of COD is allowed in water (Adjid et al., 2022). In Table 2, at sampling points 1 and 2, the COD level exceeds the quality standard. According to observations, the sample at point 2 was taken from the dam (Adjid et al., 2022). The COD value of the water is extremely high because a lot of dye waste liquid may accumulate on the riverbed (Adjid et al., 2022). The COD level at Point 4 also exceeds the quality standard, which may be caused by people from nearby villages using river water to wash clothes (Adjid et al., 2022).

3 ADVERSE IMPACT OF DYE WASTEWATER ON AQUATIC ENVIRONMENT

3.1 Dye Wastewater Influence Algae

3.1.1 The Photosynthesis Process Is Blocked

Dye wastewater greatly affect the photosynthesis process of aquatic plants because when large amounts of untreated dyes are discharged into the water, they cover the water surface. This will cause sunlight that would otherwise hit aquatic plants to be absorbed and reflected by the dye on the water surface. Therefore, the absorption of sunlight by aquatic plants, such as algae, will be severely reduced. Sunlight is one of the important factors for algae to perform photosynthesis. Without sufficient sunlight, the algae will not be able to convert the absorbed oxygen and carbon dioxide into glucose. Algae usually act as producers in the food chain, which is at the first trophic level. This means that algae can no longer provide sufficient energy to consumers. This effect is not temporary, most of dyes used in the textile sector today are azo dyes, but they are difficult to degrade naturally, especially in aquatic environments, because bacteria and fungi in the water cannot degrade the dyes. And they also have strong photostability and thermal stability. This may lead to a reduction in the number of consumers or even extinction, a significant reduction in local biodiversity and serious damage to the local ecological environment.

3.1.2 Algae Growth Parameters Are Affected

Each different dye will have a different potential impact on algae. Algae are 50% more sensitive to pollutants than species frequently utilized in toxicology studies when assessing contamination in aquatic environment (Klaine and Lewis, 1995). However, the current concentration of dyes in water is constantly increasing, which severely limits many factors of algae growth, such as pigment concentration, protein concentration and other nutrient concentrations (Samchetshabam et al., 2017). For example, the photosynthetic pigment content of algae can affect its growth, yield and nutritional value. Photosynthetic pigments, such as chlorophyll, are key substances for algae photosynthesis. They have the ability to transform light energy into chemical energy, which is stored in the organic matter it produces, thereby promoting the growth and development of algae. The more photosynthetic pigments that algae contain, the higher the efficiency of photosynthesis, and thus more organic matter can be synthesized. The content of photosynthetic pigments also affects algae production. As the photosynthetic pigment content of algae increases, crop yields will increase accordingly. Because photosynthetic pigments can improve the utilization rate of light energy by algae, the algae can synthesize more organic matter under the same light conditions, thereby increasing production. In addition, the content of photosynthetic pigments also affects the quality of algae. For example, chlorophyll is one of the most important photosynthetic pigments in algae. The higher its content, the higher the nutritional value of the algae. In addition, the protein content in algae will also affect its growth and resistance to pests and diseases. Spirulina platensis is a protein-rich algae, but increasing the dye concentration in the water will cause their growth to be inhibited and nutrient levels to be reduced (Dwivedi, 2013). The utilization of indigo dye has the potential to substantially inhibit the growth and biomass production of S. quadricauda, a freshwater microalga, while also causing alterations to its morphological (Sousa, 2012).

3.2 Dye Wastewater Influence Aquatic Environment

Azo dyes are among the most widely used synthetic dyes in the textile industry, and they are primarily used for dyeing synthetic fabrics. Azo dyes contain substances that form the basic color, and the azo structure has strong stability, so it is widely used in clothing printing and dyeing processes. However, due to problems with dyeing technology, about 15%-20% of dyes cannot be fixed on fabrics (Adjid et al., 2022). Therefore, many nitrogen-containing compounds are discharged into the water body, causing an increase in toxins and severe eutrophication in the water body. There is an increase in biochemical oxygen demand, which is an indicator of the quantity of organic matter present in a water body. It measures the amount of oxygen decomposers need to break down the organic matter. Because the organic matter in the water continues to increase, the decomposers need more oxygen to decompose them. As a result, the water's oxygen level decreases and a dead zone is formed. Dead zone is an oxygen-deprived zone in oceans and lakes, and most organisms cannot survive in anoxic environment. The formation of Dead Zone will seriously damage the ecosystem in the lake and reduce the biodiversity of the ecosystem.

4 ENVIRONMENTAL-FRIENDLY DYE WASTEWATER TREATMENT

4.1 Adsorption of Dye Wastewater Using Coral Wood Legumes

As the problem of dye wastewater pollution becomes more and more serious, more methods have been invented to treat wastewater. The main methods now include membrane separation technology, activated sludge method, adsorption method, etc (Huang et al., 2020). Among them, the adsorption method has gradually attracted attention because of its simple operation, small footprint, simple process flow, good treatment effect, and low cost, especially in the treatment of printing and dyeing wastewater (Huang et al., 2020). Research results show that in order to adsorb different types of dyes, more new adsorbents are needed (Huang et al., 2020). There is a natural adsorbent, coral wood tree legume because of its good adsorption effect and the wide variety of dyes it can adsorb, it can be used as one of the alternatives to other natural adsorbents. The adsorption effect of Coral wood tree legume is influenced by numerous factors, including pH value, adsorbent dosage, dye concentration, and contact time.

Table 3: Adsorption times for dye at various pH values (Bhanuprakash et al., 2015)

Dye	Acidic	Neutral	Basic
Crystal violet	19	19	11
Cotton blue	24	48	48
p-Rosaniline	LA	69	LA
Bromo thymol blue	48	LA	LA
Indigocaramine	72	LA	LA
Eriochrome Black-T	120	LA	LA
Patton and Reeder’s	48	LA	LA

Note: LA-less adsorption

In Table 3, experimental results also show that most dyes adsorb faster in acidic media (Bhanuprakash et al., 2015).

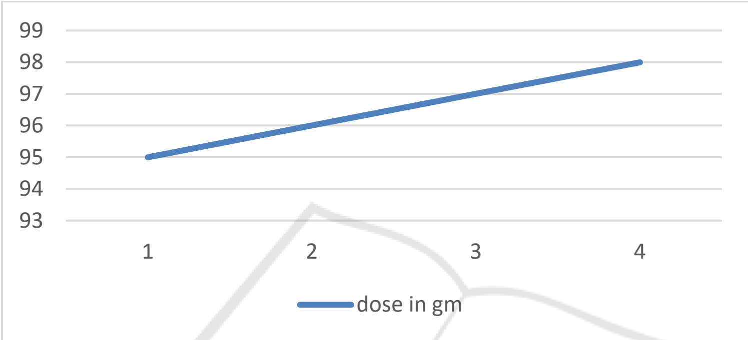

Figure 1: Relation between the dose of absorbent and percentage of removal (Bhanuprakash et al., 2015)

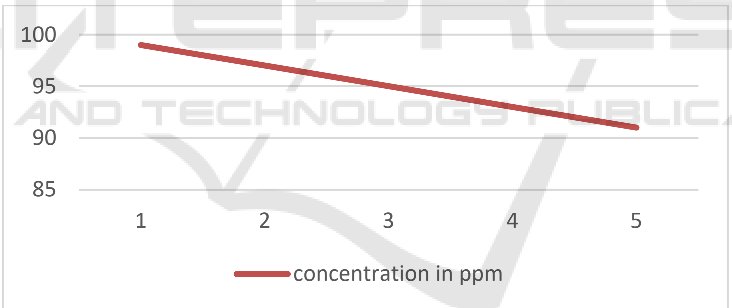

Figure 2: Relation between the concentration of all dyes and percentage of removal (Bhanuprakash et al., 2015)

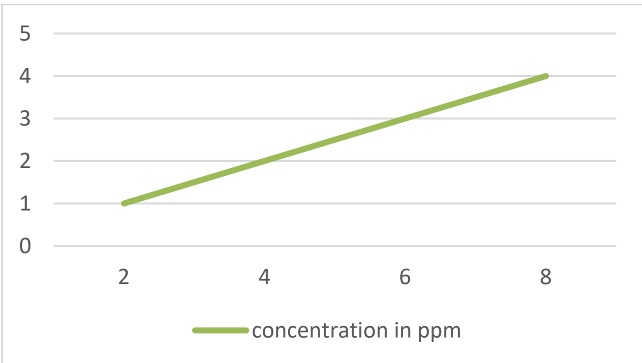

Figure 3: Relation between the contact time and amount of removal (Bhanuprakash et al., 2015)

In Figure 1, as the dose increases, the adsorption capacity increases. In Figure 2, All dye solutions have a decreasing adsorption capability as concentration rises. In Figure 3, the adsorption amount increases with the increase of contact time (Bhanuprakash et al., 2015).

5 CONCLUSION

Dye wastewater produced in the textile industry can cause great harm to the environment. Dye wastewater covering the water surface will reduce light penetration, thereby blocking algae's photosynthesis process. Moreover, the dyes in the water will inhibit the growth of algae and reduce its nutritional level by inhibiting the growing parameters of algae, including pigment and protein composition. At the same time, the discharge of azo dyes into the water will cause bacteria and fungi in the water to decompose more organic matter, resulting in an increase in biochemical oxygen demand. When photosynthesis of plants is blocked and oxygen demand increases, it is easy to form a dead zone. The balance of the local ecosystem will be disrupted, and biodiversity will be severely reduced. All in all, dye wastewater will cause huge harm to the environment, it is necessary to formulate clearer discharge standards and invent new wastewater treatment methods. At the same time, a variety of treatment methods can be used in combination to better treat dye wastewater. For example, the filtration method can be combined with the coral wood adsorption method. Although coral wood can adsorb dyes very well, in order to increase the adsorption area, the coral wood will be quashed into small pieces and then put into the water. After the adsorption process is completed, the coral wood debris will settle on the bottom of the water. If filtration can be used to separate these debris from the water after the coral wood absorbs the dye, it can achieve optimal treatment results.

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