
The Efficacy of Seaweed Powder Application for Enhancing Wastewater Quality in the Cepuk Textile Industry of Nusa Penida

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ABSTRACT

The traditional textile art of Tenun Cepuk from Nusa Penida is highly valued for its intricate designs and cultural importance. Nevertheless, the environmental predicament posed by the textile industry's wastewater, particularly due to dye-related contamination, is substantial and necessitates sustainable remedies. Seaweed powder shows considerable promise as an adsorbent for addressing dye wastewater issues within the textile sector. An essential aspect of this endeavor is to explore the dynamic relationship between different thicknesses and contact durations, as it is pivotal in optimizing the adsorption capacity and effectiveness of seaweed powder for treating dye wastewater. This research, utilizing an Experimental research design with a Posttest Only Control Group Design, is conducted to evaluate the influence of an intervention on the experimental group as compared to the control group. *Euchema cottonii* seaweed, sourced from Nusa Penida, is employed as the adsorbent. Different thicknesses of seaweed powder, namely 5 cm, 10 cm, and 15 cm, are added to tanks. Subsequently, wastewater samples from the Cepuk weaving process are introduced into each of the experimental tanks, alongside a control group. The process is allowed to continue for 24 and 72 hours as varying contact durations. The adsorption outcomes are then subjected to analysis, including parameters such as TSS, TDS, BOD₅, and COD, at the Panureksa Denpasar Laboratory.

The application of seaweed powder as an adsorbent proves to be efficient in decreasing TDS, TSS, BOD₅, and COD levels in Cepuk textile dye wastewater. The extent of reduction relies on the thickness of the adsorbent and the duration of contact. Increased thickness of the adsorbent results in a pronounced reduction in TDS, TSS, BOD₅, and COD levels, leading to an improvement in the quality of wastewater and a safer environmental impact. Specifically, an adsorbent with a thickness of 15 cm effectively reduces TDS to permissible levels. Extended contact times also lead to a significant decrease in these levels. Conclusion: The application of seaweed powder is a viable method for reducing TDS, TSS, BOD₅, and COD levels in textile dye wastewater. The thickness of the adsorbent and the duration of contact play a substantial role in improving the quality of the wastewater.

Keywords: Cepuk weaving, adsorbent, seaweed powder, dye wastewater

INTRODUCTION

Cepuk Weaving in Nusa Penida is a highly valuable cultural heritage on the island of Nusa Penida, a small island located off the coast of Bali, Indonesia. This weaving has been an integral part of the Nusa Penida community's life for centuries. Cepuk Weaving is a distinctive weaving technique in which natural fibers like cotton, coconut thread, and other local plant fibers are used to create beautiful and unique patterns¹. Cepuk Weaving from Nusa Penida not only showcases the high skills of its artisans but also reflects the cultural identity of the local community. The patterns and colors used in this weaving carry deep cultural and historical meanings, often portraying the community's relationship with its surrounding nature².

However, like many other traditional weaving industries, Cepuk Weaving production also faces serious challenges related to the use of synthetic dyes. The use of synthetic chemical dyes, while efficient in producing bright and long-lasting colors, has led to significant environmental issues. Waste from synthetic dye compounds generated during the weaving process often contains hazardous chemicals that pollute the environment, including rivers and oceans, and can pose risks to the health of the people involved in the production and use of Cepuk Weaving products. Based on the research findings, Cepuk Weaving waste needs to undergo waste management before being discharged into the environment. The levels of parameters such as TDS, TSS, color, total chrome, BOD, and COD still exceed the required wastewater quality standards³.

The use of synthetic chemical dyes in the textile industry has caused serious water and soil pollution.

Synthetic textile dyes form a substantial category of organic substances and have adverse impacts on the environment⁴. These synthetic dyes often contain hazardous compounds that are difficult to break down by the natural environment, thus threatening aquatic and soil ecosystems, as well as the quality of water used by the community⁵. Dyes are recognized as micro-contaminants that are detectable in aquatic ecosystems⁶. Textile dyes greatly diminish the visual appeal of water systems, elevate the demand for biochemical and chemical oxygen (BOD and COD), hinder the process of photosynthesis, obstruct plant growth, become part of the food chain, exhibit resistance and buildup, and could potentially contribute to harmful effects, genetic alterations, and the development of cancer⁷.

Textile industry-related water pollution alters environmental circumstances through the release of extensive wastewater containing a variety of dyes⁸. The use of natural dye waste adsorbents from natural sources like seaweed powder helps mitigate these negative impacts because seaweed powder is capable of adsorbing and binding unwanted dye compounds, thereby reducing environmental pollution⁹. The adsorption efficiency of the seaweed biochar produced is similar to that of various commercially available adsorbents, indicating its suitability for widespread use¹⁰. The use of natural-based adsorbents for textile dye waste, such as seaweed powder, holds significant importance in the context of the environment and sustainability.

METHODS

This research is an experimental study utilizing a Posttest Only Control Group Design, with the objective of assessing the impact of treatment (intervention) on the experimental group by comparing it to the control group. The *Eucheuma cottonii* seaweed used as an adsorbent is sourced from Nusa Penida agriculture. The seaweed powder is meticulously cleaned to remove impurities, then

sun-dried for 2 days. Afterward, it is blended and sifted through a 300µm mesh. The powdered particles are then dried in an oven at 105°C and stored for use as an adsorbent medium. During the application process, experimental tanks are prepared based on the number of treatments. Seaweed powder is placed in the tanks at thicknesses of 5 cm, 10 cm, and 15 cm. Subsequently, samples of wastewater

from the Cepuk weaving process, with a volume of 1.5 liters, are introduced into each experimental tank, along with a control group. This setup is left for 24 hours and 72 hours to allow for varying

contact times. The adsorption outcomes are evaluated for parameters such as TSS, TDS, BOD₅, and COD at the Panureksa Denpasar Laboratory.

Table 1. The results of the One-Way ANOVA analysis of liquid waste quality between the control group and the treatment group using seaweed powder adsorbent at various thicknesses

Treatment Groups	Significance Value (95% Confidence Level, $\alpha = 0.05$)			
	TDS	TSS	BOD ₅	COD
Control and 5 cm	0.654	0.228	0.343	0.052
Control and 10 cm	0.010*	0.000*	0.000*	0.082
Control and 15 cm	0.000*	0.000*	0.000*	0.174
5 cm and 10 cm	0.056	0.024*	0.011*	0.848
5 cm and 15 cm	0.001*	0.018*	0.003*	0.585
10 cm and 15 cm	0.099	0.891	0.541	0.723

Data analysis involves assessing data normality using the Kolmogorov-Smirnov test. Following this, a One-Way ANOVA test is

performed to determine differences in wastewater quality among the treatment groups.

RESULTS AND DISCUSSION

The Effect of Seaweed Powder Adsorbent Thickness

Seaweed powder can be utilized as an adsorbent to reduce Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) in dye wastewater. Seaweed powder possesses adsorption properties that enable it to absorb organic compounds, including dyes, from water¹⁰. When seaweed powder is added to dye wastewater, the dyes can adhere to the surface of the seaweed powder through chemical interactions, thus decreasing the dye

concentration in the water. Seaweed powder can also serve as a filtering medium to settle solid particles¹¹, which constitute Total Suspended Solids (TSS). As dye wastewater flows through seaweed powder, solid particles in the wastewater can be trapped and settled by the seaweed powder, consequently reducing the TSS concentration in the water. Based on research results, as shown in Figure 1 and Table 1, there is a decrease in

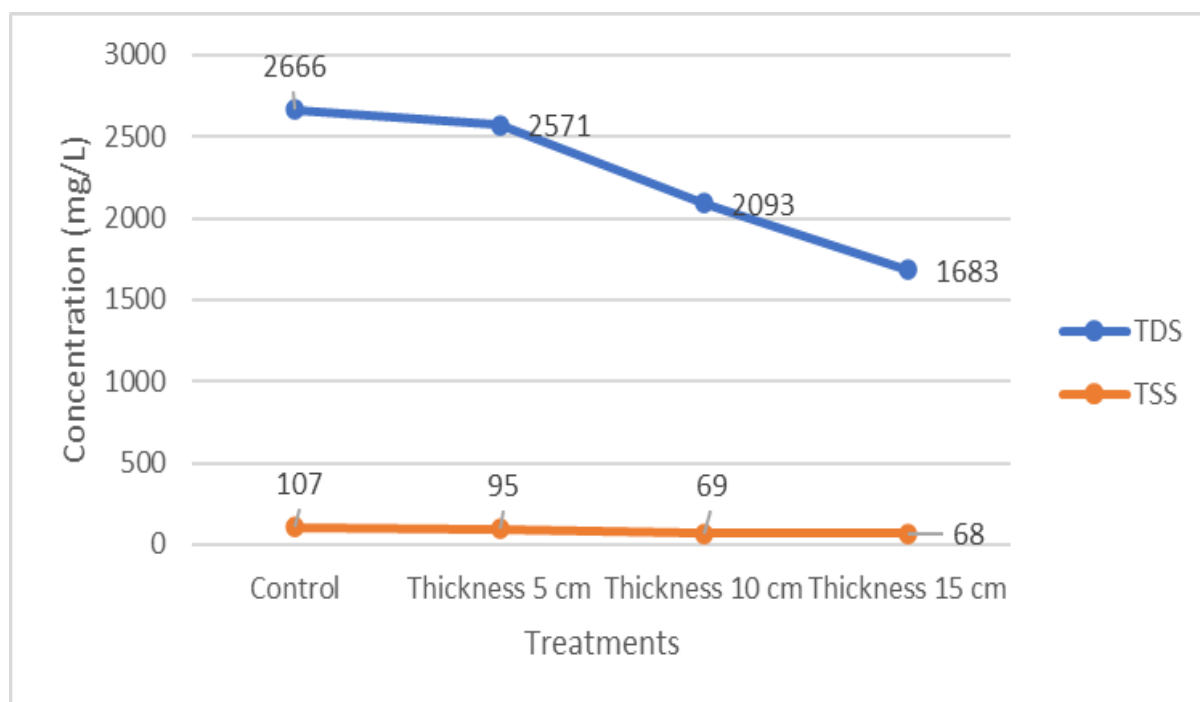


Figure 1. The Effect of Seaweed Powder Adsorbent Thickness on TDS and TSS in woven dye wastewater

TDS and TSS levels in Cepuk weaving dye wastewater, and the TDS level meets the wastewater quality requirements. The thickness of seaweed powder, as seen in its use as an adsorbent or filter medium, can influence its ability to reduce Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) in dye wastewater. The thickness of seaweed powder can act as a factor affecting the efficiency of the TDS and TSS reduction process. Based on Figure 1 and Table 1, a decrease in TDS and TSS levels is evident, with significant differences observed in the control group at thicknesses of 10 cm and 15 cm. However, there are no significant differences at these two thicknesses, suggesting that a 10 cm thickness can be considered for further development, or further research can be conducted to determine the optimal thickness for seaweed adsorbents.

The thickness of seaweed powder used as an adsorbent medium can impact adsorption capacity and the contact time between seaweed powder and organic compounds, including dyes. A thicker layer of seaweed powder provides more surface area for interaction with the organic compounds in dye wastewater, allowing the seaweed powder to absorb more dyes¹². With the optimal thickness, seaweed

powder has more time to attract dyes from the water to its surface, reducing the TDS concentration.

The thickness of seaweed powder in a filtration setup can affect its capacity to retain solid particles forming TSS (Total Suspended Solids). A thicker layer of seaweed powder provides more space to trap the solid particles present in the wastewater¹³. Sufficient thickness also allows the solid particles in dye wastewater to settle and get trapped within the seaweed powder layer, reducing the TSS concentration in the water. The influence of equilibrium and saturation needs to be considered, so that the seaweed powder thickness can reach an adsorption balance, where increasing thickness won't result in a significant improvement in TDS and TSS reduction. Therefore, the use of an optimal seaweed powder thickness needs to be evaluated through experimentation and research.

Seaweed powder can be used as an adsorbent to reduce Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in dye wastewater. Seaweed powder can act as an adsorbent to absorb some of the organic compounds present in dye wastewater. Thus, seaweed powder can lower the levels of organic compounds available for microorganisms to break down. As a result, the

use of seaweed powder can help reduce BOD in dye wastewater by decreasing the organic load broken down by microorganisms in the aquatic environment¹⁴. Seaweed powder can absorb some of the organic compounds contributing to the COD value in dye wastewater. By absorbing these compounds, seaweed powder can reduce the COD value of the wastewater. The use of seaweed powder can help reduce chemical pollution in water by lowering the levels of organic compounds that require oxygen for breakdown. This is evident in the decrease of BOD and COD in Cepuk weaving dye wastewater, as shown in Figure 2.

According to Table 1, it indicates a significant difference in the reduction of BOD5

based on variations in the thickness of seaweed adsorbents. Thicknesses of 10 cm and 15 cm show a significant difference from the control group in terms of BOD5 reduction. However, these two thicknesses are not significantly different, which can be attributed to suboptimal absorption and contact time. The BOD5 levels still indicate values above the optimal requirements, suggesting the need for a combination with other adsorbents. Similarly, with COD levels, the optimization is not yet at its maximum with the treatment of adsorbent thickness. Seaweed powder has limited adsorption capacity. If dye wastewater contains a high amount of organic compounds, seaweed powder may quickly reach its adsorption capacity, thus no longer effectively reducing COD.

The Effect of Seaweed Powder Adsorbent contact time

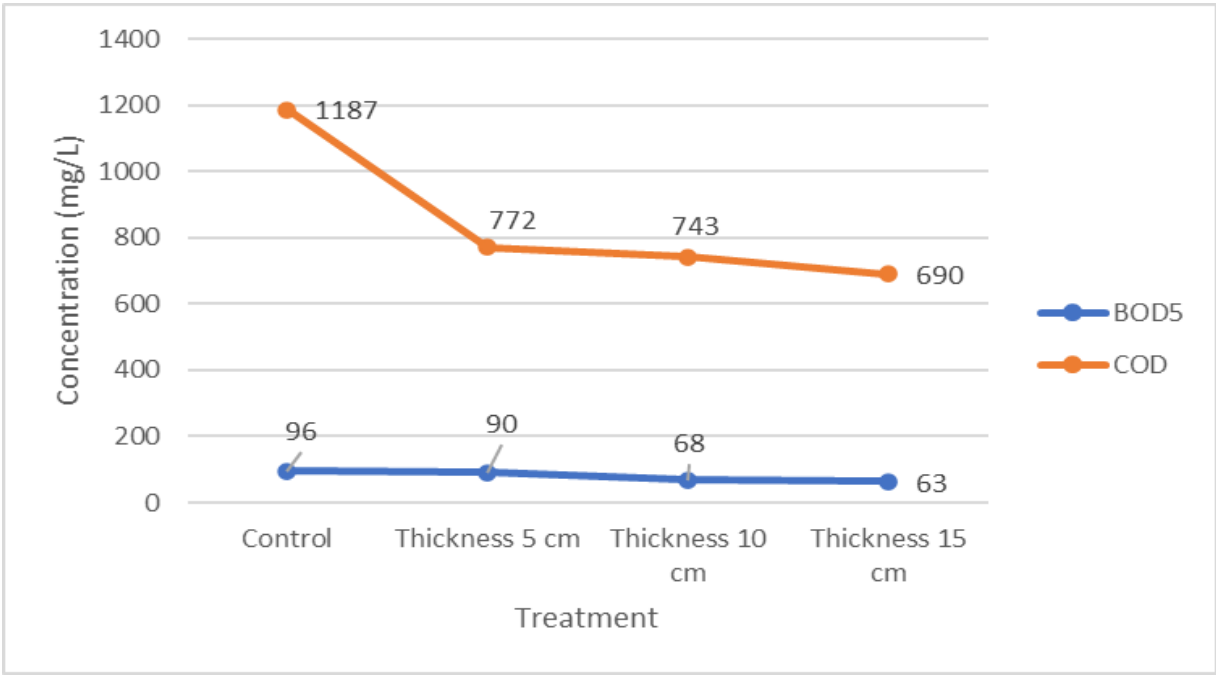


Figure 2. The Effect of Seaweed powder Adsorbent Thickness on BOD5 and COD in Woven Dye Wastewater

The contact time between seaweed powder adsorbent and dye wastewater is crucial in reducing Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). Figure 3 and Table 2 demonstrates a decrease in TDS and TSS levels with variations in the contact time between seaweed powder adsorbent and Cepuk weaving dye wastewater.

Based on Figure 3 and Table 2, it indicates a significant decrease with variations in contact time of 24 hours and 72 hours in both TDS and TSS levels. The TDS levels meet the maximum wastewater quality requirements. Figure 3 demonstrates reductions in TDS and TSS levels for both 24-hour and 72-hour contact times, although

statistically, there isn't a significant difference between these two treatments. A longer contact time allows seaweed powder more opportunities to interact with the dissolved compounds in dye

wastewater. During an extended contact period, seaweed powder can attract these dissolved compounds to its surface through the adsorption process¹⁵.

Table 2. The results of the One-Way ANOVA analysis of liquid waste quality between the control group and the treatment group using seaweed powder adsorbent at contact time

Treatment Groups	Significance Value (95% Confidence Level, $\alpha = 0.05$)			
	TDS	TSS	BOD ₅	COD
Control and 24 hours	0.022*	0.004*	0.005*	0.061
Control and 72 hours	0.018*	0.003*	0.003*	0.049
24 hours and 72 hours	0.945	0.938	0.867	0.917

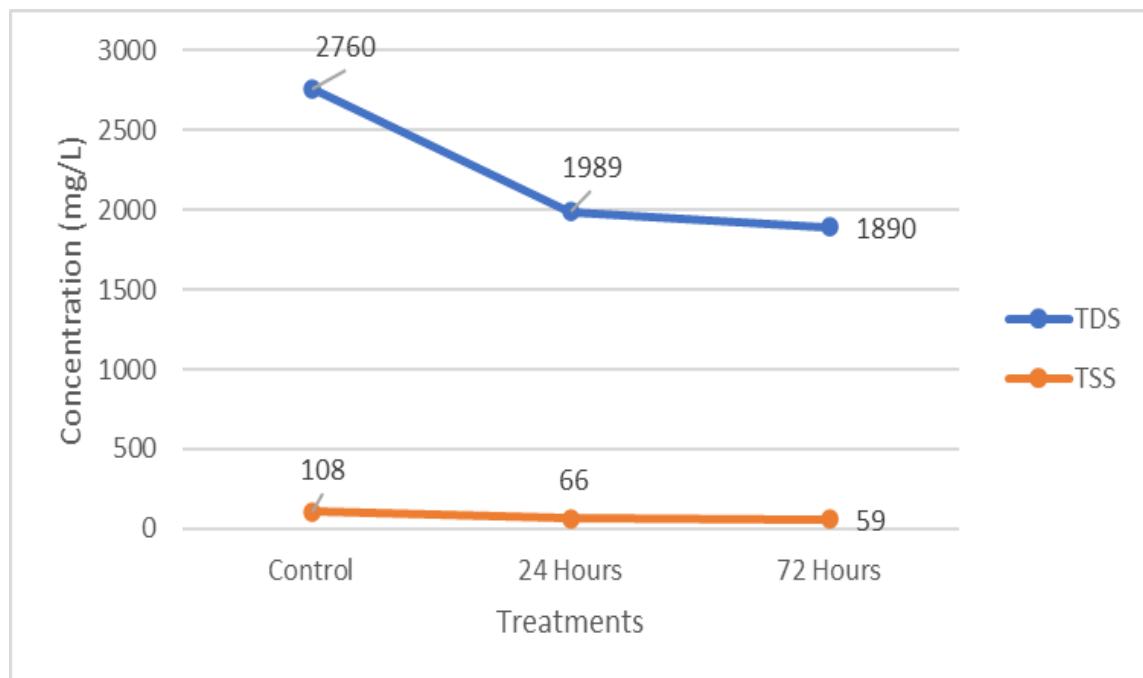


Figure 3. The Effect of Seaweed Powder Adsorbent contact time on TDS and TSS in woven dye wastewater

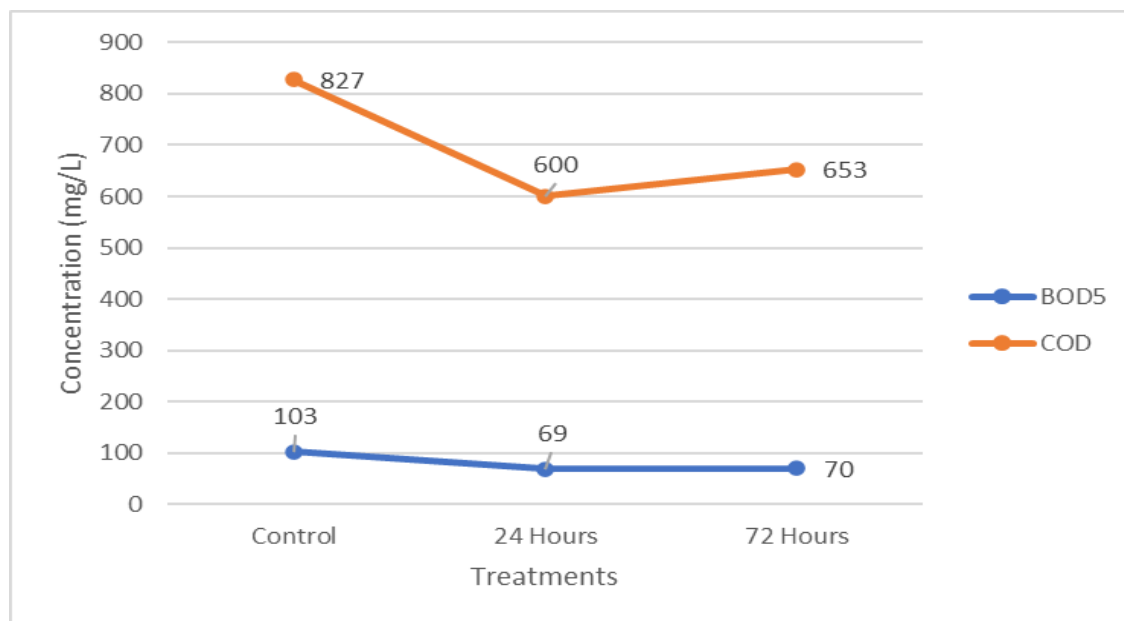


Figure 4. The Effect of Seaweed Powder Adsorbent contact time on BOD5 and COD in woven dye wastewater

The longer the contact time, the more dissolved compounds can be adsorbed by seaweed powder, reducing the TDS concentration in the water. A sufficiently long contact time enables seaweed powder to capture suspended solid particles in the water. Solid particles within TSS may become trapped or adhere to seaweed powder during prolonged contact time. This leads to a reduction in TSS concentration in dye wastewater. The optimal contact time for reducing TDS and TSS will vary depending on the specific characteristics of the wastewater and seaweed powder used. Experimental processes and testing will be required to determine the most effective contact time for reducing TDS and TSS according to the specific situation. Increasing contact time may enhance the efficiency of TDS and TSS reduction, but other factors such as flow rate, pH, and operational conditions should also be considered.

The contact time between seaweed powder adsorbent and dye wastewater significantly affects the reduction of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in the wastewater. A longer contact time provides more opportunities for seaweed powder to interact with organic compounds in the dye wastewater. Based on research results, as shown in Figure 4, there is a

decrease in BOD5 and COD with the use of seaweed powder adsorbent.

Seaweed powder has the capability to adsorb some of the organic compounds present in wastewater, reducing the organic load that needs to be broken down by microorganisms in the aquatic environment¹⁶. Consequently, with a longer contact time, more organic compounds can be adsorbed by seaweed powder, thus reducing BOD in dye wastewater. A longer contact time allows seaweed powder more time to interact with the organic compounds that contribute to COD in dye wastewater. Seaweed powder can adsorb some of these organic compounds through the adsorption process, which reduces the quantity of compounds requiring oxygen for chemical breakdown. With a longer contact time, more organic compounds can be adsorbed by seaweed powder, thus reducing the COD value of the wastewater.

The research results indicate that the COD levels are still above the required limits, even showing an increase compared to the 24-hour contact time. This could be attributed to complex chemical interactions, reversible reactions, and limitations in adsorption capacity. Some organic compounds in dye wastewater may undergo complex chemical reactions with seaweed powder¹⁷, leading to an

increase in COD. For instance, oxidation reactions between specific organic compounds and components of seaweed powder might result in the formation of more complex compounds that elevate COD¹⁸. In some cases, the adsorption reactions between seaweed powder and organic compounds may be reversible, meaning that compounds previously adsorbed on seaweed powder can be released back into the solution with longer contact

times¹⁹, increasing COD. Seaweed powder has limited adsorption capacity. If wastewater contains a high amount of organic compounds, seaweed powder may quickly reach its adsorption capacity, and extending the contact time may not lead to further COD reduction. Therefore, a combination with other adsorbents is necessary to optimize wastewater treatment²⁰.

CONCLUSIONS AND SUGGESTIONS

The use of seaweed powder as an adsorbent demonstrates its ability to lower TDS, TSS, BOD5, and COD concentrations in the wastewater from Cepuk woven dyeing. The extent of reduction in these parameters is influenced by both the thickness of the adsorbent and the duration of contact. Increased thickness of the adsorbent leads to a notable decrease in TDS, TSS, BOD5, and COD levels, resulting in an enhanced quality of wastewater and an environmentally safer outcome. For instance, an adsorbent with a 15 cm thickness effectively lowers TDS levels below the required maximum. Furthermore, the contact time plays a

crucial role in driving down these levels, with longer contact periods yielding more substantial reductions.

According to the findings of the study, additional efforts are essential to achieve a more optimal reduction in TDS, TSS, BOD5, and COD levels using seaweed powder as an adsorbent. This can be accomplished through modifications or by combining it with other adsorbent materials, taking into consideration factors such as agitation, flow rate of wastewater, pH levels, and the quality of the adsorbent being used.

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