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The Effectiveness of Seaweed and Coconut Fiber Combination as Adsorbents for Wastewater Treatment in Weaving Home Industries in Nusa Penida, Klungkung, Bali: A Study on BOD, COD, and DO Quality

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ABSTRACT

The wastewater generated from the Cepuk weaving process in Nusa Penida poses significant environmental challenges, necessitating appropriate treatment before discharge. This study assesses the effectiveness of seaweed powder (SWP) and coconut husk powder (CHP) as adsorbents for treating wastewater from the Cepuk weaving industry. Changes in water quality were evaluated through the measurement of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) levels before and after the adsorption process. Filtration and adsorption were conducted by constructing a basin to channel wastewater to the adsorbent media arranged according to treatment variations. The results indicated that the combination of seaweed powder and coconut husk powder effectively reduced BOD and COD levels while enhancing DO concentrations in the wastewater from the Cepuk dyeing process. The three different combination variations T1, T2, and T3 do not show significant differences; however, all three have the same level of effectiveness. The absorption efficiency of colorants and organic substances present in the textile waste improved with increasing adsorbent thickness. Further research on other factors influencing BOD, COD, and DO, such as adsorbent ratios, flow rates, and environmental conditions, may be necessary to optimize the application of these adsorbents.

Keywords: *wastewater treatment, BOD, COD, DO, adsorben, seaweed, coconut husk*

Introduction

Indonesia is one of the countries with a rapidly growing textile industry, including traditional weaving industries. The weaving home industry in Nusa Penida, Klungkung, Bali, has made a significant economic contribution to the local community (Amir, 2017). However, this activity also produces wastewater containing hazardous organic and inorganic substances, which, if not properly managed, can pollute the environment. The weaving craft is a traditional industry that generates wastewater, particularly from the dyeing and coloring processes of fabrics (Kopperi et al., 2023). This wastewater contains dyes and hazardous chemicals such as heavy metals, organic compounds, and oxidizing agents, which, if discharged directly into the environment without proper treatment, can contaminate water and soil sources (Al-Tohamy et al., 2022). This pollution can have negative impacts on water quality, aquatic life, and human health in the surrounding areas, making the treatment of wastewater from the weaving industry crucial to prevent broader environmental damage (Wang et al., 2022).

Water quality parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO) are important indicators for assessing the level of water pollution from this industrial wastewater. Textile waste, especially from the dyeing and coloring processes, often contains a large amount of organic materials (Amina et al., 2021). A high BOD level indicates that the waste contains a significant amount of organic matter (Nishat et al., 2023), which can deplete oxygen in the water and harm aquatic life. A high COD indicates the presence of chemicals and dyes that are not easily biodegradable, which can contaminate water and be harmful to the environment if not properly managed (Lellis et al., 2019). Untreated weaving waste can lower the DO levels in water bodies because organic materials and chemicals from the waste consume oxygen during decomposition (Azanaw et al., 2022). By monitoring BOD, COD, and DO, we can assess the level of pollution from weaving waste and the effectiveness of the waste treatment process in maintaining water quality and the environment.

Effective and environmentally friendly wastewater treatment technologies are increasingly important to preserve aquatic ecosystems. Natural adsorbents, such as seaweed and coconut husk powder, have great potential as alternative solutions for wastewater treatment due to their abundant availability, low cost, and environmentally friendly properties. The combination of these two materials is expected to enhance the adsorption capability of pollutants in the wastewater. In previous research, it was shown that the use of seaweed (*Eucheuma cottonii*) powder can reduce BOD and COD levels in Cepuk weaving waste (C. D. Sundari et al., 2024). Similarly, coconut (*Cocos nucifera*) husk powder can improve wastewater quality by decreasing BOD and COD levels in Cepuk weaving wastewater (C. D. W. H. Sundari et al., 2023).

This study aims to evaluate the effectiveness of a combination of seaweed and coconut husk powder as adsorbents in treating wastewater from the Cepuk weaving home industry in Nusa Penida. The study will measure changes in water quality based on BOD, COD, and DO parameters before and after the adsorption process. The results of this research are expected to provide a sustainable solution for wastewater treatment in the weaving industry and serve as a reference for using natural materials in wastewater treatment on a broader scale.

Research Method

The type of research conducted in the second year is a True Experimental study using a Posttest Only Control Group Design. The objective is to measure the effect of the treatment (intervention) on the experimental group by comparing it with the control group.

Preparation of Seaweed Powder (SWP) and Coconut Husk Powder (CHP)

Seaweed and coconut husk obtained from Nusa Penida were thoroughly cleaned to eliminate any impurities. The cleaned materials were then sun-dried for two days. After drying, the seaweed and coconut husk were chopped into small pieces or blended, followed by sieving through a 300 µm mesh. The granulated seaweed and coconut husk were further dried in an oven at 105°C. Once dried, they were stored in a desiccator and prepared for use as adsorbent media. Other filtering media, such as coconut shell charcoal, zeolite stones, and silica sand, were also prepared for the filtration process. Each filtering and adsorbent medium is arranged as shown in Figure 1. The arrangement is tailored to the specific filtering and adsorbent media used.

Cepuk woven waste adsorption filtration model

Each filtering and adsorbent medium is arranged as shown in Figure 1. The arrangement is tailored to the specific filtering and adsorbent media used.

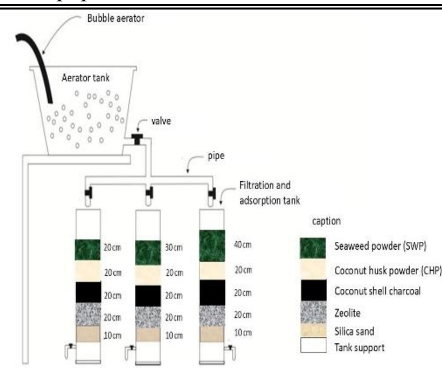

Fig del with combined SWP and CHP adsorbents

Filtration and Adsorption Process

Initially, a 10-liter sample of wastewater is placed in the experimental tank. The sample then undergoes aeration for 30 minutes to enhance treatment. After aeration, the wastewater is channeled through the adsorption and filtration pipes. Once the adsorption and filtration processes are complete, the treated wastewater is collected for quality analysis. Samples of both untreated wastewater (control) and treated wastewater are sent to the Panureksa Laboratory in Denpasar for evaluation. Finally, the quality of the wastewater is measured, focusing on the parameters of BOD_5, COD, and DO.

Statistical analysis

The data was analyzed using Microsoft Excel (2010) and the Statistical Package for the Social Sciences (SPSS; version 23), with one-way ANOVA applied to the experimental results and a significance level established at p-value < 0.05..

Results and Discussions

The effectiveness of the combination of seaweed powder and coconut fiber with various composition variations resulted in a reduction of BOD5 and COD values, as well as an increase in DO, as presented in Figures 2 and Figure 3. The results of the One-Way ANOVA statistical test, indicating significant differences among the treatments, are presented in Table 1.

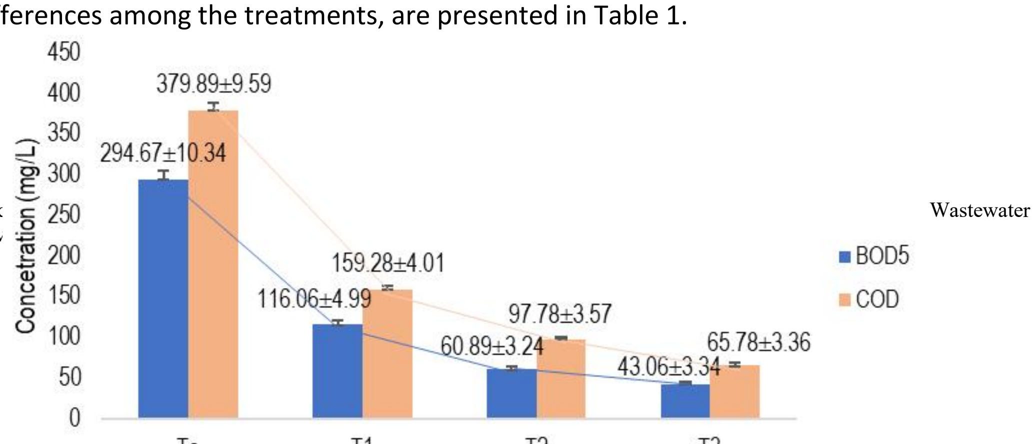

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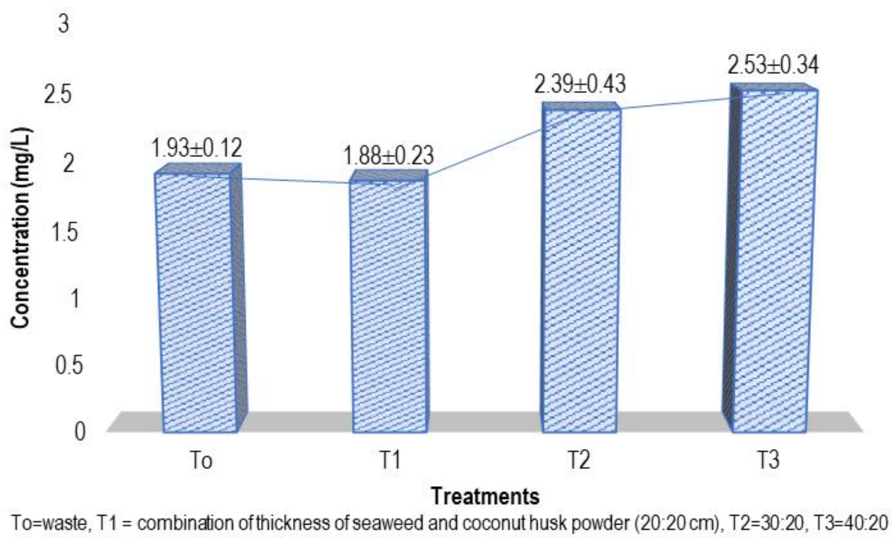
Figure 2. Reduction of BOD_5 and COD in Cepuk Weaving Liquid Waste Using Various Treatment Methods with Combined Seaweed and Coconut Husk Powder Adsorbents



Figure
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Table 1. Results of the One Way ANOVA statistical test for each treatmen

Treatments	Sig value (95% confidence interval, α = 0.05)		
	BOD_5	COD	DO
To - T1	0.000	0.000	0.761
To - T2	0.000	0.000	0.692
To - T3	0.000	0.000	0.206
T1 - T2	0.130	0.162	0.334

T1 - T3	0.047	0.035	0.381
T2 - T3	0.622	0.162	0.927

The use of a combination of seaweed powder and coconut husk powder as adsorbents to reduce Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in the dye wastewater of Cepuk woven fabric is an interesting approach to addressing environmental issues. BOD and COD are crucial indicators in assessing water quality, particularly in relation to wastewater containing complex organic and inorganic substances. Waste from the textile industry, including Cepuk woven fabric, often contains dyes that are difficult to degrade and can increase BOD and COD levels when discharged directly into the environment.

Natural adsorbents like seaweed powder and coconut husk powder have great potential in treating wastewater. Both materials are inexpensive, readily available, and possess physical and chemical properties that allow them to function as adsorbents to remove harmful substances from wastewater. Seaweed powder contains polysaccharides capable of binding heavy metal ions and organic compounds (Ordóñez et al., 2023). Moreover, its natural fibers can act as an effective filtration medium. On the other hand, coconut husk powder is rich in lignin and cellulose, enabling it to absorb organic pollutants and dissolved chemical compounds (Vieira et al., 2024). The combination of these two adsorbents aims to enhance the efficiency of absorbing hazardous substances from dye wastewater.

BOD (Biochemical Oxygen Demand) is a measure of the oxygen required by microorganisms to decompose organic matter in water over a specific period (typically 5 days)(Aguilar-Torrejón et al., 2023), while COD (Chemical Oxygen Demand) measures the total oxygen needed to oxidize both organic and inorganic substances (Lacalamita et al., 2024). High BOD and COD levels indicate that the water contains a significant amount of organic matter and chemical compounds requiring oxidation or degradation (Wojnárovits et al., 2024). The use of a combination of seaweed powder and coconut fiber powder as adsorbents works through physical and chemical absorption processes. Organic substances and dyes in the wastewater are absorbed by the surface of the adsorbent. In tests using various thicknesses of the combined seaweed and coconut fiber powders, it was proven that increasing the thickness of the adsorbent layer significantly reduced BOD and COD levels. Based on observations, different thickness combinations of seaweed powder (SWP) and coconut husk powder (CHP) were used. These variations consisted of different ratios of SWP to CHP thickness, namely T1: 20 cm SWP and 20 cm CHP, T2: 30 cm SWP and 20 cm CHP, and T3: 40 cm SWP and 20 cm CHP. The research results (Figure 2) indicated that the thicker the layer of seaweed powder used, the greater the reduction in BOD and COD levels. This finding demonstrates that the adsorption capability of the seaweed and coconut fiber powders is more effective with an increase in the adsorbent layer thickness.

~~Based on Figure 2, there was a significant reduction in BOD and COD levels after wastewater treatment using the adsorbent combination~~ Wastewater treatment using a combination of adsorbents has been able to reduce the average BOD and COD (Figure 2). For example, with the T1 combination (20:20 cm), the BOD level decreased from 294.67±10.34 mg/L to 116.06±4.99 mg/L, and the COD level decreased from 379.89±9.59 mg/L to 159.28±4.01 mg/L. With the increased thickness of the seaweed powder to 30 cm (T2), BOD further decreased to 60.89±3.24 mg/L, and COD dropped to 97.78±3.57 mg/L. At the 40 cm seaweed powder thickness (T3), BOD levels declined to 43.06±3.34 mg/L, while COD levels decreased to 65.78±3.36 mg/L. The graph of these results shows a clear trend that as the adsorbent thickness increases, the reduction in BOD and COD levels becomes more pronounced, indicating that the efficiency of absorbing dyes and organic substances in the textile wastewater improves with the increased adsorbent thickness.

Based on the One-Way ANOVA statistical test conducted (Table 1), several important insights were obtained regarding the significance of differences between each treatment in reducing BOD and COD levels. The ANOVA results showed that for comparisons between To and T1, T2, and T3, the significant values for both BOD and COD were all 0.000, indicating that the reduction in BOD and COD between the treatment without adsorbent and those with adsorbents was highly significant. This demonstrates that the use of a combination of SWP and CHP adsorbents significantly reduced BOD and COD levels in the Cepuk woven fabric wastewater. In comparing T1 with T2, the significant value for BOD was 0.130 and for COD was 0.162, indicating that the differences were not significant. However, the comparison between T1 and T3 yielded a significant value of 0.047 for BOD and 0.035 for COD, showing a significant difference between these treatments. This suggests that increasing the seaweed powder thickness from 20 cm to 40 cm significantly affected the reduction of BOD and COD levels. The comparison between T2 and T3 showed significant values of 0.622 for BOD and 0.162 for COD, indicating no significant difference between them. This suggests that increasing the seaweed powder thickness from 30 cm to 40 cm did not result in a significant difference in reducing BOD and COD levels, even though a slight decrease was observed graphically.

The use of seaweed powder and coconut husk powder as adsorbents has great potential in improving DO levels in wastewater. The combination of these two adsorbents not only aims to reduce BOD and COD but also allows for an increase in DO levels, as it adsorbs organic and chemical substances that may reduce oxygen availability. Therefore, the lower the BOD and COD, the greater the potential for an increase in DO. Based on Figure 3, in the initial condition (To), without adsorbent treatment, the DO level was recorded at around 1.93±0.12 mg/L. After using the adsorbents, the DO level showed an increase. In combination T1, the DO level increased to 1.88±0.23 mg/L. Further increases occurred in combinations T2 and T3, where the DO reached 2.39±0.43 mg/L and 2.53±0.34 mg/L, respectively. This trend indicates that increasing the thickness of the seaweed powder layer tends to increase the DO level, with the highest variation (T3) resulting in the highest DO level of 2.53±0.34 mg/L. This demonstrates the effectiveness of the SWP and CHP combination in improving water quality by increasing dissolved oxygen levels (DO observations).

The ANOVA test was used to determine whether there were significant differences in DO increase among the different treatments. From the statistical analysis results (Table 1), several important points were obtained regarding the significance of differences between treatments. The significant p-values for the differences between To (without adsorbent) and T1, T2, and T3 were 0.761, 0.692, and 0.206, respectively. This indicates that although there was an increase in DO, the differences were not statistically significant at a 95% confidence level (α = 0.05). Comparisons between T1 and T2 yielded a significant value of 0.334, T1 with T3 was 0.381, and T2 with T3 was 0.927. This shows that although there were variations in DO increases, there were no significant differences among these treatments. Overall, despite the observed increase in DO in the graph, statistical analysis indicates that the increase was not statistically significant. This may be due to data variability or other factors affecting DO measurements.

The results showing that variations in the amount of seaweed powder and coconut fiber (T1, T2, T3) did not produce significant differences in the adsorption process may be attributed to several factors. First, the maximum adsorption capacity may have already been reached, so increasing the quantity of either material no longer significantly enhances the adsorption capability (Fang et al., 2021). If the combination of seaweed powder and coconut fiber has reached saturation in absorbing contaminants, varying the amounts of each will not significantly impact the final outcome. Second, the similar porous structure characteristics of these two materials allow both to exhibit nearly identical effectiveness in absorbing organic and inorganic pollutants (Mane et al., 2024). This could make variations in their proportions produce no notable differences. Additionally, if the waste solution has a homogeneous contaminant composition, both seaweed powder and coconut fiber may work equally effectively in adsorbing the same types of contaminants, so changing their proportions does not significantly affect the results. Other factors, such as the interaction between the two adsorbent materials, may also influence the outcome, as competition between them could reduce adsorption effectiveness if one material hinders the performance of the other (Satyam & Patra, 2024). Finally, the diffusion rate of contaminants into the adsorbent pores could be a limiting factor (Abdoul et al., 2023). If the diffusion rate has reached its maximum limit, further addition of seaweed powder or coconut fiber will not affect the amount of contaminant that can be absorbed. Overall, the lack of difference in results across variations in the proportions of these two adsorbents may indicate that they have achieved optimal conditions in the adsorption process or that other factors, such as contact time or particle size, play a more significant role in contaminant absorption effectiveness.

Due to its polysaccharide content, seaweed powder can effectively adsorb a range of heavy metal ions and organic compounds present in water. This adsorption reduces the organic matter accessible for microbial breakdown, leading to a direct decrease in Biochemical Oxygen Demand (BOD). Furthermore, seaweed powder also efficiently adsorbs dissolved colorants (Al-Saeedi et al., 2023), contributing to a further reduction in Chemical Oxygen Demand (COD). Seaweed powder reduces pollutant load in water and allows for increased dissolved oxygen (Arumugam et al., 2018), thereby enhancing DO. In addition to its high lignin and cellulose content, coconut husk powder has a large surface area that can capture small particles in water (Taylor et al., 2023), thereby helping to reduce BOD and COD levels.

The combination of seaweed powder and coconut fiber as adsorbents can reduce Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels in wastewater, while also improving water quality. These materials have a high porosity structure and large surface area, enabling them to absorb both organic and inorganic pollutants. Seaweed powder contains polysaccharides like alginate, which can attract heavy metals and organic particles, forming bonds that prevent contaminants from leaching back into the water (Alba & Kontogiorgos, 2018). These polysaccharides function by drawing pollutants through ion exchange and ionic bonding mechanisms, trapping contaminants on the seaweed's surface and reducing pollutant

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concentrations in the water. Meanwhile, coconut fiber contains cellulose and lignin, which can trap pollutants through strong hydrogen bonding (Mishra et al., 2024). Lignin and cellulose are hydrophobic and lipophilic, making them effective in absorbing organic pollutants such as oils and other substances that are poorly soluble in water. The porous structure of coconut fiber also increases the contact area with pollutants, enhancing adsorption effectiveness. This adsorption process involves both physical mechanisms, where contaminants adhere to the material's surface via Van der Waals forces and hydrogen bonding, and chemical mechanisms, creating stronger and more stable bonds between pollutants and the adsorbent (Akhtar et al., 2024).

This adsorption process not only has a physical effect but also fosters a conducive environment for the growth of natural microorganisms present in wastewater. These microorganisms can use organic substances as a nutrient source, naturally breaking down complex molecules into simpler, environmentally safer components (Mukherjee et al., 2022). By combining the capabilities of seaweed powder and coconut fiber, this process can reduce the oxygen demand required for decomposition (BOD) and decrease chemical contaminants as reflected in COD measurements. This makes the combination of these two materials an effective and environmentally friendly solution for industrial wastewater treatment.

Conclusion

The use of a combined adsorbent of seaweed powder and coconut fiber has proven to be effective in reducing BOD and COD levels while increasing DO in the wastewater from Cepuk fabric dyeing processes. The T1, T2, and T3 treatments did not show significantly different results, so T1 can be used with more economical materials. Further research on other factors influencing DO improvement, such as adsorbent ratios, flow rates, and environmental conditions, may be necessary to optimize the application of this adsorbent.

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Conflic of Interest

The authors declare no conflict of interest.

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