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ACTIVATED CARBON-BASED TREATMENT AS AN ALTERNATIVE SOLUTION FOR BATIK WASTEWATER POLLUTION IN TANJUNG BUMI, MADURA

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ABSTRACT

The vast majority the batik industry produces batik waste containing synthetic dyes that is harmful to the environment. The batik industry is expanding in Indonesia and has an impact on economic growth and socio- cultural development. However, the development of batik industry also increases waste that has a detrimental impact on the environment, resulting in pollution. This also occurred in Tanjung Bumi, one of the centers of the batik industry on the island of Madura, Indonesia. This study aims to find an alternative technology for processing batik waste containing synthetic dyes. The use of activated carbon which is easy to obtain, cheap, simple and effective in decomposing waste is projected to be an alternative, for craftsmen, to process batik waste. The results of the Cr content test showed that there was a decrease in Cr levels in batik wastewater after being given activated carbon; there was a reduction in Cr levels up to 30.83 g/L after giving activated carbon with various concentrations for 21 days. In addition, there was also a significant decrease in the conductivity value of batik waste after being treated with activated carbon. These results indicate that activated carbon can be used as an alternative for batik wastewater treatment. However, to get more optimal results, the use of activated carbon for handling wastewater needs combination with other methods.

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Introduction

Batik is one of traditional textile industries in Indonesia. Batik as Indonesian cultural heritage has gained growing interest from international customers as well as local ones. UNESCO recognizes batik as a world heritage from Indonesia in Masterpieces of the Oral and Intangible Heritage of Humanity (Sulthonuddin & Herdiansyah, 2021). Batik has a variety of patterns and motifs. This diversity has a distinctive character because the geography of an area and different communities' culture strongly influence it (Kridarso, 2018). The shift in fashion tastes towards batik can increase the demand for batik. It also impacts increasing batik production and increasing the economy of batik artisans. However, an increase in batik production correlates with increased residual waste from batik production (Sutisna et al., 2017). Tanjung Bumi is one of the sub- districts in the Bangkalan Regency, one of the batik production centers on Madura Island that used synthetic dyes for batik productions.

Environmental conditions around Tanjung Bumi indicate no awareness of the importance of batik waste management. Communities around the Tanjung Bumi batik industry feel the impact of batik waste in Tanjung Bumi due to synthetic textile dyes as batik dyes. It includes a decrease in water quality, changes in the structure of the biota community, and a decrease in environmental services for water ecosystems, namely the malfunctioning of agricultural land and ponds in the Tanjung Bumi area. Public knowledge of batik and waste management, especially aquatic resources that can support ecosystem sustainability and maintain water quality to support the surrounding community's needs, is significant (Sulthonuddin & Herdiansyah, 2021).

Madura batik production also increases from time to time, so the waste generated is also increasing. However, until now, there is still no processing business for batik waste in Tanjung Bumi, especially waste from synthetic textile dyes in Tanjung Bumi batik productions.Synthetic dyes of textiles are known to contain Phenol, Sulfide, Ammonia, and heavy metals, including Cr, Pb, Cd, Hg, Ar, and Fe, which are very dangerous if they pollute the environment (Ahila et al., 2021) (Kaur, n.d.) (Ratna & Slamet, 2020). Liquid waste generated from the batik industry with synthetic textile dyes is generally large, concentrated in color with a bad smell, high pH, BOD, COD, TSS values , and various hazardous chemicals. These chemicals include Phenol, Cosmetic Soda (NaOH), Sulfuric Acid (H_2SO_4), Nitrite, Sulphide, Baking Soda ($NaHCO_3$), and Soda Ash 2 (Na_2CO_3), which are very dangerous to the environment, including for humans (Malik et al., 2018). The content of phenol and chromium in textile industry wastewater with synthetic textile dyes is very high, so it is hazardous to the environment (Dewi et al., 2019), (Kishor et al., 2021). The content and levels of a pollutant waste that pollutes the environment can be measured using physical-chemical and biological parameters to find out whether pollution has occurred or not and how to handle it (Sakthivadivel et al., 2021).

Textile dyes are organic molecules with high molecular weight and complex structures. These compounds are difficult to remove by conventional treatments, which includes chemical, physical, and biological methods. Because the new synthetic dyes developed are usually chemically and photolytically stable and therefore highly resistant to degradation (Triwiswara, 2019), and resulting in their accumulation in the environment. The development of technology for processing batik waste has been carried out by creating electrolysis technology and nanoparticles coated (Alam et al., 2021). The development of this technology can improve the quality of batik wastewater but requires skills and relatively expensive operating costs for batik artisans. It

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is not acceptable to the community, especially batik artisans. One of alternative solution is used activated carbon to remove batik wastewater. Activated carbon are effective simple, cheap and easy to control batik wastewater. Activated carbon is produced from environmental wastes with high carbon content. Lignocellulosic and coal materials have been used as raw materials planned for manufacturing of activated carbon. There are two approaches for preparing activated carbon that can be used in water purification processes: physical activation and chemical activation. Activated carbon has good potential for adsorbing heavy metals because of its greater surface area, microporous ability, and chemical complexity of its external area.

Research Methods

This research was conducted in Biology Department Universitas Brawijaya and carried out from Juli 2022 to Agustus 2022. The research method for to find an alternative technology for processing batik waste containing synthetic dyes using activated carbon which is easy to obtain, cheap, simple and effective in decomposing waste is projected to be an alternative, for craftsmen, to process batik waste. wastewater that was given activated carbon as much as 0.2 gr, 0.4 gr, 0.8 gr, 1.6 gr, 2.0 gr, 4.0 gr and 10.0 gr added to 250 ml batik wastewater and 250 ml aquades. A sampling of batik waste is taken directly from batik artisans in Tanjung Bumi Madura, that are tested in the Ecology Laboratory and Chemistry Laboratory of Brawijaya University. Analyzing batik waste data was descriptive and using descriptive statistical analysis with SPSS 20.0

Results and Discussion

The batik industry using synthetic dyes will produce liquid waste cloudy, concentrated, and contains hazardous synthetic materials. These synthetic materials are generally poorly soluble and difficult to decompose naturally in the environment. Batik waste with synthetic dyes is classified as a non-biodegradable organic compound that is very dangerous for the environment because it is toxic and becomes one of the sources of harmful pollutants. The dyes commonly used in synthetic textile dyes are remazol, naphthol, and indigosol (Kusumandari et al., 2021). Batik waste contains toxic materials that are harmful to the environment and human. Parameters used to analyze batik waste are the levels of Cr, N-NH3-N, sulfide, fat, TSS, pH, COD and BOD. Based on the measurement results of the levels of batik waste as shown in table 1, it is clear that all measurement parameters have values above the threshold set by the Indonesian government. In order to reduce the high value of these parameters, batik waste is treated using activated carbon as shown in Figure 1.

Activated carbon is added to batik wastewater which has been diluted 50% with distilled water. The provision of activated carbon is 0.2 gr, 0.4 gr, 0.8 gr, 1.6 gr, 2.0 gr, 4.0 gr and 10 gr. After being treated with activated carbon, it was found that based on the conductivity value, the administration of activated carbon weighing 0.2 gr, 1.6 gr and 10.0 gr had the most significant value after 21 days of treatment. In this study, the treatment of carbon aims to determine whether there is a decrease in Cr levels after being treated with activated carbon as much as 0.2 gr, 0.6 gr and 10 gr. The analysis of Cr content in batik waste that had been given activated carbon weighing 0.2 gr, 1.6 gr and 10.0 gr showed the results as shown in figure 2. In these results, there was a decrease in Cr levels from 74.33 gr/L to 64.33 gr/L in administration of 0.2 gr activated carbon, decrease in Cr levels from 74.33 gr/L to 58.17 gr/L in administration of 1.6 gr activated carbon, decrease in Cr levels from 74.33 gr/L to 43.50 gr/L in the administration of 10 gr activated carbon. These results indicate a significant decrease in Cr levels.

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Figure 1. Batik waste treatment using activated carbon

Table 1. Comparison of the measurement results of testing batik waste samples to the maximum threshold

Parameter	Maximum Threshold	Average Sample Test Results
Total Phenol	0,5 mg/L	27,76 mg/L
Total Chromium (Cr)	1,0 mg/L	580 mg/L
Total Ammonia (NH3-N)	8,0 mg/L	0,71 mg/L
Sulfides	0,3 mg/L	0,78 mg/L
Fat-Oil	3 mg/L	0,08 mg/L
BOD5	60 mg/L	83,38 mg/L
COD	150 mg/L	110 mg/L
pH	6,0-9,0	6,44
TSS	50 mg/L	0,22 mg/L

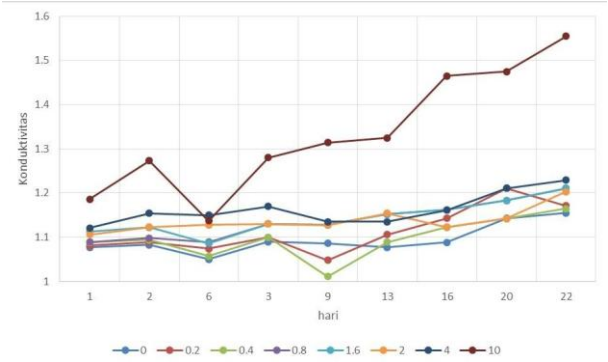


Figure 2. Results of conductivity measurements in wastewater that was given activated carbon 0.2 gr, 0.4 gr, 0.8 gr, 1.6 gr, 2.0 gr, 4.0 gr and 10 gr

The effectiveness of using activated carbon to reduce Cr levels in batik waste is influenced by the quality of the activated carbon used. In addition, the immersion time also affects the value of the effectiveness of activated carbon (Adebayo & Areo, 2021). The longer the soaking time of activated carbon on the sample, the higher the absorption will be. However, activated carbon has the maximum capacity to absorb Cr dissolved in wastewater. When the pores of the carbon have absorbed the maximum, it no longer has the ability to absorb the Cr content in the wastewater. If the Cr concentration in the wastewater is higher than the Cr content absorbed in the activated carbon, the Cr present in the activated carbon can come out and dissolve in the wastewater again. This leads to the need for proper research to determine the ability of activated carbon to absorb Cr in wastewater and the effective time required.

Activated carbon generally has a fine structure, is black in color, odorless and tasteless (Mkungunugwa et al., 2021). Activated carbon is carbon that has a good ability to absorb anions, cations, and molecules in the form of organic and inorganic compounds, both in the form of solutions and gases. Several materials that contain a lot of carbon and especially those that have pores can be used to make activated carbon. Activated carbon is generally made by physically or chemically activating carbon (Budianto et al., 2019). Differences in raw materials and activation methods used can produce different properties and quality of activated carbon. Activated carbon is composed of carbon elements which are covalently bonded in a hexagonal lattice similar to the structure of graphite.

Activated carbon is known to be a good adsorbent for the metals Cr, Hg, Pb, Cd, Ni, Cu which are contained in the liquid waste of the radiator industry, in the nickel plating industry and in the copper plating industry (Abdulrazak et al., 2017). The ability of activated carbon as a metal remover is generally influenced by pH

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and also carbon concentration. Increasing the carbon content increases the percentage of activated carbon adsorption on metal ions. The use of activated carbon is very important in the process of water and air purification. In the water purification process, carbon not only adsorbs metals such as iron, copper, nickel, but also removes odors, colors and tastes present in water solutions or wastes.

Activated carbon is widely recognized as one of the most effective adsorbent materials due to its exceptionally high surface area, well-developed pore structure, and abundance of oxygen-containing functional groups on its surface. These physicochemical characteristics enable activated carbon to adsorb a wide range of organic and inorganic contaminants through mechanisms including physical adsorption, pore filling, electrostatic attraction, hydrogen bonding, and hydrophobic interactions. Consequently, activated carbon has become an indispensable material in environmental remediation, water treatment, agriculture, and industrial pollution control.

One of the most important applications of activated carbon is in drinking water treatment, where it is used to remove pesticide residues, pharmaceutical compounds, industrial chemicals, taste- and odor-causing substances, and other emerging contaminants. Pesticides such as organophosphates, organochlorines, carbamates, and pyrethroids often persist in aquatic environments because of agricultural runoff, posing serious risks to both ecosystems and human health. Activated carbon effectively adsorbs these compounds, thereby reducing their concentration to levels that comply with drinking water quality standards. The adsorption efficiency depends on several factors, including the physicochemical properties of the pesticide, solution pH, contact time, activated carbon particle size, pore size distribution, and the presence of competing organic matter. Granular activated carbon (GAC) and powdered activated carbon (PAC) are the two most commonly used forms in water treatment facilities because they provide high adsorption capacities and can be integrated into conventional treatment systems.

Beyond water purification, activated carbon has attracted considerable attention as a soil amendment for mitigating pesticide contamination. Numerous studies have demonstrated that activated carbon applied at rates ranging from approximately 100 to 400 kg ha^{-1} can significantly reduce the bioavailability of pesticide residues by adsorbing contaminants onto its porous surface. This adsorption decreases pesticide mobility, reduces leaching into groundwater, and limits uptake by plants and soil organisms. Rather than chemically degrading pesticides, activated carbon primarily immobilizes them, thereby lowering their environmental availability and ecological toxicity. Such immobilization is particularly beneficial in agricultural systems where repeated pesticide application may lead to long-term accumulation and contamination of soil resources.

The incorporation of activated carbon into soil also contributes to improvements in soil quality. Owing to its high carbon content and stable aromatic structure, activated carbon can increase soil organic carbon storage and promote long-term carbon sequestration. Enhanced soil organic carbon generally improves soil structure, water-holding capacity, cation exchange capacity, nutrient retention, and aggregate stability. These improvements support sustainable agricultural productivity while simultaneously contributing to climate change mitigation by reducing atmospheric carbon dioxide through long-term carbon storage in soils (Mkungunugwa et al., 2021).

However, the effects of activated carbon on soil biological properties are complex and depend on application rate, feedstock source, activation method, soil characteristics, and environmental conditions. Several studies have reported reductions in microbial biomass, soil respiration, and microbial activity following activated carbon application. These reductions are

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often attributed to the adsorption of dissolved organic carbon and nutrients that would otherwise serve as substrates for microbial metabolism. Additionally, activated carbon can adsorb extracellular enzymes and signaling molecules involved in microbial communication, thereby influencing microbial community composition and metabolic processes. Nevertheless, other studies have observed neutral or even positive effects over longer periods as microbial communities adapt to the modified soil environment. Therefore, the influence of activated carbon on soil microbiology remains an active area of research and should be interpreted within the context of specific soil ecosystems (Mkungunugwa et al., 2021).

Activated carbon also influences the physical properties of soil through its thermal characteristics. Because of its dark color and relatively high heat absorption capacity, activated carbon can absorb solar radiation and moderate fluctuations in soil temperature. This thermal buffering effect may reduce the impact of light frost events by maintaining slightly higher soil temperatures during cold periods, thereby protecting plant roots and soil microorganisms from temperature-induced stress. Furthermore, improved soil porosity associated with activated carbon application can enhance aeration and water infiltration, creating more favorable conditions for root development and beneficial microbial activity.

Activated carbon is also known to have been used as an absorbent for pesticide residues in the drinking water purification process to obtain pesticide-free drinking water so that it is safe for consumption. Based on research that has been done, activated carbon is known to be able to deactivate pesticide contaminants in the soil at doses between 100-400 kg/ha. Activated carbon in the soil can improve soil quality by increasing the total organic carbon in the soil. In addition, activated carbon also has the ability to reduce microbial biomass, respiration, and aggregation as well as the effect of light freezing on the soil. This is because activated carbon has a good ability to absorb and store heat. Activated carbon is used to absorb toxic gases in the paint and synthetic dye processing industries.

To sum up, the multifunctional properties of activated carbon make it an environmentally valuable material for pollution control and resource management. Its ability to adsorb pesticides, improve water quality, enhance soil properties, sequester carbon, and remove industrial pollutants demonstrates its broad applicability across environmental and agricultural sectors. Nevertheless, optimizing activated carbon performance requires careful consideration of feedstock selection, activation techniques, application rates, and site-specific environmental conditions. Future research should focus on improving regeneration technologies, developing low-cost activated carbons from agricultural wastes, and evaluating the long-term ecological impacts of activated carbon application under diverse environmental conditions.

Conclusion

Activated carbon can be used as an alternative to deadling with batik waste and reducing levels of toxic materials in batik waste. However, it is necessary to combine theuse of activated carbon with other components to obtain better results, such as the use ofphytoremediator plants or hydromacrophyte.

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