Biosaintifika 16 (2) (2024): 213-223 p-ISSN 2085-191X | e-ISSN 2338-7610
Journal of Biology & Biology Education https://journal.unnes.ac.id/nju/index.php/biosaintifika

Characterization of Batik Waste Containing Synthetic Textile Dyes and The Artisan Awareness Regarding The Hazardous Batik Waste

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Submitted: 2024-02-08. Revised: 2024-05-10. Accepted: 2024-07-10

Abstract. Synthetic textile dyes in the Tanjung Bumi batik coloring process in Madura, Indonesia, have been used extensively for decades, raising environmental concerns due to hazardous wastewater. This research aims to evaluate the quality characteristics of synthetic textile dye wastewater, assess batik artisans' awareness of batik waste hazards, and analyze the interaction between these factors. Wastewater samples were collected from four locations with two repetitions each. Thirty-seven batik artisans participated in a survey. The wastewater analysis included measurements of BOD5, COD, pH, TSS, phenol, Cr, NH3-N, sulfide, and oil and grease. The survey assessed the artisans' use of synthetic dyes and their awareness of environmental hazards. The results showed that the toxic substance levels in Tanjung Bumi batik waste exceed the quality standard thresholds for textile waste. Survey findings indicate that 100% of respondents use synthetic textile dyes, 83.78% dispose of waste without processing, and 91.89% are unaware of the hazards posed by synthetic textile dyes. There is a direct correlation between the artisans' low awareness of the negative impacts of waste and their lack of environmental preservation practices. The novelty of this research lies in its dual evaluation of chemical wastewater characteristics and socio-environmental awareness among artisans. This approach highlights the urgent need for educational interventions and improved waste management practices. The implications are significant for developing sustainable batik production methods and enhancing environmental awareness, contributing to broader societal benefits.

Keywords: batik artisans; batik dyes; synthetic dyes; toxic materials.

How to cite : Hidayati, Y., Siswanto, D., Rumhayati, B., & Retnaningdyah, C. (2024). Characterization of Batik Waste Containing Synthetic Textile Dyes and The Artisan Awareness Regarding The Hazardous Batik Waste. *Biosaintifika: Journal of Biology & Biology Education, 16(2)*, 213-223.

DOI: http://dx.doi.org/10.15294/biosaintifika.v16i2.2325

INTRODUCTION

Batik is a cloth with specific motifs and patterns characteristic of a region in Indonesia and has been Indonesia's identity since ancient times. Batik has been recognized as one of Indonesia's world heritage by UNESCO in the Masterpieces of the Oral and Intangible Heritage of Humanity category. Batik patterns and motifs are greatly influenced by a region's culture and geographical conditions, resulting in a diversity of patterns and motifs that are different for each region in Indonesia (Kridarso, 2018). Tanjung Bumi Batik is a typical Madurese Indonesian batik produced in Bangkalan Regency, and there is also a batik production center on Madura Island, Indonesia. Tanjung Bumi batik has a typical Madurese pattern produced by batik artisans who are spread mainly in the coastal areas of Tanjung Bumi.

The demand for batik is increasing over time, increasing batik production, which is correlated with increased residual waste from batik production (Sutisna et al., 2017). In the process of dyeing Tanjung Bumi batik, batik artisans are increasingly using natural dyes because of the difficulty in obtaining plants as the primary raw material for dyes, the limited choice of colors available, and the long time required for the dyeing process with natural dyes. Synthetic textile dyes in the batik-making process are becoming

increasingly common because synthetic dyes can reduce production costs, shorten production time, have abundant availability, and provide unlimited color choices.

The profile of synthetic textile dyes in the Tanjung Bumi batik production process is needed to determine the distribution of batik artisans who use synthetic textile dyes and their threat to environmental pollution. Physical, chemical, and biological parameters of pollutant waste are measured to determine whether an environment has been polluted and how to deal with it (Lv *et.al*., 2019; Sakthivadivel et al., 2021). The measurement is needed as input for the community and government regarding the hazards of batik waste with synthetic textile dyes. The participation of the community and government is essential to overcome the problem of batik waste, especially those using synthetic textile dyes (Sulthonuddin & Herdiansyah, 2021)

The quality characteristics of synthetic textile dye wastewater in the Tanjung Bumi batik-making process need to be evaluated because synthetic textile dyes are known to contain toxic ingredients that are harmful to the environment. The toxic ingredients contained in synthetic textile dyes include Sulfide, nitrite, ammonia, phenol, soda ash 2 (Na_2CO_3), cosmetic soda (NaOH), baking soda ($NaHCO_3$), sulfuric acid (H_2SO_4), and heavy metals. Which is very hazardous if it pollutes the environment (Prayogo, 2016; Kaur, 2018; Ratna & Slamet, 2020; Ahila et al., 2021). Heavy metals in synthetic textile dyes include Cr, Pb, Cd, Hg, Ar and Fe. Apart from that, batik waste with synthetic textile dyes generally has an intense color and strong odor with high levels of BOD, COD, pH, and TSS, which is hazardous to the environment, including humans (Prayogo, 2016; Lestari et al., 2023)

The community is actively involved in the batik production process. However, there is a significant gap in their understanding of the environmental and human health hazards posed by batik waste containing synthetic textile dyes. This issue is compounded by the low awareness among batik artisans regarding the dangers of the waste they generate. Evaluations indicate that the public lacks awareness of the need for a batik waste treatment system before disposal into the environment. This evaluation is crucial as it can inform recommendations for effective waste management practices. The long-term use of synthetic textile dyes has led to environmental changes in Tanjung Bumi, including alterations in the biota community structure, decreased water quality, and reduced ecosystem services. These changes have rendered agricultural areas and ponds non-functional, severely impacting the local community. This is partly due to the impact of bioaccumulation of toxic materials including heavy metals in synthetic dyes, which are very dangerous for the ecosystem and become a threat to the environment (Dewi et al., 2019; Gaur et al., 2021; Joel et al., 2020).

The correlation between levels of toxic substances and batik artisan's knowledge of the hazards of batik waste needs to be known to determine follow-up efforts by the community and government based on an evaluation of the quality characteristics of synthetic textile dye wastewater in the Tanjung Bumi batik making process, as well as an evaluation of batik artisan's awareness of the hazards of batik waste. Able to overcome the hazard of pollution from Tanjung Bumi batik waste, known to use synthetic textile dyes. Apart from that, it is also hoped that there will be parallel efforts to preserve batik as a cultural heritage and how to preserve the environment and simultaneously prevent environmental damage due to batik waste with synthetic dyes.

The research aims to assess the environmental impacts of batik production in Tanjung Bumi, Indonesia, particularly the effects of synthetic textile dyes on the environment. By analyzing the chemical composition of the waste and evaluating the awareness of batik artisans, strategies for mitigating the hazards of batik waste disposal are aimed to be identified. Decisions on eco-friendly dyeing methods and waste management practices will be informed by the findings, ultimately contributing to the preservation of batik as a cultural heritage while protecting the environment.

METHODS

Study Area

This research was carried out at four Tanjung Bumi batik production center locations in Bangkalan Regency on Madura, East Java Province, Indonesia. The locations for sampling batik waste and respondents were taken in the Gedding, Jambangan, Tajung, and Mlogur areas.

Characterization of Batik Wastewater Profile

Two batik wastewater samples were taken from each area from different batik production industries. Each sample contained 20 liters of waste, and then the physicochemical characteristics of each wastewater sample were

measured. Wastewater was taken from the final dyeing process in the batik-making process. COD data analysis was carried out at the Jasa Tirta Laboratory, Malang City, and analysis of pH, DO, TSS, Conductivity, and BOD at the Tropical Ecosystem Ecology and Restoration Laboratory, Biology Department, Universitas Brawijaya. At the same time, Cr, S, Phenol, Fat, and N-NH_3 were analyzed at the Chemistry Laboratory Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. The analysis results obtained were compared with the quality standards set by the Indonesian government based on Minister of Environment and Forestry Regulation Number P.16/MENLHK/SETJEN/ KUM.1/4/2019 (Table 1). The batik waste research data obtained was then analyzed descriptively.

Table 1. The maximum threshold for Waste Water Quality Standards is based on the Indonesian Minister of Environment and Forestry Regulation No. P.16/MENLHK/SETJEN/KUM.1/4/2019

Parameter	Government Quality Standard Values (Maximum Limit)
BOD_5	60 mg/L
COD	150 mg/L
pH	6.0-9.0
TSS	50 mg/L
Total Phenol	0.5 mg/L
Total Chrome (Cr)	1.0 mg/L
Total Ammonia (NH_3-N)	8.0 mg/L
Sulfide	0.3mg/kg
Oil and Grease	3 mg/L

Tanjung Bumi Batik Artisan's Awareness Profile Survey

A survey of batik artisans using an expert-validated questionnaire was carried out from June 2023 to August 2023 in Tanjung Bumi, Madura, East Java. The survey method to determine the perspective of batik artisans regarding the hazards of using synthetic textile dyes as batik dyes uses *ex post facto quantitative non-experimental research*. The study population consisted of approximately 211 batik artisans from Tanjung Bumi, located on Madura Island. The sampling used *purposive sampling*, with respondents total batik artisans in Tanjung Bumi were 37 respondents. The sampling criteria were based on the age category of the batik artisan, length of time working as a batik artisan, batik artisan's knowledge of synthetic dyes used as dyes, batik waste processing systems, and batik artisan's knowledge of the impact of using synthetic dyes (Table 2). Questionnaire data were analyzed using descriptive statistical analysis with SPSS 20.0.

The next test was carried out to determine the interaction between the profile of batik waste levels and the profile of batik artisan's awareness of the hazards of batik waste. This interaction was tested using biplot analysis and descriptive analysis.

Table 2. Questionnaire for Tanjung Bumi Batik Artisans

No	Indicators	Number of Statements
1	Personal Background: This section includes questions about the age of the batik artisan (1) and how long they have been working as a batik artisan (2).	1-2
2	Materials Used: This section focuses on the types of dyes (3) used in the batik-making process, including the specific brands and forms of dye used (4). It also asks about the level of dye used by the artisans (5).	3-5
3	Waste Management: This section inquires about the waste generated during the batik-making process. It asks whether the waste is directly released into the environment (6) or if there is a waste processing system in place before disposal (7).	6-7
4	Environmental Impact: This section explores the potential environmental effects of using synthetic dyes in batik production. It asks if the artisans experience health problems such as skin irritation and if there are changes in environmental quality, including water quality, around the batik-making location (8). Additionally, it inquires about the impact on plant growth in the area (9).	8-9
5	Knowledge and Awareness: This section assesses the artisans' knowledge about the impact of using synthetic dyes on the environment and their awareness of the potential harm caused by these dyes.	10-12

Analysis Data

The data analysis involved different methods suited to the type of information collected. For the physicochemical characteristics of batik wastewater, simple statistics like averages and ranges were used to summarize the findings. These results were then compared with government standards to determine compliance. Meanwhile, in the survey of Tanjung Bumi Batik Artisans, the answers from the questionnaires were analyzed using basic statistics like counts and percentages. The software SPSS 20.0 was used in this process.

The next test was carried out to determine the interaction between the profile of batik waste levels and the profile of batik artisan's awareness of the hazards of batik waste. This interaction was tested using biplot analysis and descriptive analysis. These methods helped in gaining a better understanding of the data and identifying ways to improve environmental sustainability in the batik industry.

RESULTS AND DISCUSSION

Batik Wastewater Profile

The results of laboratory analysis of Tanjung Bumi batik wastewater in the four locations that had been studied showed that the characteristics of batik waste in several parameters had exceeded the threshold based on applicable provisions (Table 3). Based on the results of the analysis, it was known that at four sampling locations, the BOD_5, DO, COD, Total Phenol, Total Chrom (Cr), and Sulfide values had exceeded the applicable threshold values based on the regulation of the Minister of Environment and Forestry in Indonesia No. P.16/MENLHK/SETJEN/ KUM.1/4/2019. These similarity tests indicated similarities in the characteristics of the dyes used by batik artisans. However, it was known that batik artisans used two types of dye, involving dye that had a particular brand, namely indigosol dye, and unbranded dye (bulk).

The measurement values of these parameters also showed that batik waste from all sampling areas was known to contain toxic ingredients in their synthetic textile dyes and was similar to one another, thus posing a threat to existing environmental conditions. The result was indicated by the low DO, pH, and high COD, Cr, S, Phenol, and BOD values (Table 3). The high standard deviation (SD) values for DO, S, and Oil and grease in the Mlogur area, pH, S, and fat values in the Jambangan area, and S and fat values in the Mlogur area were caused by various reasons. These reasons included variations in choosing the type of color used in batik motifs and the concentration of colors used in the batik coloring process.

Table 3. The results for batik waste profiles and maximum threshold quality standard values based on Indonesian Minister of Environment and Forestry Regulation No. P.16/MENLHK/SETJEN/ KUM.1/4/2019

Parameter Test	Threshold	Unit	Gedding		Jambangan		Tajung		Mlogur	
			Average	SD	Average	SD	Average	SD	Average	SD
DO	5	mg/l	0.71	0.97	0.38	0.16	0.03	0.01	0.04	0.01
pH	6.0-9.0	-	5.35	0.24	7.19	3.22	5.23	0.35	5.41	0.23
TSS	40	mg/l	11.97	1.20	12.64	1.33	11.52	0.54	11.79	0.13
COD	150	mg/l	1570.00	56.57	1287.51	1014.70	1807.51	1127.84	920.00	127.28
Cr	1	mg/l	41.33	2.35	38.17	0.90	31.07	0.38	45.47	2.92
S	0.3	mg/l	1008.04	203.60	608.93	494.01	1267.63	277.89	768.79	312.62
Phenol	0.5	mg/l	7.69	0.37	5.99	0.13	7.13	0.16	10.45	0.29
Oil and Grease	3	mg/l	0.06	0.02	0.06	0.06	0.76	0.02	0.72	0.79
$N\text{-}NH_3$	8	mg/l	1.06	0.07	0.87	0.02	1.02	0.11	1.55	0.08
BOD_5	60	mg/l	277.50	3.54	271.00	15,56	291.50	2.12	291.00	5.68

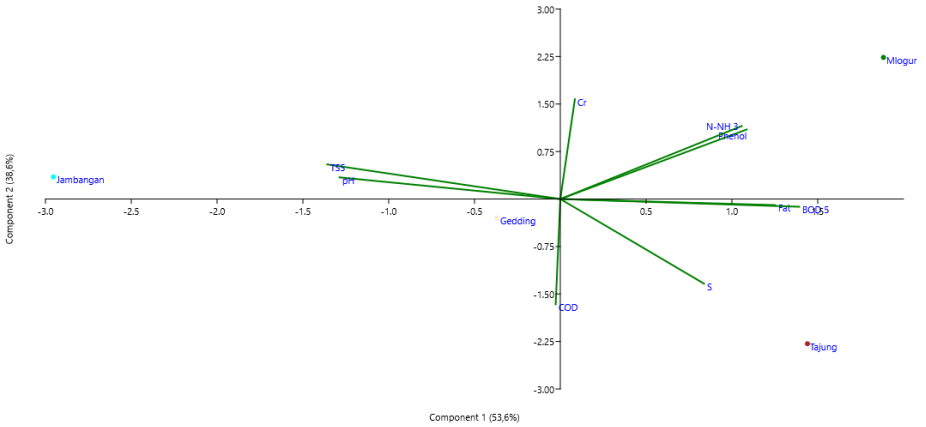

Figure 1. The biplot analysis of Tanjung Bumi Batik Wastewater. It reveals distinct differences in the chemical composition of waste samples from different areas. Tanjung stands out with the highest sulfide levels, while Mlogur has the worst quality due to its high levels of phenol, N-NH3, and Cr. These results indicate that all sampling areas contain toxic ingredients in their synthetic textile dyes, posing a significant threat to environmental conditions.

High BOD and COD content, as well as other toxic ingredients such as Cosmetic Soda (NaOH), Sulfuric Acid (H_2SO_4), Sulfide, Soda Ash 2 (Na_2CO_3), Baking Soda ($NaHCO_3$), Phenol, and Nitrite in large quantities, were the cause of the hazards of textile waste for the environment. Apart from that, the high content of heavy metals, especially Cr, Cd, Hg, Ar, Fe, and Pb, in textile waste had the potential to cause environmental pollution and be hazardous to human health (Prayogo, 2016; R. S. Dewi et al., 2019; Kishor et al., 2021; Ratna & Slamet, 2020; Ahila et al., 2021).

Based on the biplot analysis results (Figure 1), it was known that the waste characteristics in areas A (Gedding) and B (Jambangan) had a similar correlation with low levels of TSS, pH, N-NH_3, and moderate levels of Cr, S, Phenol, BOD. Sampling area C (Tajung) had the highest sulfide levels compared to the other three sampling areas; Cr, N-NH_3, COD, and oil and grease levels had moderate values but with levels above the maximum threshold, while TSS, conductivity, and pH levels were low and below the threshold. In processing plant D (Mlogur) had the highest levels of phenol, N-NH_3, and Cr with moderate BOD and COD but had values far above the threshold, and TSS, conductivity, oil and grease, and pH were below the threshold. The waste taken from Mlogur had the worst quality compared to the other three sampling areas. These results showed that batik waste from all sampling areas contained toxic ingredients in their synthetic textile dyes and was similar to one another, thus posing a threat to existing environmental conditions. Toxic ingredients in synthetic textile dyes are known to be one of the causes of environmental pollution problems worldwide because of the toxic ingredients they contain (Yaseen & Scholz, 2018).

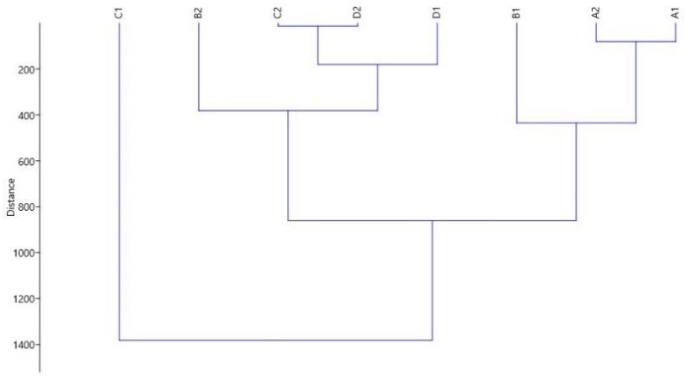

Figure 2. Clustering analysis of Tanjung Bumi Batik wastewater between locations

Based on the object's proximity to a variable, it could be seen that A1 was an object that had close characteristics of batik waste to A2, which was also known to have close characteristics of waste to B1. In the sampling area, C2 was close in character to batik waste with D2, where both of them were also close to B2 and D1. Samples taken from area D had quite different characteristics from samples from other areas and showed the highest level of waste toxicity compared to those in other sampling areas.

The profile of Tanjung Bumi batik waste obtained in four different areas generally showed a tendency towards similarities in the type of batik dye used by batik artisans. However, in areas A, B, and C, based on the results of interviews, it was known that artisans used unbranded bulk synthetic dyes with dye levels that were not as high as the type of dye used in sampling area D, which used certain brands of dye with sharper coloring results. Bulk textile dyes, like textile dyes in general, were known to contain phenols (Triwiswara, 2019; Singh & Balomajumder, 2021), sulfides, ammonia (Ndulini et al., 2018; Moondra et al., 2021) and heavy metals. Heavy metals in textile dyes include Cr, Pb, Cd, Hg, Ar, and Fe, which are very hazardous if they pollute the environment (Kaur, 2018; Ahila et al., 2021). Synthetic textile dye, known to hurt the existing ecosystem, was commonly used (Kusumandari et al., 2021). The impact of textile waste that had been used for a long time was also felt by the people around the Tanjung Bumi batik industry. The impacts of using batik dyes that used synthetic textile dyes included a decrease in water and soil quality. The decrease in water and soil quality impacted biota communities' structure changes. It caused a decrease in water ecosystem environmental services, causing a decline in the function of agricultural land and ponds in the Tanjung Bumi area.

Toxic ingredients in synthetic textile dyes are known to be one of the causes of environmental pollution problems worldwide because of the toxic ingredients they contain (Yaseen & Scholz, 2018). Tanjung Bumi batik waste was known to be liquid and continuously produced in large volumes. It contained toxic materials, which caused the waste to have a strong odor and dark-colored waste. The content of batik waste was the same as that contained in textile waste because the batik dyeing process used synthetic textile dyes.

Awareness Profile of Tanjung Bumi Batik Artisan Regarding Hazardous Waste

The high levels of toxic substances in waste were directly proportional to the results of questionnaires filled out by respondents regarding awareness of the hazards of using synthetic textile dyes in the batik dyeing process. Based on respondent data, it was known that 78.38% of batik artisans only used synthetic textile dyes as batik dyes, and the remaining 21.62% used dyes mixed with synthetic textiles and natural materials (Figure 3). This result showed that 100% of batik artisans used synthetic textile dyes entirely or mixed with natural dyes. Apart from that, based on questionnaire data, it was known that 83.78% of batik artisans directly disposed of batik waste into the surrounding environment, and 10.81% did not know what processing batik waste was. As many as 5.41% did not dispose of batik waste directly but precipitated it first (Figure 4). The hazards of using synthetic textile dyes in the batik dyeing process had yet to be realized by batik artisans. The result showed that 91.89% of respondents needed a better understanding of the hazards of batik waste (Figure 5). However, respondents also stated that they were aware that there had been many changes in the surrounding environment but did not realize that batik waste would hurt the environment, especially in the long term, even though the respondents had been working for more than five years as batik artisans (Figure 6).

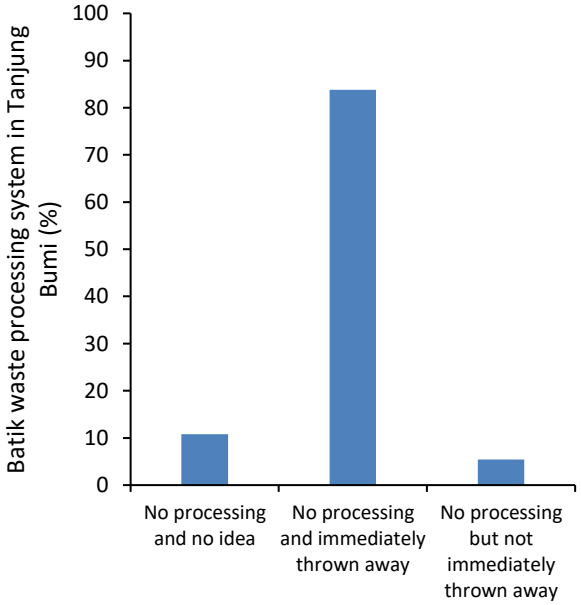

Figure 3. Artisan's knowledge of synthetic textile dyes in Batik Tanjung Bumi

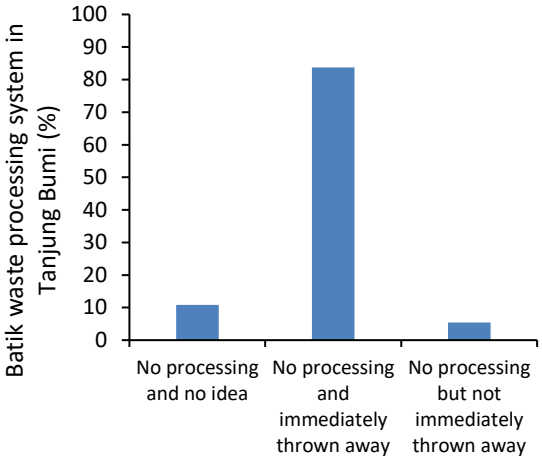

Figure 4. Batik waste processing system in Tanjung Bumi

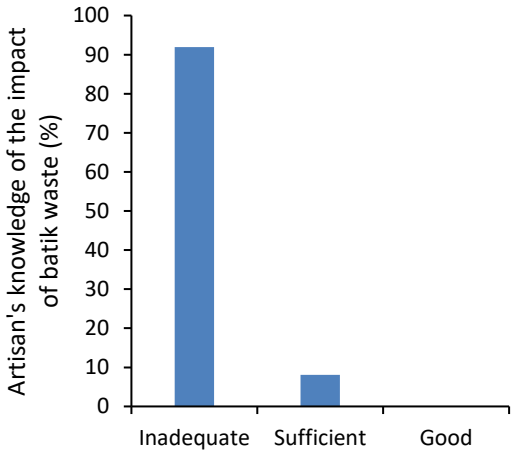

Figure 5. Artisan's knowledge of the impact of using synthetic dyes

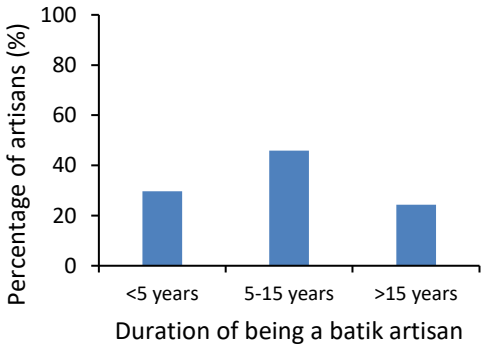

Figure 6. The duration of being a batik artisan

The low level of knowledge about the impact of using textile dyes on environmental damage was directly proportional to the need for more awareness and efforts to manage batik waste before it was thrown into the surrounding environment. Awareness of the importance of batik waste management still needed to be visible among Tanjung Bumi batik artisans. The lack of understanding of the negative impact of batik waste on the sustainability of the ecosystem resulted in no efforts to manage batik waste properly. Batik waste that is not managed correctly could be detrimental to public health, threaten the sustainability of the ecosystem, and cause environmental pollution (Alajmi et al., 2021; van Gerwen et al., 2022) . Therefore, the community needed educational efforts, especially batik artisans, about the importance of managing waste (Sulthonuddin & Herdiansyah, 2021). Waste management could be done easily and simply by utilizing local hydro macrophytes with a phytoremediation process (Suman et al., 2018; Chandanshive et al., 2020; Suryani et al., 2017; Masinire *et al*., 2021; Shrivastava & Srivastava, 2021; Slaimi et al., 2021; Suman et al., 2018). Some macrophytes can accumulate metals at concentrations in their tissues higher than the respective concentrations in the environment (Retnaningdyah & Arisoesilaningsih, 2018; Parida et al., 2020; Akhtar et al., 2020; Chandanshive et al., 2020; Ahmad, 2021; Akhtar et al., 2020). Batik wastewater also can be degraded using microorganisms (Subowo et al., 2023). In addition, efforts were also needed to develop the wisdom of local people towards cultural and environmental sustainability (Hidayati, 2019).

Correlation of Batik Wastewater Profile with Awareness Profile of Tanjung Bumi Batik Artisans

Based on the biplot analysis, it was known that artisans in Tajung and Gedding had the lowest level of knowledge regarding the impact of using synthetic dyes (Figure 7). Dye waste at this location had the highest COD, S, and BOD levels with lower TSS, conductivity, phenol, NH_3, and Cr values than other locations. Artisans in Jambangan used the same synthetic dyes as in Gedding and Tajung, namely dyes from certain brands. However, the COD and Cr levels at this location were in the medium-level category when compared with other areas; the conductivity and TSS values were the highest, while the BOD, S, phenol, and NH_3 levels were low compared to other areas. Batik artisans in Mlogur, with 50% of their artisans using non-brand dyes, produced different waste characteristics with the highest levels of Cr, NH_3, Phenol, and BOD. At the same time, the values of other parameters were low.

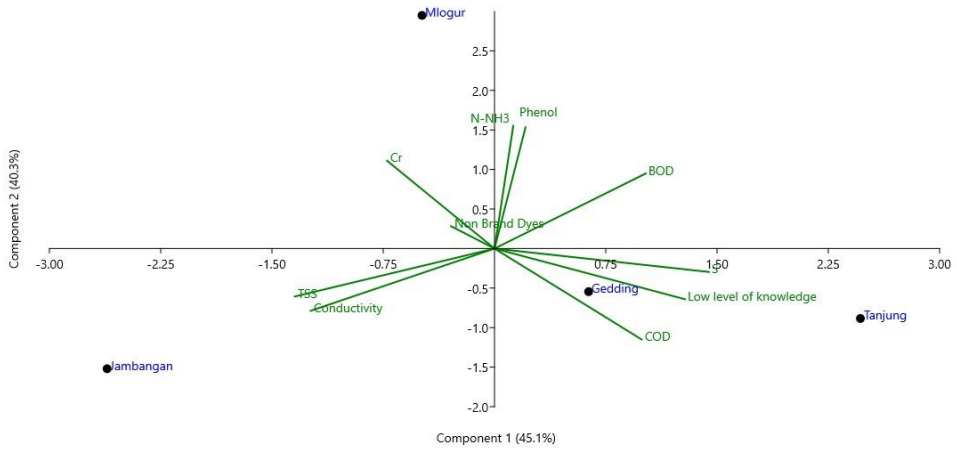

Figure 7. Biplot analysis of the correlation between artisan's knowledge of the hazards of batik waste from Tanjung Bumi Batik and the toxic material content of batik waste produced

Figure 8. Environmental conditions around Wastewater Tanjung Bumi Batik

Thus, all types of dyes used were still toxic. The use of specific brand dyes had an impact on high COD, while non-brand dyes had an impact on high Cr, phenol, and NH_3 levels. As is known, in general, Tanjung Bumi batik artisans chose to use non-brand dyes because the price was relatively lower; however, a small number of artisans chose certain brand dyes because they felt they had better color quality than non-brand ones, thus producing better batik colors. The process of dyeing tanjung bumi batik shows that most of it uses bulk synthetic textile dyes which contain phenols, sulfides, ammonia, and heavy metals as toxic materials contained in textile dyes in general (Triwiswara, 2019; Singh & Balomajumder, 2021).

Textile dyes (whether bulk /non-branded or dyes with certain brands, such as textile dyes in general) are known to contain phenol (Triwiswara, 2019; Singh & Balomajumder, 2021), sulfide, and ammonia (Ndulini et al., 2018; Moondra et al., 2021) and heavy metals. Heavy metals in textile dyes include Cr, Pb, Cd, Hg, Ar, and Fe, which are very hazardous if they pollute the environment (Kaur, 2018; Ahila et al., 2021). Synthetic textile dye, known to hurt the existing ecosystem, is commonly used (Kusumandari et al., 2021). The absence of batik waste treatment processes that use synthetic dyes results in waste being directly discharged into the surrounding environment (Figure 8). The impact of textile waste that has been used for a long time has also been felt by the people around the Tanjung Bumi batik industry. The impacts of using batik dyes that use synthetic textile dyes include a decrease in water and soil quality. The wastewater also has an impact on changes in the structure of biota communities. It causes a decrease in water ecosystem environmental services, causing a decline in the function of agricultural land and ponds in the Tanjung Bumi area.

This study presents a comprehensive toxicological analysis of batik wastewater in Tanjung Bumi, revealing significant environmental hazards posed by the use of synthetic dyes. It distinctly correlates the chemical profiles of batik waste with artisans' awareness levels, offering a socio-environmental perspective

on batik production practices that have not been extensively explored before.

The research contributes empirical evidence on hazardous substance levels in batik wastewater, highlighting severe pollution. It establishes a link between artisans' lack of awareness and high toxicity in wastewater. The study also proposes practical waste management solutions like phytoremediation and microbial degradation. These insights are crucial for policymakers to develop targeted educational initiatives and regulations, promoting sustainable batik production practices and raising environmental awareness.

CONCLUSION

This study successfully evaluated the quality characteristics of Tanjung Bumi batik wastewater, assessed batik artisans' awareness of the hazards associated with batik waste, and analyzed the interaction between these factors. The findings revealed that the BOD5, DO, COD, Total Phenol, Total Chromium (Cr), and Sulfide levels in the wastewater exceeded Indonesian regulatory thresholds. Furthermore, all respondents used synthetic textile dyes, with most disposing of batik waste directly without treatment. The correlation between low awareness among artisans and high levels of toxic substances in wastewater highlights a significant environmental and public health risk. Therefore, collaborative efforts between the community and government are essential to address these issues. Future research should focus on educational programs for sustainable practices and explore effective phytoremediation and microbial degradation techniques for wastewater treatment.

ACKNOWLEDGMENT

We recognize the assistance of the Beasiswa Pendidikan Indonesia (BPI) and Lembaga Pengelola Dana Pendidikan (LPDP) for their financial support in conducting this research.

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