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Analysis of Wastewater Quality of Jetis Batik, Sidoarjo

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Abstract
Jetis Batik Industry in Sidoarjo is recognized as a prominent batik center in East Java. Batik is known as an industry that uses both natural and synthetic dyes. This can serve as a source of environmental pollution. This study is to evaluate the quality of wastewater generated by Jetis Batik in Sidoarjo. The determined quality is then evaluated according to Permenkes 02 of 2023 and PerGub Jatim Number 72 of 2013. In this research, batik wastewater samples from 20 batik cottage industries in the Jetis region of Sidoarjo were used. It is acknowledged that it does not meet the clean water quality standards set by the Minister of Health Regulation Number 02 of 2023 in terms of TDS parameters, turbidity, color, Fe, Mn, nitrate, nitrite, pH, and chromium. Subsequent research in accordance with East Java Governor Law No. 72 of 2013 showed that TDS, pH, Fe, Mn, Cr, COD and BOD exceeded the quality criteria established by law. In addition, according to the East Java Governor Regulation No. 72 of 2023, batik liquid waste is classified into categories I, II, III, IV, and seawater, which is considered unsuitable for discharge into the marine environment. Immediate disposal of batik liquid waste into water sources without prior treatment poses a significant risk of environmental contamination.
Keywords: *batik, jetis batik, sidoarjo, permenkes 02 tahun 2023, pergub jatim 72 tahun 2013*

Abstrak
Industri batik Jetis, Sidoarjo dikenal sebagai salah satu pusat batik di Jawa Timur. Batik diketahui merupakan salah satu industri yang menggunakan pewarna alami maupun buatan. Hal ini berpotensi dapat menjadi salah satu sumber pencemar lingkungan. Penelitian ini bertujuan untuk menganalisa kualitas air limbah batik Jetis, Sidoarjo yang dihasilkan. Kualitas yang diketahui kemudian dinilai berdasarkan Permenkes Nomor 02 Tahun 2023 dan PerGub Jatim Nomor 72 Tahun 2013. Penelitian ini menggunakan sampel air limbah batik yang berasal dari 20 industri rumahan batik di wilayah Jetis, Sidoarjo. Diketahui tidak memenuhi kriteria mutu air bersih yang ditetapkan oleh Peraturan Menteri Kesehatan Nomor 02 Tahun 2023 tentang parameter TDS, kekeruhan, warna, Fe, Mn, nitrat, nitrit, pH, dan kromium. Analisis lanjutan menggunakan Peraturan Gubernur Jawa Timur Nomor 72 Tahun 2013 menunjukkan bahwa TDS, pH, Fe, Mn, Cr, COD, dan BOD melebihi baku mutu yang ditetapkan dalam peraturan tersebut. Selain itu, sesuai dengan Peraturan Gubernur Jawa Timur Nomor 72 Tahun 2023, limbah cair batik dikategorikan menjadi golongan I, II, III, IV, dan air laut yang tidak layak untuk dibuang ke lingkungan laut. Pembuangan limbah cair batik secara langsung ke badan air, tanpa pengolahan terlebih dahulu, menimbulkan risiko pencemaran lingkungan yang signifikan.
Kata Kunci: *batik, batik jetis, sidoarjo, permenkes 02 tahun 2023, pergub jatim 72 tahun 2013*

1. Introduction

The batik industry, an essential aspect of Indonesian cultural heritage, substantially impacts the economy, especially in areas such as Jetis, Sidoarjo. Nonetheless, the conventional batik production process, which encompasses multiple dyeing and waxing phases, produces significant quantities of effluent contaminated with contaminants. If left untreated, this wastewater presents a significant risk to the local ecosystem and public health. This analysis examines the characterization and evaluation of batik industrial wastewater from Jetis, Sidoarjo, with the objective of understanding pollutant composition, assessing environmental impact, and guiding the formulation of sustainable wastewater management strategies for the area. Comprehending the distinct attributes of the wastewater generated in Jetis is essential owing to the particular manufacturing techniques and dye applications common in the local batik sector.

Batik manufacture consists of six fundamental stages: design or painting, waxing, dyeing, wax removal, washing, and drying (Rahayu & Peng, 2020; Triwiswara, 2019). Synthetic dyes, organic compounds, and surfactants are commonly employed in this method to produce single- or multicolor batik

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(Bener et al., 2019; Demir & Gören, 2019). The utilization of coloring agents (reactive colors), wax coatings (potato or cornflour mixed with soda ash or sodium bicarbonate), and immersion has led to the production of industrial batik effluent (Elajel et al., 2022; Rahayu & Peng, 2020; Sulthonuddin & Herdiansyah, 2021).

Furthermore, at specific exposure durations and dye concentrations, the presence of dyes in water may be carcinogenic, causing acute or chronic effects on affected organisms (Taha et al., 2020; Velusamy et al., 2021). Additional environmental concerns may arise, including diminished light absorption and reduced oxygen levels in water, adversely impacting algae photosynthesis and consequently affecting the ecological food chain (Darvishi Cheshmeh Soltani et al., 2020; Taha et al., 2020). Wastewater generated from the batik process include synthetic dyes, heavy metals (including copper, iron, zinc, lead, and chromium), resin, wax, silicate, surfactants, and suspended particulates (Birgani et al., 2016; Daud et al., 2022), which is very toxic and non-biodegradable, responsible for water stream disruption, environmental pollution, and detrimental effects on aquatic ecosystems and human health (Daud et al., 2022; Kalyani et al., 2009; Lokhande et al., 2015; Mukimin et al., 2017). Consequently, the management and treatment of textile wastewater is essential for mitigating environmental, human, and aquatic issues.

The Batik business encounters significant hurdles, particularly among small-scale producers who frequently lack adequate wastewater treatment facilities. As a result, these manufacturers discharge wastewater into the environment, which contains contaminants including synthetic colors, heavy metals, resins, waxes, and other non-biodegradable materials. This unregulated effluent significantly endangers water quality, ecological equilibrium, and human health, hence exacerbating water pollution (Birgani et al., 2016; Fauzi & Defianisa, 2019; Kusworo et al., 2022; Mukimin et al., 2017).

The batik sector in the Jetis Sidoarjo region comprises 20 enterprises; consequently, the rising demand for batik results in the generation of liquid waste from the batik production process. Alongside the elevated dye concentration, effluent from the batik sector generates synthetic substances. Elevated concentrations of BOD and COD in water result in diminished oxygen levels, adversely affecting aquatic organisms, including fish, shrimp, and other biota. The effects on human health include diarrhea and dermatological conditions. Elevated TDS levels in water can lead to a deterioration in water quality. Total Dissolved Solids (TDS) can induce turbidity, thereby diminishing light penetration in water, leading to the mortality of organisms and interference with photosynthesis. Additionally, TDS can result in gastrointestinal disturbances and ocular irritation in humans.

2. Material and Methods

Data Collection Method

This study used a survey methodology, utilizing purposive sampling for data collection through direct field measurements and laboratory analyses. The acquired data are subjected to qualitative descriptive analysis. This research was carried out in the batik industry hub of Jetis, Sidoarjo. The data analysis was conducted qualitatively and descriptively, elucidating events through comprehensive explanations grounded in empirical evidence from field observations and laboratory results.

Table 1. Data analysis

Parameter	Allowed Maximum Concentration	Unit
Temperature	±3	°C
Total Dissolve Solid	<300	mg/L
Turbidity	<3	NTU
Color	10	TCU
Fragrance	No Fragrance	-
pH	6.5-8.5	-
Nitrate	20	mg/L
Nitrite	3	mg/L
Cr^{6+}	0.01	mg/L
Fe	0.2	mg/L
Mn	0.1	mg/L

1. Data about the outcomes of wastewater quality assessments in relation to wastewater quality requirements pertains to clean water hygiene and sanitation quality standards as outlined in PERMENKES Number 02 of 2023. Illustrated in **Table 2**.

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Table 2. Clean water hygiene and sanitation quality standards as outlined in Permenkes 02 of 2023

Parameter	Allowed Maximum Concentration		Unit
	I	II	
Temperature	38	40	°C
Total Dissolve Solid	2000	4000	mg/L
pH	5	5	-
Fe	5	10	mg/L
Mn	2	5	mg/L
Cr^{6+}	0.1	0.5	mg/L
BOD	50	150	mg/L
COD	100	300	mg/L
Mn	2	5	mg/L

2. Data regarding the assessment of the physical and chemical quality of river water in relation to Per. Gub. JATIM Number 72 of 2013, which pertains to quality criteria for various industrial activities. Depicted in Table 2.

The study was conducted in Jetis, Sidoarjo, which is at the northwestern tip of the Island of Java - Indonesia. This city is near to Surabaya which is the capital of East Java Province.

3. Results and Discussion

Wastewater sample from Jetis Sidoarjo batik, dated January 10, 2025. The sample was sourced from a batik home industry among 20 batik enterprises. The pollutants involved in the naphthol salt dyeing process include naphthol dyes, naphthol salts, caustic soda, TRO, and starch (Sulaeman; Mulyono, 2001) During the dyeing process, three categories of trash are generated: residual waste from naphthol dye (sample 1), residual waste from the color generation process involving diazonium salt/naphthol salt (sample 2), and residual waste from dyeing and color generation utilizing salt (sample 3). The comprehensive data about the assessment of the physical and chemical quality of trash is presented in **Table 3**.

Table 3. Assessment of the physical and chemical quality of trash

Parameter	Test Result Sample 1 (Salt)	Test Result Sample 2 (Nepthol)	Test Result Sample 3 (Mixed)	Average Result	Allowed Maximum Concentration	Unit
Escherichia Coli	26	25	15	22	0	CFU/100 ml
Total Coliform	71	53	23	49	0	CFU/100 ml
Temperature	29.6	29.4	29.5	29.5	±30	°C
Total Dissolve Solid	549	1455	1890	1298.0	<300	mg/L
Turbidity	516	215	661	464.0	<3	NTU
Color	740	180	300	406.7	10	TCU
pH	10	11	10	10.3	6.5-8.5	-
Nitrate	14	18	12	14.7	20	mg/L
Nitrite	10	12	8	10.0	3	mg/L
Cr^{6+}	0.5	0.3	0.5	0.4	0.01	mg/L
Fe	1.4	1.1	1.4	1.3	0.2	mg/L
Mn	0.8	0.3	0.6	0.6	0.1	mg/L

The examination of batik wastewater from three categories of batik waste indicates that all produced batik waste exceeds the quality standards established by Permenkes Number 02 of 2023 for clean water hygiene and sanitation, with the exception of the temperature parameter.

The total dissolved solids in the three types of batik wastewater produced had an average concentration of 1298 ppm. The elements responsible for elevated TDS and TSS levels originate from diazonium salt compounds that dissolve in water, subsequently disintegrating into particles of diverse sizes. Larger particles suspended in the aqueous medium are quantified as Total Suspended Solids (TSS), whereas smaller particles that dissolve in water are quantified as Total Dissolved Solids (TDS)(Indarsih et al., 2011).

The average turbidity of 464 NTU, average color of 406.7 TCU. The second measure is turbidity, which is closely associated with total suspended solids (TSS). Water is considered turbid when it contains a significant number of suspended particles, resulting in a muddy and unclean look, so suggesting the presence of hazardous compounds (Widianto et al., 2018).

The naphthol dyeing process generates waste with a high pH (alkaline) due to the use of caustic soda for dissolving the naphthol dye. The waste's pH is 10.3, above the quality requirement of 6.0 - 9.0.

The mean concentrations of nitrite and nitrate are 20 ppm and 3 ppm, respectively. Batik wastewater is characterized by elevated levels of bacteria, specifically Escherichia coli and total coliforms, averaging 22 and 49 CFU/100ml, respectively. This aligns with the research undertaken by Nicken Elok Arohmah, which indicated that following an identification test, the identified bacteria were the genera Bacillus sp. and Pseudomonas sp. (Arohmah & Rachmanto, 2023).

Nitrate (NO3) is the predominant type of nitrogen in natural aquatic environments. Nitrate originates from ammonium that infiltrates the water via waste. Nitrate concentrations may diminish as a result of microbial activity in aquatic environments. Microorganisms will oxidize ammonium to nitrite, which will subsequently be converted to nitrate by bacteria. The oxidation process will result in a reduction of dissolved oxygen concentration. Nitrate readily dissolves in water and possesses stable characteristics. Nitrate is a crucial nutrient for plants; nevertheless, elevated quantities can lead to substantial water quality issues. Excessive nitrate will expedite eutrophication, leading to heightened development of aquatic vegetation, hence influencing dissolved oxygen levels, temperature, and other parameters (Amalia et al., 2021)

The average chromium concentration is 0.4 ppm. The mean iron concentration in wastewater is 1.3 ppm, while the mean manganese concentration is 0.6 ppm. The widespread awareness and subsequent manufacturing of batik raise concerns over the exposure of workers to heavy metals due to the utilization of synthetic colors. Heavy metal concentration may be present in synthetic dyes used in textile manufacture. Certain reactive dyes include heavy metals, including cadmium, copper, and lead (Eskani et al., 2016). Numerous dyes employed in the textile industry also comprise heavy metals like Cu, Mn, Cr, Cd, Fe, Pb, Ni, and Zn (Bharadwaj & K, 2015; Handayani et al., 2020).

Batik wastewater, recognized for exceeding the quality standards outlined in Minister of Health Regulation Number 02 of 2023, was subsequently subjected to a comparative analysis against the East Java Governor Regulation Number 72 of 2013, which delineates the permissible quality standards for wastewater discharge into aquatic environments. This is undertaken to avert and mitigate the risk of significant environmental pollution.

Table 4. Assessment of the chemical Substance wastewater

Parameter	Test Result Sample 1 (Salt)	Test Result Sample 2 (Nepthol)	Test Result Sample 3 (Mixed)	Allowed Maximum Concentration		Unit
				I	II	
Temperature	29.6	29.4	29.5	38	40	°C
Total Dissolve Solid	549	1455	1890	2000	4000	mg/L
pH	10	11	10	5	5	-
Fe	1.4	1.1	1.4	5	10	mg/L
Mn	0.8	0.3	0.6	2	5	mg/L
Cr^{6+}	0.5	0.3	0.5	0.1	0.5	mg/L
BOD	115	100	140	50	150	mg/L
COD	10230	1114	6281	100	300	mg/L

I: Requirements for wastewater released into receiving water bodies classified as I, II, III, and seawater.
II: Criteria for wastewater released into Class IV receiving water bodies.

The analysis of batik wastewater from three types of batik waste indicated that all batik waste generated from the process exceeded the quality standards established by East Java Governor Regulation Number 72 of 2013 regarding quality standards for other industrial activities, with the exception of the temperature parameter. The average BOD value in wastewater was 118.3 ppm. The BOD number does not reflect the actual quantity of organic material; it solely measures the oxygen required for the decomposition of that organic material (Wulandari, 2018).

The COD value represents the quantity of oxygen required to convert organic matter in wastewater into carbon dioxide and water vapor (Metcalf dan Eddy, 1991). COD often results in higher oxygen requirement values than BOD tests because materials that are stable to biological reactions and microorganisms can be oxidized in COD tests (Fardiaz, 1992).

The elevated COD levels in wastewater average 5875 ppm due to naphthol dyes, which are manufactured chemical dyes originating from aromatic hydrocarbons like benzene, toluene, naphthalene, and anthracene. Naphthol dyes are water-insoluble compounds composed of two fundamental components: the naphthol AS (Anilid Acid) group and the producing component, which is the diazonium or salt group. This is also in line with the research of Mutia Yurida 2013, it is known in her research that the high average COD value in natural dyes is due to the natural dyes containing HCL in the extraction of Joho fruit skin. HCL is a very corrosive chemical liquid, has a pungent odor, including hazardous chemicals or B3 (Yurida et al., 2013). The BOD/COD ratio signifies the potential for biological decomposition of waste. If the BOD/COD ratio exceeds 0.5, the waste is biologically degradable; otherwise, it is not (Vymazal, 2014).

4. Conclusion

The wastewater from Jetis Batik in Sidoarjo fails to comply with the clean water quality criteria established by Minister of Health Regulation Number 02 of 2023 concerning the parameters of TDS, turbidity, color, Fe, Mn, nitrate, nitrite, pH, and chromium. Subsequent analyses utilizing East Java Governor rule Number 72 of 2013 indicate that TDS, pH, Fe, Mn, Cr, COD, and BOD surpass the quality limits established in the rule.

Moreover, pursuant to East Java Governor Regulation No. 72 of 2023, batik wastewater is categorized into classes I, II, III, IV, and seawater as unsuitable for discharge into marine environments. The direct dumping of batik wastewater into water bodies, without prior treatment, poses a significant risk of environmental pollution.

It is known that the application of color in this batik method can be categorized as "unsustainable" due of its potential for environmental damage. To enhance eco-efficiency, alternative colors (natural dyes) should be utilized, and an end-of-life plan must be implemented through the implementation of suitable technologies, including filtering systems for liquid waste processing in the batik sector.

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