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Widhi Handayani
Department of Development Studies, Satya Wacana Christian University, Salatiga 50711, Indonesia, widhyandayani@gmail.com

Yohanes Budi Widianarko
Department of Food Technology, Soegijapranata Catholic University, Semarang 50234, Indonesia, widianarko@unika.ac.id

Alberta Rika Pratiwi
Department of Food Technology, Soegijapranata Catholic University, Semarang 50234, Indonesia., pratiwi@unika.ac.id

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ADDRESSING THE DEBATE ON THE ECO-FRIENDLINESS OF INDONESIAN BATIK BY WATER FOOTPRINT APPROACH

Widhi Handayani[1]*, Yohanes Budi Widianarko[2], Alberta Rika Pratiwi[2]
[1]Department of Development Studies, Satya Wacana Christian University, Salatiga 50711, Indonesia
[2]Department of Food Technology, Soegijapranata Catholic University, Semarang, 50234, Indonesia

*Corresponding author: widhyandayani@gmail.com

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Abstract

The Indonesian batik is an intangible cultural heritage that contributes to the country's economy but raises environmental pollution. Synthetic dyes are considered to cause pollution, and the natural counterpart is recommended to replace it because natural dyes are considered more eco-friendly than synthetic ones. Therefore, this study examined the Blue Water Footprint (BWF) and Grey Water Footprint (GWF) of the batik household industry by applying synthetic dyeing and comparing the result to the natural dyeing from previous studies. This research used the Water Footprint accounting approach based on the Water Footprint Network, which involves identifying the batik process followed by measuring and calculating the consumptive water use representing BWF and degradative water use representing GWF. The BWF of batik-making process applying of synthetic dyes was 1000.914 L/day or 9.223 L/pc, and the GWF was 12,877.215 – 18,003.118 L/day or 95.39 – 142.88 L/pc. Washing consumes water most responsible for the high BWF, while dilution water for dye solution and wastewater dominates the portion of GWF. Applying both dyes produces wastewater whose quality exceeds the acceptable limit the Indonesian government sets, indicating that eco-friendliness should not be directly associated with synthetic or natural dyes. The selection of synthetic or natural dyes alone for batik production is not recommended since dyeing might be related to environmental issues and market preferences. The main problem lies in the batik artisans' general assumption regarding eco-friendliness linked to specific dyes, which needs to be improved by increasing water use efficiency with technology. Future research must focus on finding innovations to reduce water use in batik processing.

Keywords: Batik; Eco-friendliness; Natural dyes; Small-medium enterprise; Synthetic dyes; Water footprint.

1. Introduction

Indonesian batik fabrics have been produced for hundred years and recognized as Intangible Cultural Heritage by UNESCO in 2009. This recognition brings advantages in the economic aspect as batik production employs job seekers, as well as increases the national income.

Often, batik fabric is produced by small and medium enterprises (SMEs) spread in the regions of Solo, Pekalongan, Tegal, Lasem, and Banyumas (Mukimin et al., 2018) as well as Klaten (Handayani et al., 2018a).

Batik produced by SMEs are usually managed by a relatively small family-based facility with no wastewater treatment units, and their various locations make it difficult to build a centralized treatment system (Birgani et al., 2016). Consequently, the batik SMEs tend to discharge wastewater directly into channels or the soil in their surroundings, which eventually causes related pollution. The pollution is usually related to using dyes, as the batik involves dyeing in its process—generally, synthetic dyes are considered the primary source of pollution.

Hossain et al. (2018) wrote that in Bangladesh, textile industries could release wastewater in a volume of 217 million m3/year in 2016, which could be increased to 349 million m3/year in 2021, and the wastewater contains a wide range of pollutants, including heavy metals (Sakamoto et al., 2019). Regarding batik, Birgani et al. (2016) wrote that wastewater is usually produced during soaking, rinsing, and boiling or wax removal steps, which involve huge quantities of water and chemicals, such as dyes, waxes, and fixing agents. It is reported that textile production consumes a high volume of water per unit (Hossain et al., 2018), which the water footprint approach could study. In China, the annual water footprint of textile production fluctuated by an increasing trend from 10,325 Mt/a in 2001 to 14,044 Mt/a in 2007, followed by a decreasing trend in 2008-2014 by a water footprint of 12,639 Mt/a in 2014 (Li et al., 2017).

In Bangladesh, it is reported that the annual water footprint of textile industries was 1.8 billion m3/year (Hossain & Khan, 2020). Although research in textile water footprint has been widely conducted, there are limited studies on the water required for batik production by the water footprint approach. In addition to the fact that batik is produced by home industries using traditional technology – i.e., the use of canting or bamboo stylus and a block print as tools for applying wax, instead of using print screen machines to produce the products – the artisans involved are not accustomed to measuring the quantity of materials they use for production, including water, which becomes a challenge in mapping the water footprint of batik production by SMEs.

The previous study mapped the water required for the natural dye batik-making process by large-scale SMEs using the footprint approach, which was found to be 1309 – 5549 L/pc (Handayani et al., 2019). Meanwhile, in a small-scaled SME, the water required to process batik is 550.72 L/pc (Widianarko & Pratiwi, 2020). The advantage of the footprint approach is providing information on the water required in textile production because it involves the calculation of direct and indirect materials used in the form of Blue and Green as well as Grey Water Footprint, respectively, as explained by Hoekstra et al. (2011).

Our previous studies were conducted to investigate batik production by natural dyeing process because it has been indicated that natural dyes are considered more eco-friendly than synthetic ones (Handayani et al., 2018a). Nevertheless, it was found that the eco-friendliness of batik produced by natural dyeing is still questionable (Handayani et al., 2018b). Therefore, there is a need for a comparison study to map the water required by batik production when using synthetic and natural dyes. This study examines the Blue and Grey Water Footprint of a large-scale batik SME that uses synthetic dyes for production purposes, and the result was compared to the water footprint of batik produced by natural dyeing from previous studies. Finally, the debate on the eco-friendliness of batik production is addressed by this study.

2. Methods

Commonly, batik is produced by SMEs that operate as household industries using traditional technology. The workers are not accustomed to measuring and taking notes on using materials, including water. Regarding the fact that national data on water use for batik production is unavailable and that studies of batik are usually conducted sporadically across Indonesia, for this case study, we use the process water footprint instead of the product water footprint (Hoekstra et al., 2011). The data was collected by observing the batik production process and measuring the water usage during all the processes. Similar to previous studies on natural dye batik's water footprint, synthetic dyes production's water footprint is excluded due to the unavailability of data (Handayani et al., 2019).

In brief, the batik-making process consists of some steps we call dry and wet phases, as indicated by Handayani et al. (2018a). Commonly, the first step is drawing batik patterns on a cotton cloth of 2 m x 1.15 m (silk is sometimes also used instead of cotton, but it is uncommon because it is quite expensive), followed by wax covering the pattern. Following the process is dyeing, which might be conducted using natural or synthetic dyes. When the dyeing process is finished, the cloth is waxed again. The process of waxing and dyeing is usually conducted in turn each other. Finally, after all those steps are finished, the cloth will be boiled to remove the wax from the cloth, and the cloth will be dried under the sun. The list in Table 1 summarizes the process of making batik.

This study was conducted in a large-scale batik SME in Jarum village, Klaten regency, Central Java, Indonesia. The SME is a household industry that produces hand-drawn and block-printed batik and a combination of both. The batik fabrics were colored with synthetic dyes, i.e., naphthol and indigosol (vat dye). The batik production from the first step to the dyeing process was observed. Based on this observation, the wax and dyes absorbed by the fabric were calculated, and water was used during production. The water footprint approach based on Hoekstra et al. (2011) was used in this study. Furthermore, the components employed for the study were BWF, which indicates consumptive water use, and GWF, which indicates the water required to assimilate pollutants.

2.1. Assessment of blue water footprint

Hoekstra et al. (2011) wrote that BWF indicates consumptive water use, which consists of (1) the water that evaporated during the process, (2) water incorporated in the product, (3) the one abstracted from a source but returned to other water sources, and (4) lost return flow. In this study, the BWF was calculated from the evaporated water and the one incorporated in the product. The batik home industry often uses traditional technology, and the workers are not accustomed to materials measurement. As explained, the quantity of water used for production was determined by a straightforward method.

In order to calculate the water that evaporated from the wax removal process and the one used by the workers, volumes of water before and after the process were measured. Determination of the dimension of the water tank, as explained by Handayani et al. (2018b), was performed to calculate the water volume of its content. Finally, the quantity of water used was calculated by reducing the final volume by its initial volume. In case there was evaporation during the drying process, the weight of the fabric before and after its soaking in the dye or water was measured. The additional weight after the dyeing or washing processes was the water absorbed by the fabric, which evaporated when dried under the sun.

A weight measurement of the fabrics throughout the batik processing was also conducted to calculate the wax used for production and the dyes absorbed by the cloth. Therefore, the weight was measured starting from its initial state in the form of white cotton fabric (dry phase), after the application of wax (dry phase), after the wax removal process (wet phase), and until the final (dry phase) as explained by Handayani et al. (2019). Table 1 presents the wax and dyes used throughout the batik-making process.

Table 1. Application of wax and dyes and water use during batik processing stages

Materials	Common batik processing stages				
	Pattern drawing	Waxing	Dyeing	Wax removal	Drying
Dyes	No	No	Yes	No	No
Wax	No	Yes	No	No	No
Water	No	No	Yes	Yes	No

2.2. Assessment of greywater footprint (GWF)

According to Hoekstra *et al.* (2011), GWF indicates the water required to assimilate pollutants. Therefore, in this study, an evaluation of batik wastewater's characteristics was conducted, and the parameters measured were pH, Total Suspended Solid (TSS), Biological Oxygen Demand (BOD5), and Chemical Oxygen Demand (COD). The pH value was determined using a HANNA HI 9811-5 pH electrode, while a gravimetric method that involved Whatman filter paper of 0.45µm size was used to measure TSS concentration. Azide modified-iodometry was used to measure BOD5, and COD was determined using titrimetry with the open reflux method. Furthermore, all the analyses were performed according to Kruis (1995). In order to compare the result with the acceptable limit, the quality standard for textile wastewater was used, as set by the Ministry of Environment of Indonesia (2014).

In order to calculate GWF, COD was used as the suitable parameter. As the SME discharged its wastewater into the channel penetrating the soil, the point-source pollution approach was irrelevant to calculating the GWF. Therefore, the GWF was calculated as water required for diluting pollutants according to the Equation 1 of Widianarko et al. (2021):

$$df = \frac{[COD]sample}{[COD]limit} \tag{1}$$

The dilution factor (*df*) was calculated by dividing the concentration of the *COD sample* in mg/L to meet the acceptable limit set by the government. The water required to dilute the COD contained in one ml of wastewater was calculated by reducing *df* by 1. Finally, determining the total water required for the dilution process was based on Equation 2 of Widianarko et al. (2021).

$$dw = (df - 1)\ x\ wastewater\ volume \tag{2}$$

As previously explained, the dilution water (*dw*) in ml was calculated by reducing df by one and multiplying with the volume of wastewater discharged. Based on observation, it was discovered that the SME often discharged wastewater released from wax removal and washing first, followed by some dye solution after both processes. Therefore, the *dw* value was calculated for those three components of wastewater.

3. Results and Discussions

The result of this study was divided into four parts, i.e. (1) a description of the batik-making process that involved synthetic dyes for coloration, (2) the BWF assessment, (3) the characterization of batik wastewater, and (4) the GWF of the batik-making process by synthetic dye coloration.

3.1. The batik-making process by synthetic dyes coloration

Generally, the batik-making process by synthetic dye coloration is similar to the report of Handayani et al. (2018a). The difference is that this process consumes less time than natural dye coloration because in the synthetic, the soaking-drying repetition is unnecessary, which makes it easier for the SME to produce more products. During coloration, the dyeing workers used synthetic dyes of naphthol and indigosol. Although dipping the fabric into the dye is the main technique employed (Figure 1a), there is another way to color specific patterns by painting (Figure 1b). After the fabric is painted, it is dipped into the dyes to produce other patterns.

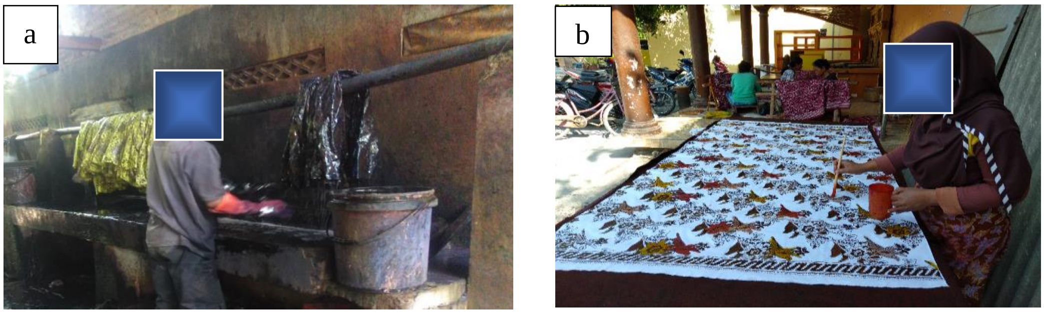

Figure. 1 Dyeing batik by (a) dipping technique and (b) painting technique to color specific batik pattern (Source: Personal documentation, 2019)

Contrary to natural dyeing, using mordants like lime, alum, and copperas is unnecessary. Naphthol was usually applied by combining it with its salt to form the color, while indigosol application was fixed using hydrochloric acid (HCl). After the dyeing process, the fabric was boiled to remove the wax, followed by final drying.

Table 2. Weight of fabric during batik processing

Type of batik produced	Weight of fabric (g) during batik processing			
	White fabric (dry)	Waxing (dry)	Wax removal (wet)	Final drying (dry)
Hand-drawn	255.00	550.00	571.67	277.09
Block-printed	226.67	443.33	538.33	243.34

Table 2 shows the weight of the fabric during its initial condition/state, waxing, wax removal, and after final drying. Based on the results, the materials used for batik production were calculated and presented in Table 3.

Table 3. Water, wax, and dyes usage to produce a piece of batik fabric

Type of batik produced	Materials attached to or absorbed by a piece of batik fabric by synthetic dyes coloration		
	Wax (g)	Water (ml)	Dyes (g)
Hand-drawn	295.00	294.58	22.09
Block-printed	216.67	295.00	16.67

The results showed that hand-drawn batik production used more waxes than block-printed, as indicated by the materials' weight in Table 3. Nevertheless, this is possibly influenced by the quality of materials used for production because the hand-drawn batik is usually made of good quality wax, which is yellowish-brown in color, while the block-printed employed darker ones recovered from the wax removal process. A previous study indicated that the density of the excellent quality wax was 0.94 g/cm^3, while that of the recovered was 0.90 g/cm^3 (Widianarko & Pratiwi, 2020). Hence, the difference in weight of the wax used to produce the various batik fabrics might correspond to its density.

This study discovered that waxes were usually recollected in a vessel with a 49 cm diameter and 20 cm height (Figure 2a), equaling 37,695.70 cm^3. When the volume is multiplied by the recovered density of 0.90 g/cm^3 (Widianarko & Pratiwi, 2020), the wax recollected is 33,926.13 g or 33.93 kg. Furthermore, the interview conducted for the batik workers indicated that to recycle 80 kg of waxes, 7 kg of rosin or colophony (Figure 2b), 2 kg of paraffin, 2 kg of cat's eye resin extracted from *Shorea javanica*, and 2 kg of micro wax were added (Figure 2c). This differed from the previous study because the wax was usually recollected, cleaned from trashes, and reused directly in other batik SMEs. Nevertheless, it indicates that the home industry has been recycling waxes instead of recollecting them.

(a) (b) (c)

Figure. 2 The recovered wax (a), rosin (b), and cat's eye resin for wax recycling
(Source: Personal documentation, 2019)

The result in Table 3 indicates that the water absorbed by the fabrics was similar, i.e., around 295 ml or 0.295 L. This follows the previous study that reported the water absorbed by the batik fabric produced through the natural dyeing process of different SMEs was 0.18 L and 0.30 L (Handayani et al., 2019; Widianarko & Pratiwi, 2020). However, it is indicated that the dyes absorbed during hand-drawn and block-printed batik production were around 22.09 g and 16.67 g per piece of fabric. The SME produced hand-drawn and block-printed batik in a dimension of 2.25 m x 1.15 m and 2.00 m x 1.15 m, respectively. Furthermore, when the dye's weight was divided by the batik's area, 8.53 g/m^{2,} and 7.25 g/m^2 were obtained. These values are much lower than the batik natural dyeing process in which 17.99 g of dye per m^2 of fabric was absorbed (Widianarko & Pratiwi, 2020). In addition, this fact supports the advantage of using synthetic dye, which indicates that with a small weight, good coloration is produced.

3.2. The BWF of batik by synthetic dyes coloration

The BWF assessment result is presented in Table 4, which indicated that the water consumed for batik production was 960.606 to 1,034.545 L/day or equal to 1,000.914 L/day on average. Among the three processes, namely, soaking, dyeing, and wax removal, water was consumed chiefly during the third, i.e., on average, 220.460 L/day, with 438.480 L/day for washing. During the dyeing process, 97.029 L of water was used per day, and when the quantity was divided by the number of colored fabrics, relatively low water consumption was obtained in the range of average 2.371 to 3.933 L/pc or 2.859 L for a piece of fabric. Nursanti et al. (2018) reported that 6.000 L of water was used in the synthetic dye coloration of four pieces of batik fabric produced in Surakarta. This indicates that the industry average consumed 1.500 L/pc of water for dyeing. Therefore, the result of this study is higher than the report of Nursanti et al. (2018). It is indicated that optimal water use for batik production is 25-50 L/m cloth (Nugroho et al., 2022), meaning a piece of batik fabric of 2 m x 1.15 m size will consume 115 L of water at maximum. Compared to this result, the BWF of this research is much lower than the optimal water use indicated by Nugroho et al. (2022).

The data in Table 4 also indicated that the number of batiks produced during three observation times fluctuated. Although the SME usually produces batik fabrics of around 100 pcs/day, but could be lesser due to some reasons. When the production is less than 100 pcs, the water consumed for dyeing becomes higher, indicating inefficiency. In order to elevate its efficiency, it is possible to increase the production of batik fabrics or, at worst, reduce the use of water to ensure a decline in water consumption.

Compared to the natural dye, previous results showed that the BWF of the batik natural dyeing process produced by a large-scale enterprise was 4.680 L/pc (Handayani et al., 2019). Regarding that the SME in this study is large-scaled as indicated by its daily production volume, it is clear that BWF produced from batik-making using synthetic dyes was 9.223 L/pc and is higher than that of the natural counterpart. Although the type of coloration might influence this difference, batik artisans' behavior might also contribute to that difference (Handayani et al., 2021; Widianarko & Pratiwi, 2020). This indicates that different habits among batik artisans usually lead to diverse water use. That difference might be related to the perception of the batik artisans toward the water. The study of Sonta et al. (2017) revealed that their perception of the watershed influences the behavior of the community toward Setu watershed in Pekalongan, whether the watershed is a public toilet, an abnormal water body, or a place to discharge wastes, etcetera. Hence, it is essential to dig deeper into the perception of batik artisans regarding water resources if the behavior of batik artisans will be improved.

Table 4. BWF of the batik-making process by synthetic dye coloration

No.	BWF components	Observation			Average
		1	2	3	
1	Fabric soaking (L/day)	41.579	26.400	6.490	24.823
	Number of fabrics soaked (pcs/day)	126	80	25	71
	Water for soaking (L/pc)	0.330	0.330	0.259	0.340
2	Dyeing				
	a. Dyeing process (L/day)	113.904	55.144	122.040	97.029
	b. Washing (L/day)	184.800	184.800	184.800	184.800
	Number of fabrics dyed (pcs/day)	126	61	135	107
	Water for dyeing (L/pc)	2.371	3.933	2.273	2.859
3	Wax removal				
	a. water for wax removal (L/day)		220.46		220.46
	b. water evaporated (L/day)		35.322		35.322
	c. water for washing (L/day)		438.48		438.48
	Total BWF/day (L/day)	1,034.545	960.606	1,007.592	1,000.914
	BWF/pc (L/pc)	8.21	12.00	7.46	9.223

Compared to a previous study which indicated 60 L/day of water was used for natural dyeing (Handayani et al., 2019), this study found that 97 L/day of water was required for synthetic dyeing. Based on our observation and interview with the batik workers, they used eight water vessels of 1.13 L, equal to 9.040 L, to dissolve the dye for ten fabrics' coloration. The more the fabrics, the more water they used. Unfortunately, it was observed that the home industry often discharged some dyes after the processes were finished. This phenomenon is seldom found in home industries that produce their batik by natural dyeing because they usually use the dye extract ultimately, except for indigo. The natural dye batik artisans often extract the dyes from barks at once. The extract was usually applied for coloration for days until it was used ultimately, with no possibility to discharge into the environment. This difference is more related to the material properties, in which the limitation of synthetic dyes in terms of not being used repetitively is indicated.

3.3. Characterization of batik wastewater by synthetic dyeing

The characteristics of batik wastewater in this study are presented in Table 5. A previous study indicates that batik wastewater characteristics usually fluctuate over time (Handayani et al., 2019). Therefore, some parameters are put into range instead of calculating their average. The dyes of naphthol and indigosol were alkaline as indicated by their pH value, which falls in the range of 10.35 to 11.06. This follows the finding of Birgani et al. (2016), which indicated that the pH of the wastewater after the soaking step was 11.30. The pH after wax removal tends to be acid, which is different from the findings of Mukimin et al. (2018), which reported that the pH of batik wastewater was 9.80, and Birgani et al. (2016), which indicated it to be 12.10. This difference is attributable to hydrochloric acid (HCl) to ensure the color is fixed after dyeing with indigosol, which will be absorbed by the dye and might eventually affect the pH of the wastewater. Even when the wax removal involved soda ash, which is common among batik artisans (Widianarko & Pratiwi, 2020), the property of the HCl tends to affect the wastewater more than soda ash because it is known to be strongly acidic.

Table 5. Characteristic of batik wastewater by synthetic dyes coloration

Parameters	Batik processing steps					Acceptable limit*
	Dyeing-naphthol	Dyeing-indigosol	Washing dyes	Wax removal	Final washing	
pH	11.60	10.35	11.50	5.80	6.00	6 – 9
TSS (mg/L)	3,799 – 16,160	1,755 – 11,040	658 – 1,636	972	127 – 466	50
BOD5 (mg/L)	37.50 – 67.50	67.50 – 75.00	38.75 – 45.00	5.50	12.50 – 21.00	50
COD (mg/L)	3,740 – 9,360	2,160 – 8,780	1,930 – 3,480	2,870	1,280	150
BOD/COD ratio	0.007 - 0.010	0.008 – 0.030	0.013 – 0.020	0.002	0.009 – 0.016	---

Based on Table 5, the BOD5 value was around 50 mg/L, except for indigosol. Furthermore, the result is much lower when compared to Khalik et al. (2015), Kassim et al. (2018), and Tangahu et al. (2019), who reported the BOD5 value of batik wastewater to be 341.25, 439.50, and 2,710 mg/L, respectively. This study indicates that the lowest BOD5 and pH were found in the wastewater released from wax removal. Since BOD5 indicates the oxygen required to degrade organic matter aerobically (Lee & Nikraz, 2015), its low value corresponds with the oxygen needed for aerobic degradation. Consequently, there is minimal microbial activity in the wastewater. Hydrochloric acid for fixation and soda ash for wax

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removal corresponds to this result. By comparison, the wastewater of other studies might be collected from final disposal, which is very likely to be a mixture obtained from all the processing steps, and this reason tends to explain the difference in concentration of BOD5 between this study and others.

It was discovered that the COD concentration of batik wastewater was high and exceeded the acceptable limit set by the Ministry of Environment of Indonesia (2014). Furthermore, the COD concentration has been reported to reach 4,092 mg/L (Khalik et al., 2015), 4,915 mg/L (Birgani et al., 2016), 661.5 mg/L (Kassim et al., 2018), 870 mg/L (Mukimin et al., 2018), and 3,855 mg/L (Tangahu et al., 2019). Finally, the BOD5/COD ratio was calculated to evaluate the wastewater's biodegradability, as Dinçer (2020) and Suryawan et al. (2018) indicated. Table 5 showed that the BOD5/COD ratio of the wastewater from all the steps was meager, i.e., less than 0.10, which indicates the biodegradability of the wastewater is very low, as Dinçer (2020) wrote that biodegradation requires a BOD/COD ratio of the wastewater in the range of 0.40 – 0.50.

Pramugani et al. (2022) found that the BOD5/COD ratio of synthetic batik wastewater after around 15-30 minutes of ozonation was 0.085, which indicates similarity to the result of this study. Sela et al. (2020) also found that the BOD and COD concentration of textile wastewater in Bangladesh were 60 g/L and 250 g/L, respectively, which indicated its BOD/COD ratio is 0.24. Using 0.1 g of chitosan could reduce the BOD concentration to 30 g/L. At the same time, COD was 140 g/L (Sela et al., 2020), which, unfortunately, did not change the biodegradability of the wastewater as the BOD/COD ratio was still in the value of 0.21. However, Suryawan et al. (2018) reported that ozonation could increase the biodegradability of RB-5-containing wastewater indicated by an increase of BOD5/COD ratio to 0.40 – 0.60 – depending on the treatments – from its initial BOD5/COD ratio of less than 0.40.

Felaza & Priadi (2016) reported that the COD of natural dyes, namely *sogan* woods, *jalawe* or myrobalan, *Indigofera*, and *tingi*, were 1,316 mg/L, 2,453 mg/L, 1,734 mg/L, and 1,665 mg/L, respectively. Handayani et al. (2018b) found that the COD of natural dyes could reach 1,500 mg/L for mahogany extract (*Swietenia* sp.), 1,280 mg/L for myrobalan extract (*Terminalia bellirica*), and 6,640 mg/L for indigo extract (*Indigofera* sp.) of an SME. However, depending on the different formulas of extraction, the COD of natural dye extract of smaller SME tends to reach 2,160 mg/L for indigo, 14,726.67 mg/L for mixed *sogan* woods extract, and 37,546.67 mg/L for myrobalan extract (Widianarko & Pratiwi, 2020).

It was also reported in another SME that COD of mahogany extract (*Swietenia* sp.), extract of indigo (*Indigofera* sp.), and *tingi* wood extract (*Ceriops* sp.) were 4,475 mg/L, 2,360 mg/L, and 3,610 mg/L, respectively (Widianarko et al., 2021). It is indicated that the COD of natural dyes was in the range of 1,280 to 37,546.67 mg/L. When synthetic dyes were compared to their counterpart, the COD of naphthol and indigosol tend to be higher than some natural dyes but lower than others. Regarding BOD5/COD ratio, it was reported that the BOD5/COD ratio of *sogan* woods, myrobalan, and indigo were 0.15, 0.40, and 0.15, respectively (Felaza & Priadi, 2016). While our previous study showed that the BOD5/COD ratio of extract mahogany extract and myrobalan extract were both 0.30, the BOD5/COD ratio of indigo-containing wastewater was reported to be 0.011 (Handayani et al., 2018b). The results indicate that the biodegradation of natural dye batik wastewater is still challenging.

3.4. The GWF of batik produced by synthetic dyes coloration

The GWF of a batik-making process involving coloration by synthetic dyes is presented in Table 6. This is calculated based on two processes involved, i.e., dyeing and wax removal, which discharges wastewater. It is indicated that GWF for dyeing is higher than for wax removal. Furthermore, the GWF for the dyeing process consists only of water to dilute the dyes and wastewater from washing, which suggests a high COD concentration of the dyes, as presented in Table 5. As previously explained, the home industry often discharges some portion of dyes after all the processes are finished. When the COD is high, the water required for dilution will also be considerably high. Therefore, reducing the dyes' discharge is recommended since some water is consumed for dilution, mainly when the COD is high.

Overall, Table 6 suggests the total GWF of batik production by synthetic dye coloration is 12,877 L/day or equal to 95.39 L/pc to 18,003 L/day or 142.88 L/pc. This GWF is lower than natural dye batik production, which is 65,207 L/day (Handayani et al., 2019). The lower GWF might correspond to the COD load of the synthetic dyes. This study indicates that the COD of both naphthol and indigo are considerably high, while the difference falls on the COD of wastewater from washing. High COD contained in the wastewater from the washing process might correspond to using natural dyes. Mordants are used with the application of natural dyes to fix the dye onto the cloth because natural dyes are reported to have a low affinity to fabrics (Christie, 2015). The wax removal process or boiling might influence the properties of natural dyes, and during the process, some dyes might fade into the water. Hence, during the washing, some dye molecules, waxes, and other materials, such as starch or soda ash, could suspend in the water, which is the reason for the high COD.

Table 6. GWF of the batik-making process by synthetic dye coloration

No.	GWF components	Water required for dilution (L/day)	
1.	Dyeing process	1st observation	2nd observation
	a. Dilution water for the naphthol dye solution	7,298.250	2,844.416
	b. Dilution water for indigosol dye solution	226.701	973.293
	d. Dilution of water for wastewater from washing	3,284.978	1,756.428
	GWF for the dyeing process	10,809.929	5,574.136
2.	Wax removal	1st observation	2nd observation
	a. Dilution water for wastewater discharged from wax removal	3,996.940	
	b. Dilution water for wastewater discharged from the washing	3,306.139	
	GWF from the wax removal process	7,303.079	
	Total GWF (L/day)	18,003.118	12,877.215
	Number of fabrics produced	126	135
	Total GWF (L/pc)	142.88	95.39

3.5. Synthetic and natural dyes: Which one is more eco-friendly?

For a hundred years, the coloration of textile by human has been carried out by using natural dyes. Indigo (*Indigofera tinctoria*), noni (*Morinda citrifolia*), and annatto (*Bixa orellana*) were among some plant species used to dye batik in the 18th century (Raffless, 2019). However, natural dyes are extracted from plants and other sources such as minerals, ochre, and haematites providing yellow, red, and brown colors (Christie 2015), and also from animals, namely insects and mollusks (Christie, 2015). Cochineal and lac dyes are made from insects. For example, the *Dactylopius coccus* and *Kerria lacca* produce carmine and red dye, respectively, while the Tyrian purple is from the sea snail *Bolinus brandaris* (Adeel et al., 2018). Since natural dyes are unstable concerning washing, light exposure, and low affinity for fabrics, using mordants as fixing agents becomes essential in the dyeing process (Christie, 2015).

In 1856, when the aniline purple or mauveine was discovered, synthetic dyes were replaced with natural dyes for textile coloration. After the mid of 20th century, the dyes' impact increased (Adeel et al., 2018), particularly dyes from the azo group. Azo bond cleavage releases aromatic amines that harm human health and the aquatic ecosystem (Crettaz et al., 2019), which might result from the dyes' direct and indirect effects (Al-Gubury et al., 2022). Due to this situation, some countries have strictly banned synthetic dyes – including azo dyes – from the goods consumed for daily life (Adeel et al., 2018; Crettaz et al., 2019). Subsequently, the revival of natural dyes was uplifted, which also happened to the batik home industry.

The previous study revealed that batik made from natural dye has been attracting attention as an eco-friendly product, and this exact image has also been developed in Jarum village, while the synthetic counterpart was not (Handayani et al., 2018a). Fauzi & Defianisa (2019) reported that batik production by synthetic dyes generates 614.38 kg/100 sheets of batik, or equal to 25.28 m^3 wastewater per ton of batik, while natural dyeing production generates 550.60 kg/100 sheets of batik which is equal to 19.11 m^3 wastewater per ton of batik. This study recommends the use of natural dyes instead of synthetic dyes.

However, Fauzi & Defianisa (2019) did not include the wastewater quality in their explanation, which is the limitation of their study, and could lead to the thought that natural dye is better than synthetic ones. This is in line with the recent report of Bide (2014) that sustainability is erroneously related to natural – harmless and synthetic–toxic assumptions. However, previous studies found that the natural dye batik industry has been creating pollution which disturbs the people in the environment due to its wastewater which has a quality that does not meet the acceptable limit required by the Indonesian Government (Handayani et al., 2018a; Handayani et al., 2018b).

This study points out that the COD of synthetic and natural dye-batik wastewater exceeded the regulation of Indonesian government, despite which one is higher than another. Regarding biodegradability, the result is similar to a previous study conducted for natural dyes, which indicates the BOD5/COD of natural dye wastewater is less than 0.30 (Handayani et al., 2018b). Furthermore, the study of Felaza & Priadi (2016) indicates that implementation of cleaner production reduced the BOD5 while the COD concentration was not affected, which eventually lowered the BOD5/COD ratio and means the wastewater's biodegradability was decreased. Based on this finding, they did not recommend using the BOD5/COD ratio as the main parameter for wastewater quality improvement (Felaza & Priadi, 2016).

Nevertheless, when biodegradability is considered one indicator of eco-friendliness (Saxena & Raja, 2014), it is clear that the wastewater of both dyes fails to meet the biodegradability requirement. As a consequence, eco-friendliness could not be expected. The high GWF of 12,877 L/day or equal to 95.39 L/pc to 18,003 L/day or 142.88 L/pc for synthetic dyes and 65,207 L/day for natural dyes (Handayani et al., 2019) supports our argument that none of the production using both dyes are eco-friendly. Therefore, the use of wastewater treatment technology for batik production of whichever dyes is unavoidable. A study by Budiyanto et al. (2018) indicates that even wastewater treatment plant is available.

However, as it is poorly managed and lacks environmental awareness, it has been leading batik production in Pekalongan to pollute the community's dug well.

The selection of synthetic or natural dye was not the best solution to realize the eco-friendliness of batik production because of the previous reason unless a study that proves the easiness of batik wastewater degradation is conducted. We argue that batik product made from natural or synthetic dyes' application which discharges wastewater with fast degradation performance, tends to be more acceptable because it relates to its treatment's ease. However, since the selection of natural or synthetic dyes is related to environmental concerns and consumer or market preferences, it seems impossible to force the batik artisans to select one. The natural dyes produced calm and cool batik colors, but their dependence on chemical fixing agents and light fastness still become issues that need to be addressed (Das, 2011), as well as to guarantee that their sources have to be provided sustainably for industrial scale (Bhattacharjee & Reid, 2011). Conversely, synthetic dyes produce stable, bright colors of a broad spectrum over time (Bide, 2014) with a small weight of dyes. Nevertheless, this is challenged by its adverse effect on human health and the ecosystem. Natural and synthetic dyes have advantages and disadvantages.

A recommendation was provided on reducing water usage for direct consumption and dilution. Also, it is suggested that the synthetic dyes applied by batik home industries were used ultimately instead of discharging the remnant into the environment because their COD is considerably high. The additional ingredients, such as soda ash, should be reduced and monitored regularly to avoid high COD load. Water use efficiency is increasable by reducing direct water use, augmenting the production capacity, reusing possible grey water, and performing wastewater treatment. Through the Balai Besar Penelitian Batik (Research Agency for Batik), the government shares the standard method for the wax removal process to ensure that all artisans have the same standard in using soda ash or starch. It has been occurring that the batik artisans tend to use those materials left unmonitored, which can increase the COD load.

Furthermore, it was highlighted that the problem lies not in the two dyes but in the assumption of eco-friendliness, which erroneously relates natural as eco-friendly and synthetic as not eco-friendly, as Bide (2014) reported. Regarding the latter, such improvement has to be made in the assumption or general mindset of the people and artisans on the definition of eco-friendliness simultaneously with optimizing water conservation to realize sustainable batik production. Finally, the limitation of this research is that while we are seeking to explore the water footprint of batik production based on the case study in the field, the external factor(s) that influence water use in batik production, such as habit or behavior of batik artisans, cannot be minimized. Therefore, if a study comparing natural and synthetic dyes is conducted, it needs to be conducted in a laboratory where such external factors can be minimized.

4. Conclusion

This study discovered that the BWF of the batik-making process, which involved the application of synthetic dyes, was 1000.914 L/day or 9.223 L/pc, and the GWF was 12,877.215 – 18,003.118 L/day or 95.39 – 142.88 L/pc. Washing, both for dyeing and wax removal, is an activity that consumes water most and is responsible for the high BWF. In contrast, dilution water is the dominant portion of GWF, particularly to dilute the dye solution and wastewater discharged into the environment. By comparison, the BWF produced from this study is higher than the natural dye-batik of a large-scaled SME, while the GWF is lower than its natural counterpart. Nevertheless, the wastewater quality indicates that both natural and synthetic dyeing contribute to ecosystem degradation since it exceeds the acceptable limit set by the Indonesian government. Based on this result, there was no recommendation on which of the dyes is better since both are related to environmental concerns and consumer preferences. The main problem discovered is a general assumption of eco-friendliness, which required some efforts to improve it simultaneously with water use efficiency.

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Author Contribution
The authors declare that all authors bring contributions in the writing of this article. Conceptualization, WH, BW, and AP; Methodology, WH; Investigation, WH; Writing – Original Draft Preparation, WH; Writing – Review & Editing, BW and AP; Supervision, BW and AP; Project Administration, WH and AP; and Funding Acquisition, BW.

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