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Water Footprint of the Natural Coloured Batik-Making Process: A Study on a Batik Small Enterprise in Jarum Village, Klaten Regency, Indonesia

Widhi Handayani[a,*], Budi Widianarko[b], Alberta Rika Pratiwi[b]

[a]Faculty of Interdisciplinary Studies, Satya Wacana Christian University, Jl. Diponegoro 52-60 Salatiga 50711, Central Java, Indonesia
[b]Faculty of Agricultural Technology, Soegijapranata Catholic University, Jl. Pawiyatan Luhur IV/1 Bendan Dhuwur Semarang 50234, Central Java, Indonesia
widhyandayani@gmail.com

Indonesian batik is usually produced by Small and Medium Enterprises (SMEs) which tend to induce environmental problems. Batik wastewater has caused pollution in some regions of Central Java, resulting in odour, allergic reactions among the local population, and the degradation of water quality. Batik production also requires a substantial volume of water. This study examines the water footprint of natural coloured hand drawn batik-making process by a small enterprise in the Jarum village, Klaten. Blue Water Footprint was determined by direct measurement, while Grey Water Footprint was estimated by calculating the water required to dilute COD. High concentration of TSS, BOD5, and COD were found in natural dye extracts and wastewater. The Water Footprint (WF) analysis indicated that Grey Water Footprint was 37,343.15 L/d, which has a higher portion in the total WF than the Blue Water Footprint which was only 105.63 L/d. This result indicated the need to reduce pollution and to increase awareness among batik artisans. Promotions of behavioural change toward a more efficient use of water resources are advisable.

1. Introduction

Indonesian Batik is one of the World’s Cultural Heritage which has been produced across 38 regions in the island of Java (Mukimin et al., 2018). Batik is usually produced by Small and Medium Enterprises (SMEs), which were reported by Pimenova and van der Vorst (2004) to contribute to environmental degradation. Birgani et al. (2016) observed that the batik industry consists of relatively small, home based factories with no wastewater treatment units which discharge the wastewater without proper treatment. This habit causes water pollution, which has been reported to occur in Sragen (Kristijanto et al., 2011), Klaten (Handayani et al., 2018a), and Pekalongan (Budiyanto et al., 2018). Severe pollution was observed at the Pekalongan river stream which passes by areas populated with batik industries (Naqsyabandi et al., 2018). Discolouration of groundwater and odour due to infiltration of batik wastewater to dug wells (Budiyanto et al., 2018) and high incidence of allergies (Ahmad et al., 2010) are some of the negative impacts caused by the batik wastewater. As water is vital for life, the decrease in its quality makes it unconsumable. Therefore, the issue of pollution is not merely related to the diminishment of water quality but also to water scarcity, as explained by Pereira et al. (2002).
Currently, batik is produced using synthetic dyes and it was argued that water pollution caused by batik industries corresponded to synthetic colourants usage (Riyanto and Puspitasari, 2018). This situation encouraged the use of natural colourants for batik dyeing as they can be used to dye many types of natural fibres and exhibit antimicrobial properties (Mansour, 2018).
Unfortunately, previous studies showed that natural dyes application did not necessarily make batik production more eco-friendly. River pollution caused by natural dye-based batik productions was reported to have occurred in Jarum village, Klaten (Handayani et al., 2018a). It was also reported that natural-coloured batik consumes a lot of water for its production process, which is expressed as the water footprint (Handayani et al.,

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2019). Wang et al. (2018) wrote that the water footprint approach provided a good methodology in assessing problems related to the environment and in addressing the challenges of water resources. Unfortunately, the previous study only focused on a large-scale batik SME based on the assumption that the larger SMEs, the higher volumes of wastewater will be discharged (Handayani et al., 2019). The possibility that small-scale enterprises could generate wastewater in relatively higher volume, particularly in terms of the water/batik product ratio, has not been examined. The objective of this study is examining water footprint of the natural coloured batik-making process of a batik small enterprise in Jarum village, Klaten regency, Indonesia.

2. Material and methods

This research was conducted in Jarum village, Klaten, Central Java, Indonesia. A batik small-scale enterprise was selected for this research. Data were collected through observation and laboratory analysis. The observation was conducted three times, namely in March, May, and June 2019. Observation was conducted mainly on the process of dyeing and wax removal. Included in this observation were data collected on the raw materials and supporting materials used for batik production.

2.1 Parameters and sample analysis

The measurement of wax, water, and natural dyes absorbed by batik cloths was conducted as outlined by Handayani et al. (2019). It was done by measuring the weight of (1) white cotton cloth of a specified width and length prior to subjecting it to the batik-making process (dry); (2) hand-drawn cotton cloth (dry); (3) hand-drawn cotton cloth after wax removal and washing (wet); and (4) batik cloth after the drying process (dry). In this study, the calculation of batik water footprint was conducted based on Hoekstra et al. (2011) and the water footprint components used were blue water footprint (BWF) and grey water footprint (GWF). Hoekstra et al. (2011) wrote that BWF represents the freshwater consumed during the process, whether it is absorbed by the products or evaporated, and GWF represents the volume of water required to assimilate pollutants. In this study, while the level of BWF was determined using direct measurement of water volume and the indirect method to measure evaporated water, the GWF determination was not determined by point source pollution as the wastewater did not flow directly into the surface water body. Therefore, the GWF is determined by calculating the water required to dilute the COD contained in wastewater from its initial concentration to the acceptable limit as regulated by the Indonesian Government and the Business Social Responsibility (BSR) Water Quality Standard (ZDHC, 2016). Finally, as formulated by Hoekstra et al. (2011), the sum of water footprint components, in this case BWF and GWF, will result in the WF of the batik-making process, as illustrated by Eq(1):

$$WF(proc) = Blue\ Water\ Footprint + \ Grey\ Water\ Footprint \quad (1)$$

The water volume was measured as explanation of Handayani et al. (2018a). In case the water is collected in a cubical vessel (Figure 1), the volume of water is calculated using Eq(2):

$$v = l\ x\ w\ x\ (h - h1) \quad (2)$$

where v represents the volume of water, l represents the length of the vessel, and the width of the vessel is represented by w. Furthermore, h represents the height of the vessel, and h_1 represents the height of empty space of the vessel. Therefore, the height used to measure the water volume is the subtraction of h to h_1 which results in h_0.

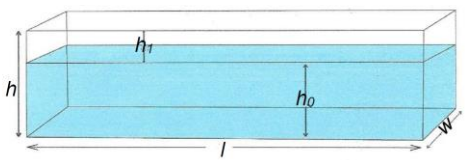

Figure 1: The cubical vessel

The study also conducted characterisation of wastewater and natural dye extracts derived from leaves of indigo (*Indigofera tinctoria*), barks of *tingi* (*Ceriops tagal*), *tegeran* (*Cudrania javanensis*), *soga jambal* (*Peltophorum pterocarpum)*, and fruits of myrobalan (*Terminalia bellirica*). The wastewater was collected from wax removal and washing processes. Both the extracts and the wastewater were collected in 300 ml plastic bottles and were stored in the dark for further analysis. The pH was measured using Hanna HI 9811-5 kit, whereas Total Suspended Solid (TSS) was determined by sample filtration using Whatman GmbH filter paper with 47 mm diameter and pore size of 0.45 μm, which was then dried at 105 °C for 2 h. The residual weight was measured using a four-digit Ohaus PA 224 balance. BOD5 was determined using the iodometric method with azide modification, and COD was determined using the open reflux-titrimetric method. The measurement of BOD5 and COD was conducted based on Kruis (1995). In order to measure the water moisture content of the batik cloth, we took two samples of full-patterned batik cloths of the same design and two samples of less-patterned batik cloths of the same design. The cloths were cut into two different parts sized 5 cm x 16 cm each and measured using an Ohaus MB 45 moisture balance. There were two kinds of wax used by the enterprise. The first one is the good quality wax and the second is the lower quality wax which is usually recollected from after the wax removal process. The measurement of wax density was conducted by placing the wax in a beaker glass and subsequently melting it in a Memmert U 30 oven at 105 °C for 2 h. Its weight in its liquid form was measured using a two-digit ACIS AD 300i balance.

3. Results and discussion

3.1. Production of batik using natural dyes

The batik enterprise observed in this research produces two kinds of batik, i.e. the hand-drawn batik (main product) and a combination of block print and hand-drawn techniques combined with the use of natural dyes for colouring. The enterprise used natural dyes derived from plants, i.e. indigo (*I. tinctoria*) to produce blue shades, a mix of tingi (*C. tagal*), tegeran (*C. javanensis*), and soga jambal (*P. pterocarpum*) barks in a proportion of 3:3:3 to produce reddish dark brown (sogan woods) hue, and myrobalan fruit (*T. bellirica*) to produce yellowish brown shade. Some of the colourants are presented in Figure 2.

Figure 2: Barks of P. pterocarpum (a), C. javanensis (b), C. tagal (c), and (d) is dried fruits of T. bellirica

3.2. Raw materials used in the production of batik cloths

The process of making hand-drawn batik in this enterprise was typically similar to the observations of Handayani et al. (2018b). As a small-scale enterprise, it has no workers who work at the production home. Instead, the batik artisans tend to assign the drawings on cotton cloths on female homeworkers who will finish the tasks at their own homes. Unfortunately, as hand drawing batik is only a side activity for these housewives, they were usually only doing it in their spare time, and this is the reason why this enterprise could not produce batik cloths in a short time. On average, it takes two weeks to finish 68 pieces of batik cotton cloths in the sizes of 2.50 m x 1.05 m and 2.00 m x 1.15 m by natural dyeing. The raw materials used during the batik-making process are presented in Table 1.

Table 1: Raw materials used in producing a piece of batik cloth

Raw material	Unit	Observation			
		1st	2nd	3rd	Average
Wax	g/m^2 cloth	123.81	187.00	143.49	151.43
Natural dyes	g/m^2 cloth	19.05	23.49	11.43	17.99
Water	L/m^2 cloth	0.22	0.18	0.13	0.18

Based on the data in Table 1, the amount of raw materials used in a piece of batik cloth can be calculated. The wax, natural dyes, and water absorbed or attached to a 2.50 m x 1.05 m batik cloth were 397.50 g, 47.22 g, and 0.47 L. For a 2.00 m x 1.15 m batik cloth, only 348.29 g of wax and 41.38 g of dyes were used, and 0.41 L of water absorbed. Moisture content analysis of batik clothes after they were dried and kept for weeks showed that the moisture content was only 6.35 % for full-patterned and 5.51 % for less-patterned cloths. This indicates that long-term storage of the cloths does not significantly affect their dryness. We also found that until the final stage, only the dyes were absorbed by the cloth as the wax is removed by boiling and the water evaporates when dried. Only a small portion of the wax will be disposed of because it is usually recollected and reused. Figure 3a shows the recollected wax in its full size, with a diameter of 71 cm and 3 cm in thickness, which is equal to 11,871 cm^3 in volume.

Visually, the recollected wax was darker (Figure 3b) than the good quality wax (Figure 3c). The lower quality wax cracked easily; therefore, it was not used to cover the patterns in order to avoid defects. Analysis of density indicated a slight difference in density between the two waxes, i.e. 0.94 g/cm^3 for the recollected wax and 0.90 g/cm^3 for the good quality wax. The wax removal process seemed to have affected the wax in terms of colour and fragility. Based on the calculation, the recollected wax weighed 11,158.74 g or 11.16 kg, and this suggested that the industry made an effort to minimise waste by recollecting and reusing resources, such as wax.

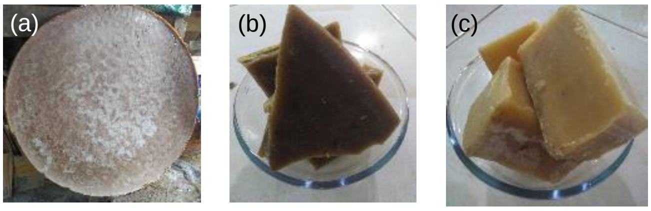

Figure 3: Pictures of recollected wax resulted from wax-removal process in (a) its full size, (b) after it was cut into pieces, (c) in comparison to good quality wax

3.3. The features of natural dye and batik wastewater

The features of natural dye extracts and batik wastewater are presented in Table 2. They were benchmarked against the acceptable limits regulated by the Indonesian Government as per the Regulation of the Ministry of Environment and Forestry of Indonesia No. 5 (MEF, 2014) and BSR Water Quality Standards (ZDHC, 2016). In general, both natural dye extracts and the wastewater contained high levels of TSS, COD, and BOD5 which exceeded the acceptable limit (Table 1) and this is in line with the findings of Handayani et al. (2018a).

Table 2: Features of natural dye extracts and batik wastewater

Parameters	Samples					Acceptable Limit for Textile Wastewater	
	Natural Dye Extracts			Wastewater		Indonesian Government (MEF, 2014)	BSR Water Quality Standard (ZDHC, 2016)
	Indigo	Sogan woods	Myrobalan	Wax-removal (boiling)	Washing		
pH	8.87	6.43	4.50	9.40	7.57	6.00 – 9.00	6.00 – 9.00
TSS (mg/L)	1,986.33	2,571.67	7,013.67	3,581.00	429.00	50.00	30.00
BOD5 (mg/L)	16.83	75.00	91.50	120.00	33.75	60.00	30.00
COD (mg/L)	2,160	14,726.67	37,546.67	25,280.00	1,246.67	150.00	200.00

On the natural dyes, indigo and myrobalan extracts tend to be alkaline and acidic, as indicated by their pH. The high pH of indigo dye might relate to the lime added to the dye, while the acidity of myrobalan was also reported by Handayani et al. (2018a). Among the three extracts, only indigo dye exhibited the acceptable concentration of BOD5 level and this could relate to some substances which were added into the dyes, such as lime, which created an alkaline environment that might not be favourable for microbial growth. In fact, the myrobalan and *sogan* wood extracts were easily covered by fungus, as expected by the high levels of BOD5.

Interestingly, the CODs contained in the myrobalan extract and indigo were much higher and lower, than the findings of Handayani et al. (2018a) at the large-scale SME. This might suggest a composition variance between the artisans in preparing the extracts. The high concentration of BOD5 and COD contained in the *sogan woods* and myrobalan extracts should not be a cause for any concern because those extracts were usually applied only for colouring and were not released to the environment. It is found from this study that the wastewater of natural coloured batik produced from the boiling step tend to be alkaline and was neutral for the washing process. The COD of wastewater produced from the boiling stage was higher than that of the batik textile in Malaysia which was reported to be 13,600 mg/L (Birgani et al., 2016). The addition of soda ash and starch might contribute to the high pH of the wastewater and high concentrations of COD and BOD5.

The water footprint of the batik-making process is presented in Table 3. In comparison to the findings of Handayani et al. (2019), the WF of the batik-making process in this small-scale SME (550.72 L/piece) was found to be lower than that of the large-scale SME (1,309 L/piece). The result indicated that the BWF of the batik-making process was 105.63 L/d or equal to 1.55 L/piece. This volume is much lower than found by Nursanti et al. (2018) that reported the direct water volume required to produce a block print batik sized 2.75

m x 1.75 m was 6.41 L. Handayani et al. (2019) reported that a large-scale SME required 234 L as BWF to produce 50 pieces/d of natural-coloured batik cloths, or equal to 4.68 L/piece. In addition to production technique which might be water-consuming, these differences could correspond to human behaviour in water use.

Table 3: Water use and calculation of water footprint on the batik-making process

Water Footprint	Process	Water usage	Measured components
1. BWF	a. Dyeing (L/d)	73.49	Volume of natural dyes extract used for dyeing
	b. Wax removal (L/d)	20.26	Volume of water which evaporated during wax removal
	c. Drying (L/d)	11.88	Volume of water which evaporated during the drying process
	Total BWF (L/d)	105.63	
2. GWF	a. Dyeing (L/d)	237.52	Volume of natural indigo dyes and dilution water
	b. Wax removal (L/d)	33,163.27	Volume of wastewater and dilution water
	c. Washing (L/d)	3,942.36	Volume of wastewater and dilution water
	Total GWF (L/d)	37,343.15	
	WF (L/d)	37,448.78	This is the WF of the batik-making process
	WF (L/unit)	550.72	This is the WF (process) for a piece of batik sized 2.50 m x 1.05 m
	WF (L/m^2)	209.79	This is the WF (process) per m^2 of batik cloth

In comparison to the textile industry, the BWF of knit and woven products in Bangladesh was 102 and 130 Mm^3, while the GWF was 600 and 858 Mm^3 where 62.85 % of the total WF came from the stage of fabric washing, dyeing, and finishing (Hossain and Khan, 2017). This study also found that the GWF was higher than the BWF as reported by Handayani et al. (2019), indicating water pollution issue which could lead to water scarcity in the long run. It should be note that the boiling process was usually took place at once in two weeks and this indicates a tendency to save water. This might relate to the fact that they rely on their dug wells to draw water from, for domestic activities and batik productions. Unfortunately, the high value of GWF suggested an existing problem with water management for batik production. As indicated by the definition of GWF, pollution could be considered as inefficient water use because clean water is consumed in order to assimilate pollutants (Hoekstra et al., 2011). Water management is significant to face the water scarcity issue, particularly by minimising waste, pollution, and extraction of water (Fan et al., 2019), as well as integrative policies for water (Zucaro et al., 2017). Therefore, future works should be focused on the effort to address the issue of pollution and to increase the awareness of batik artisans to use water more efficiently.

4. Conclusion

The small-scale batik SME in Jarum village used wax, natural dyes, and water with concentrations of 151.43 g/m^2 of cloth, 17.99 g/m^2 of cloth, and 0.18 g/m^2 of cloth. The batik artisan made an effort to recover wax for a further batik process. This study found that both natural dye extracts and wastewater contained high concentrations of TSS, BOD5, and COD, which exceeded the acceptable limits set by the Indonesian Government and BSR Water Quality Standard. The Water Footprint of the batik-making process by the SME was 37,448.78 L/d or equal to 550.72 L/piece or 209.79 L/m^2 of cloth. The Grey Water Footprint has a higher portion of total WF than the Blue Water Footprint, indicated the need to reduce pollution and to increase the awareness of batik artisans. Promotions for behavioural change toward a more efficient use of water resources are advisable.

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