Implementation of Cleaner Production in a Natural Dye *Batik* Industry SME: A way to Enhance Biodegradability of *Batik* Wastewater?

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Abstract. Utilization of natural dye in *batik* industry is a preventive solution taken to avoid environmental problems. Natural dyes is used to substitute synthetic dyes, naphtol and indigosol which has COD of 10.000-20.000 mg/L. Although the solution has been taken, the wastewater quality still exceed the limits stated on Regulation of the Ministry of the Environment No.5/2014. The research aim is to generate cleaner production solution, specifically material substitution and process modification to increase biodegradability. The implementation is conducted six times. The research process is pre-assessment of natural dye and *batik* wastewater, implementation of material substitution in mordanting, washing material and process modification. Natural dyes used has BOD of 203-975 mg/L, COD 1.316-2.453 mg/L and BOD/COD 0,1-0,4. Through statistical analysis with 95% level of confidence, the results show no significant changes to BOD, COD, BOD/COD as well as colour reduction. The results of options implemented is BOD value of 99-450 mg/L, COD 402-1.102 mg/L, TSS 105-540 mg/L, colour 291-2.408 Pt-Co and BOD/COD 0,2-0,4. Hence, wastewater treatment is needed and unit designed for wastewater flow of 0,09 m^3/day is anaerobic baffled reactor with the size of 0,6 m x 0,45 m x 0,5 m, HRT of 36,4 hour and SRT of 6 days.

1 Introduction

Being Indonesia's cultural heritage, *batik* is famous of its contribution in culture and economy. There are now 50.000 *batik* industries growing rapidly in Indonesia (Ministry of Industries, 2014) [1]. Aside from the positive outcomes that these industries has brought, there are negative impacts as well. The *batik* processing generates waste that has low biodegradability and it pollute the environment (Subki, 2011) [2]. The environmental pollution occurred in region with centralized *batik* industries (Mratihatani, 2013) [3]. Preventive solution has been taken by several small and medium *batik* industries to solve the problem which is by the use of natural dyes. This solution is categorized as material substitution in types of cleaner production implementation. The natural dyes is derived from various types of plants (Purnomo, 2004) [4], hence it is assumed to be more biodegradable than the synthetic dyes.

The natural dyes is easily degraded through biological process or biodegradable with the ration of BOD$_5$/COD approximately 0,5 (Chan et.al, 2000) [5]. The high level of biodegradability indicated that the wastewater can degrade the organic substances without the need for physical and chemical process, hence it can be treated biologically. One of the cause of the non-biodegradable nature is that the *batik* processing still requires chemical substances in mordanting, washing and fixating process (Supraptro, 2000) [6]. The examples of chemical substances used is alum which contains Al and turkey red oil which is the detergent used for washing process. This is presumed to be the cause why the accumulation of natural dye batik wastewater has low biodegradability, hence the preventive solution of cleaner production is needed. The types of cleaner production options which can be used are input substitution and process modification (Van Berkel, 2000) [7].

The aim of this study is to discover which process and material caused the low level of biodegradability in natural dye batik wastewater, know the right process modification and material substitution to support the cleaner production, learn the impact of cleaner production to the biodegradability as well as recommend wastewater treatment needed after the preventive actions are taken. The results of this research will be a recommendation for further implementation of cleaner production in natural dye *batik* industry to support the use of natural dye and the development of eco-industries.

2 Theoretical Overview

There are several types of *batik* processing in the *batik* industry. The process can be divided in to traditional process and fabrication process with modern technology. Overall, the *batik* processing consists of pre-treatment, waxing, dyeing, washing and drying. The *batik* processing in natural dye *batik* industry is shown in Figure 1.

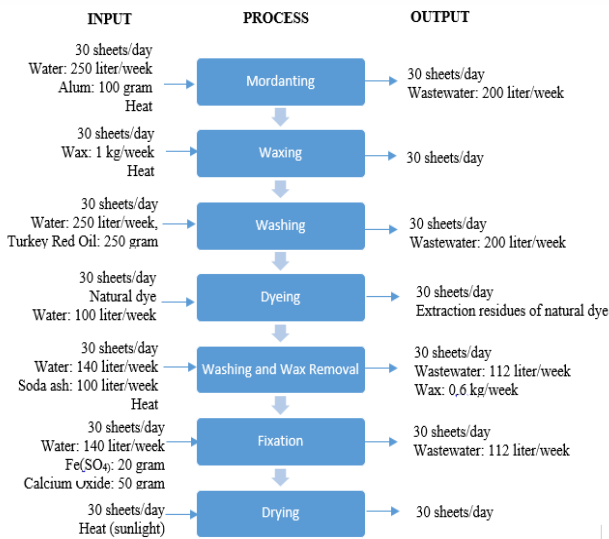[a] Corresponding author: efelaza@yahoo.com

Figure 1. Batik processing flow diagram

The input used for dyeing in this case is natural dyes. Indonesia has more than 150 types of plant which can be used as the source of natural dyes, identified by the Center of Batik Industrial Research and Development Yogyakarta (Supraptro, 2000) [6]. The natural dyes is divided into several categories, which are mordant, direct, acid/base and vessel. Each of these category produces

different colors and endurance which varied based on the media used. Natural dyes has BOD_5/COD value of approximately 0,5 (Chan P. et.al, 2000) [5]. The difference of the BOD_5/COD ratio or biodegradability between natural dyes and synthetic dyes is shown in Table 1.

Table 1. Characteristics of Natural Dyes and Synthetic Dyes

Parameter	Natural dyes (with mordant)	Natural dyes (without mordant)	Synthetic Dyes
BOD_5 (mg/L)	799– 2700,0	1000-4800	-
COD (mg/L)	1700- 4800,4	1700-4600	-
BOD_5/COD (mg/L)	0,2 – 0,6	0.5-1,1	0,4 – 1,1

Source: Chan, P. et.al, 2000 [5]

The natural dyes is used in the case study location, however the characteristic of the accumulation of wastewater still exceed the quality standard stated on the Regulation of the Ministry of Environment number 5 year 2014. The results of the wastewater accumulation from each step of batik processing is shown in Table 2.

Table 2. Preliminary Results of the Accumulation of Natural Dye Batik Wastewater

Parameter	Test Methodology	Unit	Acc. Sample 1	Acc. Sample 2	Washing with TRO	Fixation
BOD_5	IKM/5.4.5/BLK-Y	mg/L	81,74	18,10	282,3	40,5
COD	APHA 5220-C,2005	mg/L	1320,96	1198,08	668,9	86,9
BOD_5/COD	-	-	0,062	0,015	0,422	0,466
Oil/Grease	SNI 06-6898.10-2004	mg/L	9	7	5	3
Color	SNI 06-2413-1991	Pt Co	692,2	880,1	60,5	195,5
Turbidity	SNI 06-6989.25-2005	NTU	89,76	22,9	60,5	20,4

The wastewater characteristic results in Table 2 shown that the wastewater still exceed the quality standard. There are two types of approach in tackling pollutants in the wastewater, which are end-of-pipe and pollution prevention. Cleaner production is a sustainable application of integrated preventive strategy to process, produce, increase efficiency and minimize the risk for human and the environment (UNEP, 1995) [8]. The concept of cleaner production is focused on material and energy conservation, prevention of hazardous substances, minimize the level and amount of emission and waste (Nurdalia, 2006) [9]. The types of cleaner production consist of product modification, input substitution, technology modification, better housekeeping and on-site recycling (Van Berkel, 2000) [7]. Material substitution in batik industries is used to support the cleaner production effort. One of the example is the use of *lerak* or *Sapindus mukorossi* as detergent (Ernawati, 2013) [10]. Material substitution of dyes to the less hazardous substance can be a way to increase biodegradability of textile wastewater (Ozturk, 2009) [11].

3 Research Methodology

The methodology used in this study is implementation of cleaner production, specifically input substitution and process modification. The steps of this study consist of preliminary test of natural dyes and accumulated wastewater characteristic in each process, implementation of washing input substitution, implementation of mordanting input substitution and process modification. Washing material substitution alternative used is *lerak,* lemon and baking soda, while the alternative for the mordant substitute is *tunjung*. The volume of each material used is 1 liter for *lerak*, 750 mL for lemon and 750 mL for baking soda. *Tunjung* which is used for mordant alternative is 100 gram. Process modification used is filtration of wastewater from the results of washing and wax removal using 0,1 mm filter.

In the preliminary test of wastewater characteristics, sampling is conducted through composite sampling where the samples is collected by mixing the samples of wastewater produced from each process, while the sampling for wastewater from each process is collected using grab sampling technique which represents the condition of wastewater at the time of sampling from each stage of *batik* processing. The total samples for

sampling and implementation of cleaner production is 40 samples.

The research variables of this study is divided to independent and dependent variables, where the independent variable is the material of substitution. Whereas the dependent variables are COD, BOD, TSS and color. The wastewater test conducted is adapted to the National Standard of Indonesia which is shown in Table 3.

Table 3. Methodology for Wastewater Characteristic Test

Parameter	Unit	Methodology
COD	mg/L	SNI 6989.73:2009
BOD	mg/L	SNI 6989.72:2009
TSS	mg/L	SNI 06 – 6989.27 – 2005
Color	mg/L	SNI 06- 6989.80:2011

The data of this study consist of primary and secondary data. The primary data is collected through survey and test of wastewater quality. The collection of primary data is using direct observation in case study location, interview with the SME staff and testing of wastewater characteristics. Whereas the secondary data for this study is collected through the literature of batik processing, wastewater quality standard and cleaner production alternatives.

The analysis of the result of cleaner production is based on the Guidance Manual: How to Establish and Operate Cleaner Production Centers (UNIDO and UNEP), where the steps used for this study is planning element which consist of goals setting and program scope as well as identification of pollutant source, pre-assessment element, which consist of information collection, basic information preparation and raw materials and material balance, along with assessment element which consist of detailed information collection, material balance and identification and evaluation of cleaner production recommendation.

In order to validate the analysis results from wastewater samples, statistic test named independent t-test is conducted (Berthouex, 2002) [12]. The aim of this method is to compare two variable which are randomly distributed. The final result of this test is conclusion on statistic basis of the results of implementation which can be concluded whether the cleaner production made a significant difference or not.

4 Results and Discussion

On this study, natural dyes which were used in the case study location is tested, which are *soga, indigofera, jalawe* and *tingi*. The comparison between the natural dyes used in the case study location and the ones in the literature as well as synthetic dyes is shown in Table 4.

Table 4. Comparison of Dyes Quality in the Case Study Location and Literature

Name of Dyes	BOD (mg/L)	COD (mg/L)	BOD/ COD	TSS (mg/L)	Color (Pt-Co)
Soga	203	1.316	0,15	164	14,217
Indigofera	260	1.734	0,15	98	480
Jalawe	984	2.453	0,4	615	27.128
Tingi	475	1.665	0,29	54	14.889
Naphtol (2014)	3.200	13.800	0,23	-	-
Napthol (2010)	5.400	19.921	0,27	-	-
Indigosol	3.050	10.230	0,29	-	-
Natural Dyes (2000)	796-4.755	1.759-4.790	0,16-0,6	-	-

Source: Zuhria, 2014 [13]; Lestari, 2010 [14] dan Chan, 2000 [5]

The results of the quality of the natural dyes are then tested statistically through independent t-test. The results of the statistical estimation is shown in Table 5.

Table 5. Results of Independent t-test of the comparison of BOD, COD and BOD/COD of natural and synthetic dyes

Parame-ter	BOD (mg/L)		COD (mg/L)		BOD/COD	
	S*	N*	S	N	S	N
Sample 1	3.200	203,4	13.800	1.316	0,232	0,155
Sample 2	5.400	260,2	19.921	1.734	0,271	0,150
Sample 3	3.050	984,6	10.230	2.453	0,298	0,401
Sample 4	-	475,8	-	1.665	-	0,286
Average	3.883,3	481,0	14.650,3	1.792	0,267	0,248
Variance	1.730.833,3	189.709,2	24.021.170,3	227.633,3	0,001	0,014
$t_{5,0.025}$*s(y$_1$-y$_2$)	1.721,1		6.115,6		0,155	
Interval	5.123	1.681	18.970	6.740	0,17	-0,14

*S = Synthetic, N= Natural

The results stated in Table 5, shown that the BOD and COD of natural dyes are statistically proven to be lower than synthetic dyes. However, in terms of BOD/COD, there are no conclusion can be taken statistically. By analyzing the results, it is proven that there is still a need for improvement of cleaner production implementation in natural dyes *batik* industry, because the wastewater quality still exceed the limit stated by the regulation. The results of the cleaner production implemented in the study location is as shown in Figure 2.
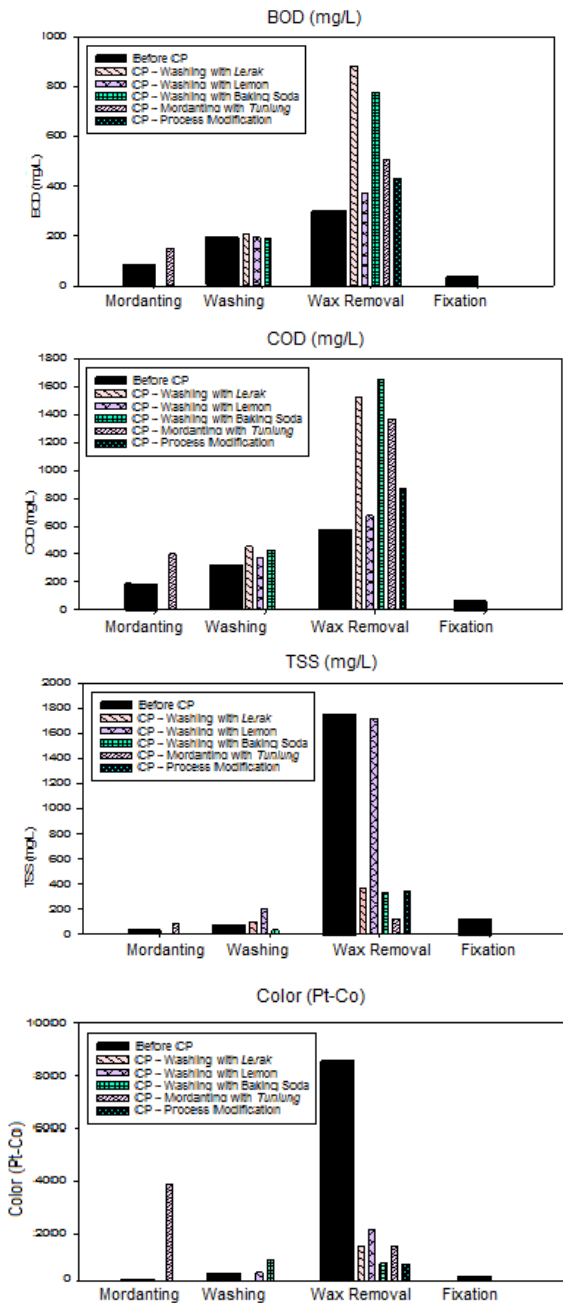
Figure 2. Wastewater Quality after Cleaner Production

The results of implementation of cleaner production conducted in this study in Figure 2, shown that the substitution of *mordant* from alum to *tunjung,* results in higher BOD, COD, TSS and color. Hence, the best option of material for *mordanting* process is alum. By the results of implementation in washing process, in terms of BOD and COD there is no significant decrease by the options implemented. In the wax removal process, it is shown that the process modification results in decrease of TSS and color in the wastewater.

The option of cleaner production chosen for further analysis is *mordanting* with alum, washing with lemon and process modification of wax removal. The accumulation of wastewater before and after the implementation of the chosen option is tested to obtain the wastewater quality. The results of the implementation is shown in Table 6.

Table 6. Results of Wastewater Accumulation before and after Cleaner Production

Name of Industry	BOD (mg/L)	COD (mg/L)	BOD/COD
Before CP	394	651	0,6
After CP	230	646	0,36
Textile Industry (2000)	393	950	0,4
Batik C (2006)	326	22.076	0,014
Batik F (2006)	407	1.337	0,3
Batik I	652	22.613	0,028

Source: Nurdalia, 2006 [9]

The results shown that the BOD and COD is decreased due to the cleaner production option applied. However, in terms of BOD/COD, the chosen cleaner production option did not increase the biodegradability of the wastewater. The ratio of BOD/COD is decreased from 0,6 to 0,36. The BOD/COD should not be the main parameter for the improvement of wastewater quality, because although the biodegradability decreased, if the BOD and COD are seen separately, both of these parameters decreased.

Statistical analysis of independent t-test is conducted to assure the difference of the wastewater quality before and after the implementation. The results of the test proven that with 95% level of confidence, there are no conclusion which can be taken statistically that there is a significant difference before and after the implementation of cleaner production, due to the large number of variant and low number of samples taken.

The quality of wastewater after cleaner production still exceed the limit stated in the regulation. Hence, wastewater treatment unit is needed for this *batik* industry. The unit suggested for treating the wastewater is anaerobic baffled reactor with the volume of 0,6 m x 0,45 m x 0,5 m with HRT of 36,4 hour and SRT of 6 days.

5 Conclusion

The conclusions of this study are of the following:

1. Accumulation of natural dye batik wastewater from the whole *batik* processing resulted in average biodegradability of 0,6.

2. The natural dye used in this study has biodegradability which varied between 0,15-0,4. In terms of quality, natural dye is proven to be better than the synthetic dyes

3. Material substitution and process modification with the best results are alum for mordanting process, washing with lemon and process modification of washing and wax removal. Statistically, with significance level of 95%, the cleaner production option used in this study does not bring a significant change to the wastewater quality. The fluctuation of wastewater characteristics caused insignificant change of the result of material substitution and process modification to the wastewater quality, in terms of biodegradability

4. The accumulation results after the chosen cleaner production option are wastewater with BOD value of 99-450 mg/L, COD value of 401-1.102 mg/L, TSS value of

104-540 mg/L and color value of 201-2.408 Pt-Co. The biodegradability of wastewater after the cleaner production option is 0,2-0,4.

The recommendation given for the similar study is to increase the number of samples collected for research in home industries, conduct modification process or material substitution for the extraction of natural dyes for better biodegradability of natural dye and conduct further study using different methodology of biodegradability test, such as respirometer for oxygen uptake, biological methane potential and anaerobic toxicity assay.

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