Analysis for cleaner production implementation strategy in batik industry in Bogor

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Abstract. The batik industry potentially pollutes the environment with the liquid waste of synthetic dyes. Cleaner production approach can be implemented to minimize pollution concerning environmental, technical as well as economic aspects. This study was aimed to analyze the strategy for implementing a cleaner production concept in the batik industry located in Bogor concerning technical, environmental and financial aspects. The methods used in this study were a quick scan for waste identification along with with the production flow, fishbone diagram for problems’ mapping, and analytical hierarchy process (AHP) for selecting the best strategy. The quick scan result indicated that dyeing, soaking and rinsing processes were main contributors of the dye waste. The use of natural dyes was considered as the best strategy to achieve environment-friendly and sustainable batik industry, whereas the production process and batik industry were the most important factor and actor, respectively. The use of bucket under drying fabrics to retain falling water is recommended as the best option, with low investment cost and a payback period of 6 months. Sustainable batik industry through institutional development is also recommended for optimizing the use of resources to provide natural dyes, as well as skillful entrepreneurs, and workers of dyes-extracting and batik industries.

Keywords: batik industry in Bogor, cleaner production, sustainability

1. Introduction
The use of synthetic dyes is common in the dyeing process of batik production. However, the waste of dyes potentially pollutes the environment. The waste of synthetic dyes is categorized as hazardous waste containing heavy metals, associated allergic, carcinogenic, which are toxic to human and environment [13]. Wastewater from the batik industry may contain surfactant, synthetic dyes, pigment, resin, dispersant, inorganic salt, heavy metals, biocide, and high COD value. Synthetic dyes are normally less biodegradable compounds [12].

Implementation of cleaner production concept is considered as a proper strategy for preventive and integrative environmental management that minimize wastes with a possible increase of income. The strategy may consist of a change of material and input, technology and process modification, product modification, reuse and recycle of wastes, and improved housekeeping [2];[3]. Natural dyeing in textiles as one of cleaner production strategies have been reported elsewhere as of great interest in both research fields as well as textile industries due to increasing attention to aspects of water pollution, the sustainability of raw materials and processed products, biodegradability and other environmental-friendly attributes. The previous research reviewed the availability of natural dyes, extraction methods and its application in Indonesian textile/batik small scale enterprises [5]. The...
enterprises mainly faced problem on the limited raw materials and extraction method to produce natural dyes.

This study was aimed to analyze the strategy for implementing cleaner production concept in the batik industry sustainably with respect to technical, environmental and financial aspects. Batik industries located in Bogor was assessed to identify the main sources of wastes, possible process modification as well as reuse and recycle of wastes. It was preliminary research for formulation recommendation to establish sustainable batik industries.

2. Method
Data was collected from batik industries located in Bogor city, namely Batik Bumiku, and Batik Tradisiku. A quick scan method was used to identify the potential sources of waste generation and to calculate the mass balance of each processing stage. Direct measurement of the materials, products, and wastes along the production process was carried out in the batik industries.

A fishbone diagram was used to map the problems that contribute to the implementation of cleaner production in batik industry, whilst analytical hierarchy process (AHP) was used to identify the main actor, factor, objective, and to select the best strategy for achieving sustainable batik industry. The respondents for AHP included practitioners in the batik industry and academicians.

Selection of cleaner production options was carried out with respect to the financial, technical and environmental feasibility. Financial feasibility of the selected options was analyzed based on the cost of investment and operation, potential saving and additional income, and payback period. Technical feasibility was analyzed based on the ease for implementing the options such as the availability of cleaner technology and inputs for cleaner batik industry. Environmental feasibility was analyzed based on its possibility to reduce pollution to the environment.

3. Results and discussion

3.1. Quick scan
The quick scan was carried at all stages of the production process. As shown in Table 1, the waste is mostly generated at soaking, rinsing, and dyeing processes with a total waste of 614.38 kg/100 sheet of batik which is equivalent to 25.28 m³ wastewater containing synthetic dyes/ton of batik. The amount of waste is higher than the maximum allowable waste for textile and batik industry (20 m³/ton) [8].

| Process       | Input (kg) | Output (kg) | Waste (kg) |
|---------------|------------|-------------|------------|
| Soaking       | 91.76      | 81.70       | 10.06      |
| Dyeing 1      | 123.15     | 123.15      | -          |
| Drying 1      | 81.84      | 81.84       | -          |
| Fixation 1    | 149.52     | 149.52      | -          |
| Drying 2      | 82.20      | 82.20       | -          |
| Salt cleaning 1| 110.66    | 81.84       | 28.82      |
| Dyeing 2      | 133.15     | 81.97       | 51.18      |
| Drying 3      | 81.97      | 71.97       | 10         |
| Fixation 2    | 149.30     | 82.33       | 66.97      |
| Drying 4      | 82.33      | 82.33       | 10         |
| Salt cleaning 2| 110.79   | 81.97       | 28.82      |
| Boiling       | 383.05     | 52.97       | 330.08     |
| Rinsing       | 82.97      | 52.97       | 50         |
| Drying 5      | 52.97      | 24.57       | 28.40      |
In contrast, as shown in Table 2, the production process of batik using natural dyes discharged lower amount of waste (550.60 kg for 100 sheet or equivalent to 19.11 m$^3$ton$^{-1}$). The waste was mostly generated at dyeing, boiling and rinsing processes.

Table 2. Mass balance of batik production process using natural dyes (based on 100 sheets of products).

| Process  | Input (kg) | Output (kg) | Waste (kg) |
|----------|------------|-------------|------------|
| Soaking  | 70.76      | 55.30       | 15.46      |
| Dyeing   | 458.6      | 318.42      | 140.18     |
| Fixating | 74.54      | 57.54       | 17         |
| Drying   | 57.54      | 34.54       | 23         |
| Boiling  | 335.62     | 53.66       | 281.96     |
| Rinsing  | 103.66     | 53.66       | 50         |
| Drying   | 53.66      | 30.66       | 23         |

Efforts to minimize waste has been performed by the batik industry that the use of natural dyes in the dyeing process by reusing of wax and saving the remaining natural dyes for the other batch. The sources of natural dyes are shown in Table 3. The waste of biomass is used for handy craft.

Table 3. Natural dyes used at ‘Bumiku’ batik industry.

| Plant as the source of the dye | Color             |
|--------------------------------|-------------------|
| Ketapang (Terminalia catappa)  | Yellow green      |
| Kenari (Canarium indicum)     | Red               |
| Mahoni (Swietenia mahagoni)   | Brown red         |
| Guava (Psidium guajava)       | Yellow-brown      |
| Hardwood (Tectona grandis)    | Brown peach       |

3.2. Analytical Hierarchy Process (AHP)
As shown in Figure 1, the results of AHP indicated there were an important actor and factor to achieve the goal of environmental-friendly and sustainable batik industry, namely the batik industry and production process. The use of natural dyes is selected as the best strategy with respect to these important actor and factor as well as the main objective, namely to optimize the use of resources.
Availability of natural dyes and waste load are of importance that needs to be considered for implementing cleaner production in the batik industry. Despite many advantages of natural dyes, natural dyes have a significantly lower affinity to fibers, which causes the use of a larger amount of dyes remains in the bath after dyeing [7]. This may increase the amount of wastewater load from the batik industry. However, in contrast with the use of synthetic dyes, the waste of natural dyes is classified as biodegradable. The implementation of cleaner production principles successfully reduced the amount of wastewater (see Table 3). In addition, the dyeing process of fabrics with natural dyes requires longer time [4].

Natural dyes are generally supposed to be affordable, non-toxic, renewable and sustainable resources with minimal environmental impact. Dyeing of fabrics with natural dyes, however, often leads to problems such as narrow shade range, and lower colorfastness of the dyed textile, therefore mordant is needed to improve affinity between dye and fiber. There are three types of mordant, namely metallic mordant (metal salt of aluminum, chromium, iron, copper, and tin), tannins, and oil mordant [10]. The use of metallic mordant may increase the pollution that harms the environment. The use of chitosan as eco-friendly mordant has been reported [14]. Prabhu and Teli reported that tannins from tamarind seed coat extract can be successfully employed as a natural mordant for dyeing cotton, wool, and silk fabrics with natural dyes [9]. It was also reported to be possible to produce fabrics with good antibacterial activity. Indonesia has abandon resources of natural dyes and eco-friendly mordant that need to be explored and utilized sustainably in the batik industry.
3.3. Cleaner production options

The drawback of natural dyes caused limited interest of batik industries to use natural dyes instead of synthetic dyes such as not easily available in the market, not many color choices, and easily fade [6]. Figure 3 shows the fishbone diagram of the problems that may contribute to the reluctant of the batik industry in using synthetic dyes, which include production cost and process, availability of natural dyes, and human resources. In respect to these problems, the cleaner production options are described in Table 4. The options were then the assessed basis of technical, environmental and financial aspects. The selected options are shown in Table 5.

![Figure 2. Fishbone diagram of batik industry.](image)

**Table 4. Cleaner production options.**

| Process     | Problems                          | Current handling                                      | Cleaner production options                                      |
|-------------|-----------------------------------|------------------------------------------------------|-----------------------------------------------------------------|
| Soaking     | Inefficient use of dyes           | Wastewater containing natural dyes is discharged to the environment | Reuse of remaining water in dye bath for rinsing                 |
| Preparation| Limited availability of natural dyes | Planting sources of natural dyes                      | Establish dyes-producing plantation located closely with the SME cluster of batik industry (Kampung Batik) |
|             | Limited supplier of natural dyes  | Use of agent to collect the biomass containing natural dyes | Local institutional development to support batik industry:       |
|             |                                   |                                                      | - Extraction of natural colorant                                 |
|             |                                   |                                                      | - Collection and marketing                                      |
|             |                                   |                                                      | - Financial supports                                             |
| Drying      | Loss of dyes                       | No action                                            | Use of buckets to retain falling water from the hanging fabrics during drying process |
|             | Longer period of working process   | Limited worker                                       | Employ more workers                                              |
3.4. Sustainable batik industry
The growing concern over the environmental quality and user health has led to a gradual interest of the reintroduction of natural dyes into the fashion and textile industries [1]. Results of the analytical hierarchy process, however, indicated that the availability of natural dyes is considered an important factor. Basically, main sources of natural dyes can be divided into three categories, namely primary products from agriculture, waste, and by-product from farming and forestry, and wastes from the food and beverage industries [11]. The content of dye in biomass is normally low, therefore a huge amount of biomass is required for large scale production of natural dyes. This situation makes the use of natural dyes for coloring the fabrics (including batik) is limited in the small and possibly medium scale industry.

Establishment of dyes-producing plantation in the form of agroforestry together with clusters of batik industries could be the best options for developing sustainable batik industries. As shown in Figure 4, the traditional knowledge, local wisdom and national heritages are important aspects that need to be considered together with science and technology from R&D centers and universities for possible creating of new knowledge that fits with the local conditions for institutional development. Carvalho and Ramos reported that a revival of natural dyes (and ancient/local know how) in addition to the new cutting edge technologies allows for industrial feasibility [1].

The roles government are to develop regulation and supporting infrastructure for sustainable batik industry, whereas the roles of NGOs are mainly to advocate and to campaign the implementation of environmental-friendly practices toward sustainable industry. Training of local communities will result in skillful entrepreneurs and workers for sustainable production of natural dyes and batik industry.

Figure 3. Institutional development for sustainable batik industry.
4. Conclusion

The use of natural dyes is considered as the best strategy to achieve the goal of environmental-friendly and sustainable batik industry, in which batik industry and production process are the key actor and factor, respectively, with the objective to optimize the use of resources. The best cleaner production option, namely the use of bucket under drying fabrics to retain falling water is recommended with respect to technical, environmental and financial consideration. It considers low investment cost with a payback period of 6 months. It also recommended developing a sustainable batik industry through institutional development for optimizing the use of resources to provide natural dyes, as well as skillful entrepreneurs, and workers of dyes-extracting and batik industries.

Reference

[1] Carvalho C and Ramos G 2016 Sustainability and biotechnology – Natural or bio dyes resources in textiles J. Textile Science and Engineering 6:239
[2] Fauzi AM, Rahmawakhida, Hidetoshi Y 2008 Kajian strategi produksi bersih di industri kecil tapioka: kasus kelurahan Ciluar, Kecamatan Bogor Utara. Jurnal Teknologi Industri Pertanian. 18 (2): 60-65
[3] Indrasti NS and Fauzi AM 2009 Produksi Bersih. Bogor (ID): IPB Press
[4] Hartini S, Nurmalasari S, Rinawari DI 2014 Model pemilihan bahan pewarna alam coklat batik tulis solo dengan menggunakan metode Analytical Hierarchy Process (AHP) Jurnal Teknik Industri. 9(2): 77-85
[5] Indrianingsih AW, Darsih C, Maryana R 2013 Pewarna Alam dari Ekstrak Tanaman dan Aplikasinya di Usaha Kecil Menengah Tekstil Indonesia. Seminar Nasional Kimia dan Pendidikan Kimia V di Balai Pengembangan Prosed dan Teknologi Kimia LIPI Yogyakarta, 6 April 2013
[6] Indrianingsih AW and Darsih C 2013 Natural dyes from plant extracts and its applications in Indonesian textile small medium scale enterprise Energi 11 (1): 16 - 22
[7] Krizova H 2015 Natural dyes: their past, present, future and sustainability. In book: Recent Developments in Fibrous Material Science. Klemenakova D, Militky J and Mishra R (eds). Kanina-o.p.s Publisher
[8] [PEMPROV JATENG] Peraturan Pemerintahan Provinsi Jawa Tengah 2012 Peraturan Daerah Provinsi Jawa Tengah No. 5 Tahun 2012 Tentang Perubahan Atas Peraturan Daerah Provinsi Jawa Tengah No. 10 Tahun 2004 Tentang Baku Mutu Air Limbah
[9] Prabhu KH and Teli MD 2014 Eco-dyeing using Tamarindus indica L. seed coat tannin as natural mordant for textiles with antibacterial activity Journal of Saudi Chemical Society 18: 864-872
[10] Sentilkumar RP, Bhuvaneswari V, Sathiayavimal S, Amsaveni R, Kalaiselvi M, Malayaman V 2015 Natural colours from dyeing plants for textiles Int.J.Biosci.Nanosci 2(7) 160 - 173
[11] Shahid M, Shahid-ul-Islam, Mohammad F 2013 Recent advancements in natural dye application: a review Journal of Cleaner Production 53: 310-331
[12] Sirait M 2018 Cleaner production options for reducing industrial waste: the case of batik industry in Malang, East Java-Indonesia.
[13] Siva R 2007 Status of natural dyes and dye-yielding plants in India Current Science 92(7): 916-925
[14] Teli MD, Sheikh J and Shastrakar P 2013 Exploratory investigation of chitosan as mordant for eco-friendly antibacterial printing of cotton with natural dyes Journal of Textile http://dx.doi.org/10.1155/2013/320510.