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Life Cycle Assessment Approach to Evaluation of Environmental Impact Batik Industry

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ABSTRAK

Industri batik merupakan salah satu bisnis tekstil yang paling berkembang di Indonesia. Hasil samping dari proses membatik adalah berbagai bentuk limbah, seperti limbah padat dan limbah cair. Pencemaran terutama bersumber dari limbah cair yang berupa zat warna yang dihasilkan sisa bahan pewarna, proses pencucian dan pembilasan kain batik. Pada umumnya limbah industri batik terdiri dari dari sisa mori, ceceran lilin, sisa air pewarnaan, sisa lilin dan air pelorodan. Salah satu cara untuk mengurangi dampak lingkungan dari proses pembuatan batik adalah dengan menggunakan analisis *life cycle assessment* (LCA). Penelitian ini bertujuan untuk menganalisis dampak lingkungan dari proses pembuatan batik dan input bahan baku yang memiliki dampak lingkungan paling signifikan. Analisis dampak lingkungan dilakukan dengan menginventarisasi input dan output berdasarkan database ecoinvent 3 menggunakan software Simapro 9.1.1. Metode analisis dampak lingkungan dilakukan dengan *environmental product declaration* (EPD) 2018. Hasil analisis *gate-to-gate* menunjukkan bahwa dampak lingkungan tertinggi adalah pemanasan global. Sedangkan dari sisi penggunaan bahan baku dan energi, parafin perlu diminimalisir. Penggunaan parafin menyumbang 68,705% dari total dampak lingkungan dari proses pembuatan batik.

***Kata kunci*: Batik, LCA, Dampak Lingkungan, Limbah**

ABSTRACT

The batik industry is one of the most developed textile businesses in Indonesia. The by-products of the batik-making process are various forms of waste, such as solid waste and wastewater. Pollution mainly comes from liquid waste in the form of dyes produced by residual dyes, washing and rinsing processes for batik cloth. In general, batik industry waste consists of residual mori, spilled wax, residual staining water, wax residue and pelorodan water. This liquid waste is generated due to the use of synthetic dyes in the batik industry. One way to reduce the environmental impact of the batik-making process is by using a life cycle assessment (LCA) analysis. This study aims to analyze the environmental effects of the batik-making process and the raw material input, which has the most significant environmental impact. Environmental impact assessment is carried out by inventorying inputs and outputs based on the ecoinvent 3 databases with Simapro 9.1.1 software. The environmental impact analysis method is carried out with the 2018 environmental product declaration (EPD). The results of the gate-to-gate analysis show that the highest environmental impact is global warming. Meanwhile, from the use of raw materials and energy, paraffin needs to be minimized. The use of paraffin accounts for 68.705% of the total environmental impact of the batik-making process.

***Keywords*: Batik, LCA, Environmental Impact, Waste**

1. INTRODUCTION

Batik is one of Indonesia's most valuable national cultures. Batik has its charm, both from its historical value elements and its motives. Regions in Indonesia have a pattern, their characteristics according to the features of the area. Activities batik besides providing benefits from an economic point of view can

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also cause the problem is in the form of waste generated from the production process. Batik industrial activity produces wastewater that contains dyes. Wastewater containing colour is usually challenging to treat because it has low biodegradability [1]. Textile wastewater which contains paraffin and dye is generally discharged directly into water bodies. Paraffin is a class of dangerous compounds that have a straight chain structure (normal) and branched chain (isomer). The batik industry wastewater comes from the rest of parrafin process as well as coloring with both natural and synthetic azo dyes, so it contains high pollutants. The high level of COD is because the dye is a chemically synthesized dye derived from aromatic hydrocarbons such as benzene, toluene, naphthalene, and anthracene. This causes the value of the BOD/COD ratio of wastewater to be low. The high level of COD is because the dye is a chemical synthetic dye derived from aromatic hydrocarbons such as benzene, toluene, naphthalene, and anthracene.

If the by-products of the wastewater still discarded, it will cause environmental impacts such as aesthetic decline and ecological health [2]. However, apart from producing wastewater, the textile industry also uses a large amount of energy. One way to assess the environmental impact that can result from the processing of the batik industry is a life cycle assessment (LCA).

LCA is a method of measuring the environmental impact of a production process [3]. LCA simulations can be used to improve the production process to be more environmentally friendly. Based on ISO 14040, the LCA method has main lines: goal and scope definition, inventory analysis, impact analysis, and interpretation. Through the LCA study, it is hoped that more comprehensive of the environmental impact of the batik production. The study of LCA in Indonesia is currently still in its early stages of development. The number of scientific publications related to LCA in Indonesia is relatively low compared to other Southeast Asian countries [4]. This research is also beneficial as database development for LCA analysis in Indonesia, especially in the textile industry sector. This research was conducted using Simapro 9.1.1 software. This software has been widely used by the industrial sector, consultants, and institutions in various countries [5]. This research aims to calculate the environmental impact of the batik industry in Indonesia and analyze the environmental impact, which is highest based on the gate-to-gate process and raw material.

2. RESEARCH METHODS

The scope used in this study is gate-to-gate, which means that it only assesses one cycle in the industry. This research was conducted from November to December 2020. The location of the Batik industry in this study is in the Yogyakarta area, Indonesia. Life Cycle Assessment (LCA) is an approach used to analyze the environmental impact in a cradle to the grave environment [6]. This study uses the basis of ISO 14040, which consists of determining goals and scope, life cycle inventory (LCI), life cycle impact assessment (LCIA), and data interpretation. LCI analysis was carried out using the Ecoinvent 3 database, while LCIA analysis was carried out using the Environmental Product Declaration (EPD) 2018 method. This research was conducted by combining primary, secondary data and literature studies to calculate the LCI and LCIA phases in the LCA method.

3. RESULTS AND DISCUSSION

The goal to be achieved is the environmental impact of the gate-to-gate batik-making process. The schematic gate-to-gate batik production in this research show in Figure 1. This study uses an inventory for every 100 pieces of batik cloth produced in one process. 100 pieces of batik require some synthetic dyes or paraffin.

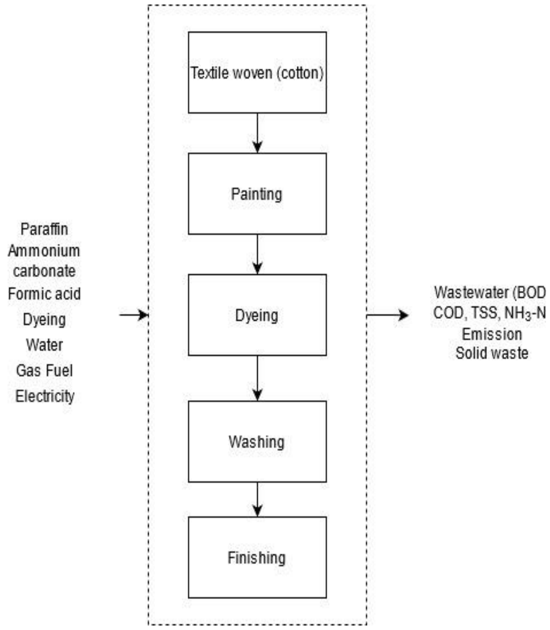

Figure 1. Batik making process diagram.

3.1. LIFE CYCLE INVENTORY (LCI)

The life cycle inventory (LCI) step for inventorying the data needed includes the materials and energy used during the batik-making process. The data inventoried in this study were raw materials in the form of woven textile (cotton), paraffin, ammonium carbonate, formic acid, dyeing, and water. Meanwhile, energy use comes from gas, fuel, and electricity. The result of wastewater inventory data is based on pollutant concentrations (Table 1).

Table 1. The quality of batik industry wastewater

Parameters	Concentration	Unit
BOD	2713	mg/L
COD	10461	mg/L
Ammonia-N	6.8	mg/L
TSS	40.18	mg/L

Table 2. Inventory data for LCA analysis in the manufacture of 100 pieces of batik products

Input			
Textile woven (cotton)	150	kg	
Paraffin	636972	kg	
Ammonium carbonate	2124	kg	
Formic acid	6066	kg	
Dyeing	49540	kg	
Water	3432000	L	**for every 100 pcs of batik produced**
Gas Fuel	6672	kg	
Electricity	44	kWh	
Output			
BOD	9307.58	kg	
COD	35912.45	kg	
Ammonia-N	23.34	kg	
TSS	137.28	kg	

The data in Table 1 can be calculated by multiplying the pollutant concentration and amount of wastewater to make an inventory of mass pollutants. LCI for the total amount of raw materials and energy in the Batik industry is shown in Table 2. The process of making stamped batik can be done faster than written batik, which is less than 1 day, according to the light conditions of the sun. The production process usually starts with patterning or design, batik or pick-up, coloring, pelorodan, rinsing and drying. The raw materials and additives used include chemicals used for the coloring process and for the process of pelorodan. The amount of production that is quite a lot will affect the surrounding environment because the waste produced is a side effect.

These data are used in the data input process in the LCI stage in the Simapro 9.1.1 software. SimaPro 9.1.1 is the 9th generation software of interpretation the use of the life cycle assessment method, which aims to analyze and compare the environment of a product. The result will calculate inputs such as quantity and quality of raw materials and produce output a graphic value.

3.2. LCIA

LCIA is output data in the form of a product impact score analyzed using the life cycle assessment method. The characterization of the gate-to-gate of the batik-making process show in Table 3. The impact of Global Warming Potential (GWP100a) is the most significant measurable impact when viewed from the mass. Based on the input and output data given in the Table 2, then it will be correlated with the resulting environmental impact. such as for example the dye used, electricity produces any impact, the gas fuel used and others. Synthetic dyes and paraffins used contribute to the amount of SO_2 dan PO_4. The impact of global warming is usually caused by the emission of CO_2 and CH_4 gases [6]. Then with the effects of acidification, photochemical oxidation, and eutrophication. Djunaidi, et al. [7] also showed the highest score on the impact of climate change [7]. Besides that, the effect of water quality purification, such as eutrophication. This environmental impact needs to be considered because the impact of water scarcity from batik production reaches 577,000 m^3 eq/100 pcs. The LCA analysis shows that it is higher than the water footprint analysis, where batik making requires 102.5 liters of direct water or 6.41 liters of water per piece [8].

Table 3. Environmental impact-based gate-to-gate analysis in the batik industry

Environmental Impact	Score	Unit
Acidification (fate not incl.)	4180	kg SO_2 eq.
Eutrophication	1910	kg PO_4 eq.
Global Warming (GWP100a)	640000	kg CO_2 eq.
Photochemical Oxidation	2950	kg NMVOC.
Abiotic Depletion, elements	14.2	kg Sb eq.
Abiotic Depletion, fossil fuels	35200000	MJ eq.
Water scarcity	577000	m^3 eq.
Ozone layer depletion (ODP)	0.0598	kg CFC-11 eq.

The material usage in batik processing network data shown the primary input use of paraffin, dyeing, and fuel gas (Figure 2). The raw materials for making batik paraffin are made of various mixtures in cat's eye resin, paraffin, wasp wax, lard or animal fat, coconut oil, and used loro and batik wax [9]. Textile waste pollution mainly comes from liquid waste in the form of dyes produced by residual dyes, the washing process, and the rinsing of batik cloth. In general, the batik industrial waste consists of the remaining mori, the wax spilled, the remaining coloring water, the remaining wax, and the water, which causes the organic content in the waste to be high. These materials tend not to be biodegradable, so they are tough to process in a biological process. Based on the detailed environmental impact scores in Table 4, the impact of using paraffin and dyeing tends to be greater than energy use. Therefore, the focus of material substitution such as the use of environmentally friendly paraffin and dyes.

Table 4. Characterization of environmental impact based on raw material (input) in the batik industry

Environmental Impact	Paraffin	Dyeing	Electricity	Refinery gas	Unit
Acidification (fate not incl.)	2940	787	0.205	333	kg SO_2 eq.
Eutrophication	499	276	0.245	287	kg PO_4 eq.
Global Warming (GWP100a)	423000	171000	46.5	24400	kg CO_2 eq.
Photochemical Oxidation	2280	458	0.135	146	kg NMVOC
Abiotic Depletion, elements	11.8	2.07	0.0000676	0.00845	kg Sb eq.
Abiotic Depletion, fossil fuels	32500000	1950000	485	342000	MJ
Water scarcity	270000	131000	7.46	29800	kg SO_2
Ozone layer depletion (ODP)	0.0238	0.034	0.00000145	-0.000718	kg CFC-11 eq.

The impact of global warming is mainly caused by the use of paraffin, amounting to 68.397% (Table 5). The impact of eutrophication and water scarcity also shows that paraffin has a role of 46,976% and 62.673%, respectively (Table 5). Meanwhile, the dyeing process resulted in eutrophication and water scarcity effects of 25.983% 30.408%, respectively (Table 5). Meanwhile, the use of electrical energy appears to be very low for each of the environmental impacts. The use of refineries in batik making contributed 27.018% to the impact of eutrophication. This is because most of the emissions from the refinery firing process are NO_x [10, 11]. The average percentage of impact shows that paraffin has a 68.705% role in the environmental impact.

Table 5. Normalization of environmental impact based on raw material (input) in the batik industry

Environmental Impact	Paraffin	Dyeing	Electricity	Refinery gas	Unit
Acidification (fate not incl.)	72.410	19.383	0.005	8.202	%
Eutrophication	46.976	25.983	0.023	27.018	%
Global Warming (GWP100a)	68.397	27.650	0.008	3.945	%
Photochemical Oxidation	79.053	15.880	0.005	5.062	%
Abiotic Depletion, elements	85.023	14.915	0.000	0.061	%
Abiotic Depletion, fossil fuels	93.411	5.605	0.001	0.983	%
Water scarcity	62.673	30.408	0.002	6.917	%
Ozone layer depletion (ODP)	41.693	59.562	0.003	-1.258	%
Average	68.705	24.923	0.006	6.366	%

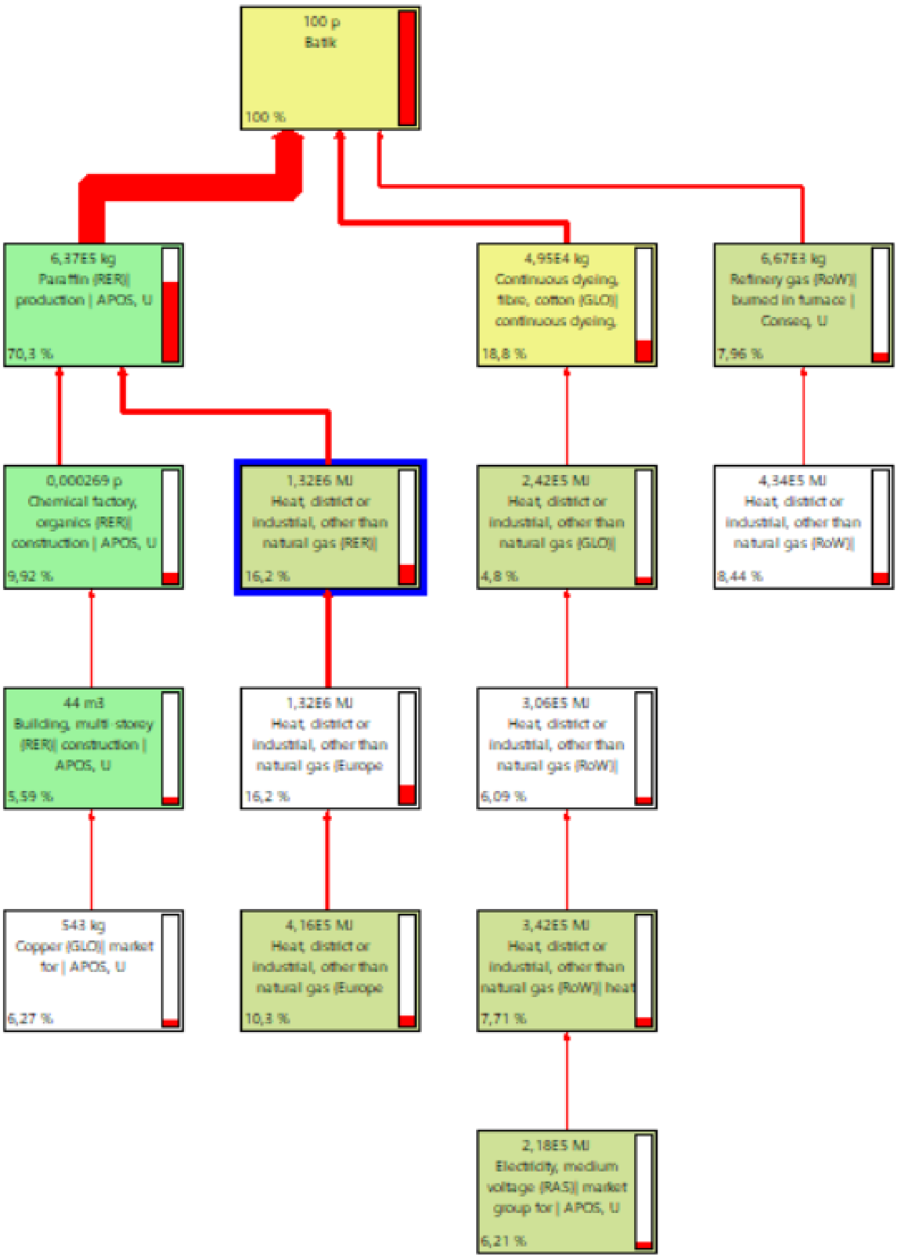

Figure 2. The results of the networking calculations for the process of making 100 pcs of batik

3.3. INTERPRETATION

Because the environmental impact analysis states that the highest impact is paraffin and dye, the effort needed to make is to minimize these raw materials. Indrayani recommends that saving paraffin be done by recording the identification of the use of paraffin, using recycled paraffin for the batik process [12]. Syahputra, et al. [13] suggest that the waxing process of paraffin materials can use an electric stove because electric compost [13] is more environmentally friendly and does not cause pollution and is safer from fire hazards. In terms of dyes, dyes used in the industrial batik process must use in natural dyes. The use of synthetic dyes will provide complexity in handling waste. The recommended natural dye is in powder form, which will have a higher environmental impact in liquid form [14].

4. CONCLUSION

The results of the gate-to-gate analysis of the manufacturing process of 100 pcs show that the most significant impact is global warming potential. The potential environmental impacts studied in this study are based on running in the research period November 2020 to December 2020. Of the four inputs included in the batik-making process, the use of paraffin needs to be minimized. The use of paraffin contributes to 68.705%, and it is necessary to study a suitable material substitution as a substitute for paraffin. In addition, the use of paraffin will also enter wastewater and can cause lower biodegradability. Further studies to recycle paraffin waste need to be carried out to reduce environmental impact and cleaner production in the batik-making industry. Reduction of environmental impact can be done by reducing the discharge of waste water generated. For example, reducing synthetic dyes and paraffin used in the production process, replacing dyes with more environmentally friendly materials. The batik-making process that is used and has the potential to generate waste can be rearranged so that less waste is generated.

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