Efficiency Assessment of Batik Industry Wastewater Treatment Plant in Center for Handicraft and Batik Indonesia

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***Abstract*— Batik as Indonesian cultural heritage has gained growing interest from international customers as well as local ones. However, the increasing production is also followed by negative impacts to environment in the form of wastewater. Most of batik industries dispose their wastewater directly into the environment without prior treatment. Therefore, it is necessary to build a wastewater treatment plant (WWTP) as a pilot project for the industries. This paper is focused on efficiency evaluation of the wastewater treatment process for batik industry WWTP at the Center for Handicraft and Batik which can serve as a model for small scales industries. Wastewater samples were taken from each treatment unit outlets. Eleven parameters were analyzed from the samples: pH, temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), phenol, total chrome, total ammonia (NH3-N), sulphides (S), and oil and grease. Treatment efficiency was calculated for all parameters and the effluent analysis results were compared with permissible maximum values as stated in Local Regulation of Special Region of Yogyakarta No. 7 of 2016 on Wastewater Discharged Standards. The results indicate that each treatment process could reduce the concentration of the pollutants. The overall value final effluent was below the standard so the effluent could be discharged safely to the environment.**

Keywords*— *wastewater, batik, WWTP, efficiency

I. Introduction

Batik is one of traditional textile industries in Indonesia. Since UNESCO's official recognition of batik as Intangible Cultural Heritage of Humanity in 2009, Indonesia's batik industries have rapidly grown, contributing significantly to Indonesia's economic growth. The increase of batik demands has caused batik manufacturers to increase their production capacity which in turn also caused greater effects to the environment. In Indonesia, batik is mostly produced by Small and Medium Enterprises (SMEs). They usually build their processing units alongside the river, residential area or other places which are not designed as industrial areas. Therefore, the facilities to treat their industrial effluents are not available. The SMEs usually discharge the effluents into a special vessel or directly into a river or drainage system after minimal or no treatment [1, 2]. The discharge of wastewater without proper treatment is one of the major problems faced by the batik industries [3].

The untreated batik wastewater leads to several environmental problems. The dyes are chemically stabile, non-biodegradable and some of them are suspected as carcinogens and toxics [4, 5]. Thus, an appropriate treatment is needed to remediate the effluents in compliance with local standards and regulations.

Measures have been taken by government, industries, universities, research institutes and other organizations to prevent the water pollution caused by batik industries. Some Wastewater Treatment Plants (WWTPs) have been built using various waste water treatment technologies. However, to the best of my knowledge, a little attention has been paid to investigate the efficiency of the batik WWTPs performance. The efficiency of a wastewater treatment is important as it serves as a basic indicator of WWTP function [6]. It depends on the amount and composition of waste water, condition and type of sewer network, producers, used technical and climatic equipment and other conditions [7]. Performance evaluation of WWTP is required to assess the existing effluent quality in order to meet higher treatment requirements, and to know whether the treatment plant is likely to handle higher hydraulic and organic loading [8]. Since there are only a few batik WWTP in Indonesia, the efficiency assessment is also needed to determine the feasibility of a WWTP as a pilot project to be implemented in other batik industries. The assessment results can also be used as recommendation of WWTP optimization [9].

Center for Handicraft and Batik (CHB) is a research institution located in Yogyakarta, Indonesia. Its main purpose is to provide services regarding research, development, training, testing, certification and standardization for handicraft and batik industries. Batik industry wastewater is generated from research and training activities. The wastewater is treated in the wastewater treatment plant before it is discharged to the environment.

In this study, the performance efficiency of WWTP in CHB was evaluated. The aim of this study was to assess the performance of batik WWTP in CHB regarding its accordance to the permissible standards as stated in the Local Regulation of Special Region of Yogyakarta No. 7 of 2016 on Wastewater Discharged Standards.

II. Literature Review

A. Batik Wastewater

The process of making batik involves six main stages namely painting, applying wax, coloring, removing wax, washing, and drying process using gray cloth, synthetic dyes, wax, energy and water as raw materials [5]. As one of main elements in such process, the chemical reagents used in batik manufactures varies in chemical composition ranging from inorganic to organic compounds [2]. The wastewater generated from the processes requires huge number of organic compounds of a complex structure. If the batik wastewater is not treated well, it will lead to several environmental problems. The dyes are chemically stable and non-biodegradable as well as some of them are suspected as carcinogens and toxics [4, 5]. Thus, an appropriate treatment is needed to remediate the effluents in compliance with local standards and regulations [3, 10]. The locals use traditional methods for producing batik, so the untreated effluents contain dyes, waxes, heavy metals [11] with high total dissolved solids (TDS), total suspended solid (TSS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) contents [12]. The effluents are known to be one of the most difficult substances to treat due to the recalcitrant nature of dyes and other chemicals [11, 13].

B. *Batik Wastewater Treatment Technologies*

There are several methods applied in batik wastewater treatment such as chemical, physical and biological methods. One of the most common chemical processes in wastewater treatment is coagulation [14]. It is the process of adding coagulant to destabilize colloidal particles so that the particles collide and grow [15]. However, the residue of coagulants such as alum and ferric chloride can cause Alzheimer diseases and similar health-related problems [14].

The use of oxidizing agents such as fenton, ozone, hydrogen peroxide (H_2O_2) and ultraviolet is promising as an alternative for better treatment [16-18]. However, some studies show that while these oxidants offer an effective decolorization, the COD removal is not significant [19, 20].

Sorption has gained wide attention over the last decades as a physical method to remove impurities from wastewater [17]. This process has been found to be effective and economical in removing dyes and reduce BOD [17, 21]. Some examples of commonly used adsorbents are activated carbon, inorganic oxides, and natural adsorbents (such as clays and clay minerals, cellulosic materials, chitin and chitosan) [19]. However, a study by [14] indicated that some adsorbents have limited adsorption capacities of the dyes.

A membrane is a layer that is able to separate a mixture of two or more components [14]. Filtration using membrane has been employed to remove dyestuff from textile wastewater effectively [17, 21]. A membrane is resistant to temperature, adverse chemical environment and microbial attack [22]. However, it has some issues regarding the residue disposal, the possibility of clogging and the membrane displacements [19].

Biological methods are by far the most universal technique for dye wastewater decolorization [22]. The microbes used in the methods degrade the organic matters in the wastewater [5]. Compared to the chemical and physical methods, biological methods have some advantages such as most cost effective, lower sludge production, applicable to wide range of dyes, and non-toxic end products [14, 21]. A wide range of microorganisms have been utilized applied to treat dye wastewater, such as bacteria [18], algae [19] and filamentous fungi [15, 19, 20].

To effectively remove the pollutants in the wastewater, batik WWTP usually employs the combination of the three methods with various sequences [22].

III. METHODOLOGY

A. *Profile of WWTP*

The wastewater plant contains primary and secondary level. The primary level consists of wax trap tank, sedimentation tank, coagulation-flocculation tank, anaerobic filters, and activated carbon adsorption. The secondary one is formed by the sludge drying bed to dewater the sludge.

- *Wax trap tank*. The wax trap tank is located near the wax removal process unit. The wax is removed from the batik fabric by boiling the fabric in hot water to dissolve the wax and rinsing it with clean water. The wastewater from those processes, which contains a large amount of wax, is treated in the wax trap tank. It is then allowed to sit in the tank until the wax float at the surface of the tanks due to its lighter density. The wax is then removed regularly to be recycled and reused in the next batik process.
- *Sedimentation tank*. The sedimentation tank allows the suspended solids to settle out of the wastewater because of the greater specific gravity compared to water.
- *Coagulation-flocculation tank.* In this tank alum is added as coagulant and it is then rapidly mixed. Coagulation is the process of destabilizing colloidal particles so that particles growth can occur as a result of particles collisions [5]. Bigger particles can settle more easily and separate with the liquid phase. The solid phase is removed into sand bed filter while the liquid phase flows into the next treatment unit.
- *Sludge drying bed*. Sludge drying bed is provided to dewater sludge with filtration and evaporation mechanism. Its construction consists of stones, gravels and sand. Perforated pipes at the bottom of the system flows the liquid to the anaerobic filter. The dry solids are removed periodically and stored in the hazardous waste storage.
- *Anaerobic Filters*. In this WWTP, there are 2 anaerobic filter units, providing 48 hours of contact time. During this time the microorganisms which are attached in the filter media degrade the organic matters in the wastewater.
- *Adsorption tank*. In this unit, activated carbon adsorbs the heavy metal and remaining dyes from wastewater. The activated carbon used are from coconut shells and woods.

B. *Sampling and Analysis*

Wastewater samples were taken every three months starting from January to December 2018. Grab water samples were collected at four sampling points: the inlet of WWTP (P1); the outlet of the sedimentation tank (P2); the outlet of coagulation-flocculation tank (P3); and the outlet of WWTP (P4). The layout of WWTP and the sampling points is illustrated in Fig. 1. The taken samples were immediately transported in two-liter plastic bottles to accredited environmental laboratories of BBTKL, Ministry of Health to be analyzed. All the laboratory analysis for the samples was done according to Standard Methods of the examination of water and wastewater. Based on the results, the removal efficiencies of the different parameters for each stage in the WWTP could be determined.

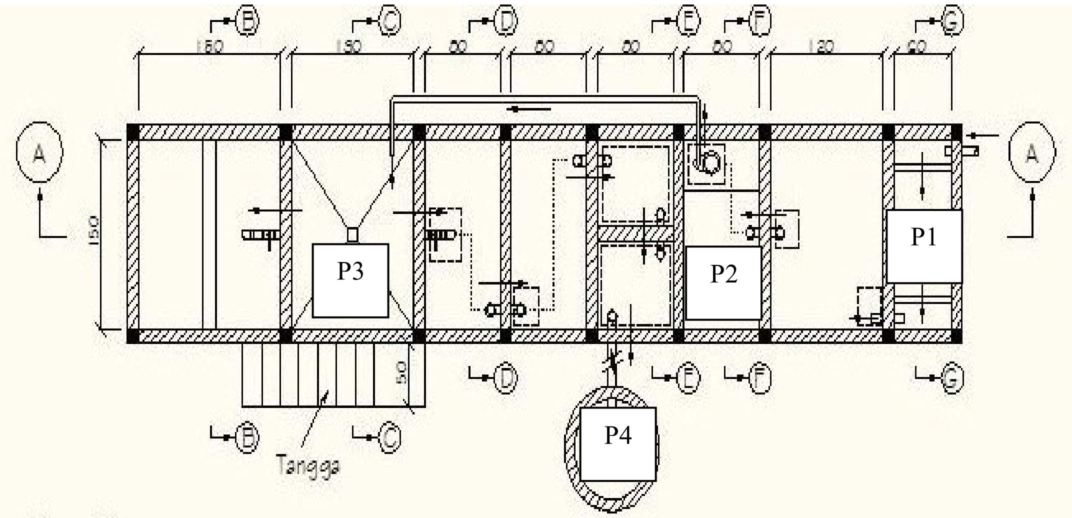

Fig. 1. WWTP layout and sampling points

Eleven parameters were analyzed according to Local Regulation of Special Region of Yogyakarta No. 7 of 2016 on Wastewater Discharged Standards as shown in Table I. The effluent of the WWTP has to follow the permissible limit in the standards before being discharged into the environment.

TABLE I. BATIK WASTEWATER DISCHARGED STANDARDS

Parameter	Unit	Permissible Limits	Methods
BOD_5	mg/L	85	Standard methods
COD	mg/L	250	Closed reflux
TDS	mg/L	2000	Gravimetric
TSS	mg/L	60	Gravimetric
Phenol	mg/L	0.5	Spectrophotometry
Total Chrome	mg/L	1	Atomic Adsorption Spectrophotometry
Amonia total (NH_3-N)	mg/L	3	Spectrophotometry - Nessler
Sulfida (S)	mg/L	0.3	Spectrophotometry - Methylene Blue
Total Oil and Grease	mg/L	5	Gravimetric
Temperature	ºC	±3ºC from air temperature	Thermometer
pH	-	6.0 - 9.0	pH meter

C. *Efficiency Calculation*

The removal efficiency was assessed for all observed parameters. The efficiency of cleaning process E_A (%) is defined by the standard ČSN 75 6401 as the ratio between removed concentration of pollutants and their initial concentration. The removed efficiency of component A in the system is given by the equation:

$$E_A = = \frac{C_I - C_E}{C_I} \cdot 100\% \quad (1)$$

where: C_I is the concentration at the system input (mg/l) and C_E is the concentration at the system output (mg/l).

IV. RESULTS AND ANALYSIS

The efficiency of each determined treatment unit is illustrated in Table II to Table IV.

TABLE II. EFFICIENCY OF SEDIMENTATION TANK

Parameter	Unit	P1	P2	Efficiency (%)	Permissible Limit
BOD_5	mg/L	2050	180	91.22	85
COD	mg/L	7817.5	404.4	94.83	250
TDS	mg/L	483	356	26.29	2000
TSS	mg/L	1315	530	59.70	60
Phenol	mg/L	0.2035	0.20	1.23	0.5
Total Chrome	mg/L	< 0.0213	< 0.02	-	1
Amonia total (NH_3-N)	mg/L	0.2463	0.23	5.68	3
Sulphide (S)	mg/L	0.5218	0.43	17.21	0.3
Total Oil and Grease	mg/L	11	10	9.10	5
Temperature	ºC	29.1	29.1		±3ºC from air temperature
pH	-	7.2	7,5		6.0 - 9.0

TABLE III. EFFICIENCY OF COAGULATION-FLOCCULATION TANK

Parameter	Unit	P2	P3	Efficiency (%)	Permissible Limit
BOD_5	mg/L	180	110	38.89	85
COD	mg/L	404.4	264.3	34.64	250
TDS	mg/L	356	257	27.80	2000
TSS	mg/L	530	86	83.77	60
Phenol	mg/L	0.20	0.19	5.97	0.5
Total Chrome	mg/L	< 0.0213	< 0.0213	-	1
Amonia total (NH_3-N)	mg/L	0.23	0.15	35.99	3
Sulphide (S)	mg/L	0.43	0.33	22.92	0.3
Total Oil and Grease	mg/L	10	7	30	5

Temperature	ºC	29.1	29.1		±3ºC from air temperature
pH	-	180	110	38.89	6.0 - 9.0

TABLE IV. EFFICIENCY OF ANAEROBIC FILTER-ADSORPTION TANK

Parameter	Unit	P3	P4	Efficiency (%)	Permissible Limit
BOD_5	mg/L	110	26	76.36	85
COD	mg/L	264.3	66.2	74.95	250
TDS	mg/L	257	143	44.35	2000
TSS	mg/L	86	12	86.05	60
Phenol	mg/L	0.19	0.179	5.29	0.5
Total Chrome	mg/L	< 0.0213	< 0.0213	-	1
Amonia total (NH_3-N)	mg/L	0.15	0.14	2.89	3
Sulphide (S)	mg/L	0.33	0.291	12.61	0.3
Total Oil and Grease	mg/L	7	4.8	31.43	5
Temperature	ºC	29.1	29.1		±3ºC from air temperature
pH	-	6.9	7,2		6.0 - 9.0

A. BOD

The BOD test aimed to calculate the oxygen required by the microorganisms to degrade the organic substances in wastewater. This test is one of the most important tests in monitoring the activity of river pollution. By measuring the BOD level, it is possible to determine the level of environmental contamination at any time [23]. BOD value is also used to measure the abundance of organic waste as an effort to plan and evaluate the efficiency of the biological treatment system of organic waste management. Changes in organic matter content expressed by the BOD value will occur in every cleaning process of the rivers polluted by organic wastes [24].

The BOD value in the WWTP influent was 2050 mg/L in average. This value was around 24 times higher than the standards. During the monitoring period, the WWTP could reduce the BOD up to 98.7% of efficiency in total. The effluent contained 26 mg/L of BOD concentration, which was below the permissible limit.

The biggest BOD removal occurred in wax removal and sedimentation tank. In this process, BOD decreased to 180 mg/L with 91.2 of efficiency. Wax contributed a large amount of BOD in the wastewater. Thus, the removal of the wax at the initial stage of the treatment reduced the BOD value significantly. In sedimentation tank, most of the solids have settled down. The sampling point for this point was located in the coagulation tank before the wastewater was chemically treated. The wastewater was pumped up from the sedimentation to coagulation tank. During that process, the aeration might occur in the pump and contributed to the decrease of BOD. The coagulation-flocculation process did not contribute significantly to BOD reduction.

After biological process in anaerobic filter and activated carbon adsorption happened, BOD value reached below permissible limit. Microorganisms in anaerobic filter degraded organic compounds in wastewater such as azo groups, thus reducing the BOD. The efficiency was 76.4% and the final BOD concentration was 26 mg/L.

B. COD

Chemical Oxygen Demand (COD) is the amount of oxygen required to oxidize the organic substances in wastewater through chemical reactions. The chemical reaction will convert the organic substances into CO_2 and H_2O [25].

The batik wastewater that contains wax, resin, dyes and fixing agent such as silicate results in high COD [13]. COD removal was a similar manner as the BOD efficiency. The COD value (7817.5 mg/L) was far above the standards. The overall efficiency of WWTP for COD was 99.1%.

Based on the analysis results, it was found that the COD values decreased in each treatment process. In the early stage (P2), the percentage of COD removal was 91.2%. The decline of the COD value was because the solid material had started to settle and had been oxidized in the pumping process [25]. The efficiency of COD removal in the coagulation process was 34.6%. However, after coagulation and flocculation process occurred, the COD value reached only slightly above the standards. In the biological and adsorption process, the efficiency was 74.9%. According to [26] the performance characterization of the anaerobic filter versus organic load added is important. The removal of COD in the processes prior to biological process prevented organic shock loads in anaerobic filter, resulting in relatively high removal efficiency.

C. TSS

TSS (Total Suspended Solid) is the number of suspended particles that are not dissolved in wastewater. The utilization of dyes, wax and fixing agents was attributed to the high concentration of TSS in the WWTP influent (1315 mg/L). The initial stage of WWTP removed more than half of TSS concentration (59.7%). The highest removal efficiency increased drastically in coagulation-flocculation process (83.8%). Coagulation indicates the process which colloidal particles and very fine solid suspensions are destabilized, so that they can begin to agglomerate if the conditions are appropriate. The colloids commonly found in wastewater are stable because of the electrical charge that they carry. The charge of colloids can be positive or negative. However, most colloidal particles in wastewater have a negative charge. The addition of alum as coagulant created positively charged ions and neutralized the repulsive charges between the particles. The van der Waals force then caused the particles to agglomerate and formed micro floc. Flocculation refers to the process by which destabilized particles actually conglomerate into larger aggregates so that they can be separated from the wastewater [27]. TSS concentration decreased considerably during biological treatment, achieving 12 mg/L and reached below permissible limit. The removal efficiency was 86%. It indicated that the biological content in the wastewater was attributed to the TSS concentration.

D. TDS

TDS (Total Dissolved Solid) is the amount of dissolved particles that present in wastewater. The particles size is small enough to survive the filtration process. In the WWTP influent, the TDS concentration has reached the standards (483 mg/L). During the treatment processes, TDS decreased so that it reached 143 mg/l in the effluent. The total removal efficiency was 70.4%. The highest removal efficiency was obtained by biological treatment process (44.4%). These results indicated the ability of microorganisms to remove TDS from wastewater.

E. Phenol and Total Chrome

Phenolic compounds have hazardous effects and high toxicity even in low concentration. In batik wastewater, phenol is originated from alcohol groups used as a means for removing wax. Phenol concentration in the influent was far below the permissible limit.

Chrome is usually found in batik synthetic dyes, thus it is carried into the wastewater. However, in this WWTP influent, the total chrome concentration was below 0.0213 which was the limit of detected chrome value in the AAS used. Therefore it can be said that the chrome concentration was very low.

F. Total Ammonia (NH_3-N)

Ammonia is typically found in synthetic batik wastewater due to the use of sodium nitrite as oxidizing agent in coloring process using indigosol dyes [28]. However the concentration of ammonia in WWTP influent (0.2463 mg/L) was already in accordance with the standards (3 mg/L). It might be because most of the coloring processes were conducted by using other dyes such as naphtol and remazol. It was found that every treatment process in the WWTP can reduce the ammonia further, reaching 0.1444 mg/L in the effluent.

G. Sulphides

The concentration of sulphides in WWTP influent (0.5218 mg/L) was fairly above the permissible standards (0.3 mg/L). Sulphides are often found in batik synthetic dyes and in hydrochloric acid (H_2SO_4), which is used as indigosol dyes solvents. The highest sulphides removal efficiency occurred during coagulation and flocculation process (22.9%). Sulphides concentration reached below the permissible limit after biological and adsorption process, which was 0.29 mg/L.

H. Total Oil and Grease

Oil and grease were found in batik wastewater because wax is used as dye resisting agent in the production process. After being dyed, the wax is removed thus it presents in the wastewater. The initial oil and grease concentration was 11 mg/L indicating more than two times of the allowed standards. Oil and grease causes damages for aquatic organisms, plant, animal as well as mutagenic and carcinogenic for human being [29]. During the treatment processes, oil and grease decreased to 4.8 mg/L in the effluent. The total removal efficiency was 56.4%. The highest removal efficiency was observed in biological treatment process (31.4%).

I. pH and Temperature

pH and temperature are indicators of the biological process in the WWTP. In this WWTP there is no unit process aiming to adjust the pH. The use of both acid and alkaline in the production process makes the pH in the influent neutral (7.2). After coagulation and flocculation process, the pH slightly dropped into 6.9 due to alum which was utilized as coagulant. However, this value was still in the permissible range according to the standard. The temperature was constant (29.1°C) throughout the units and it was still in the range of room temperature.

J. Total efficiency of WWTP

The measured values of all parameters at inlet and outlet of WWTP are shown in Table V. The WWTP can reduce all the parameters below the permissible limits in the standards. The total average efficiency is 65.2%. The highest efficiency is was in COD and TSS removal (99.1%) and the lowest is in phenol removal (12.0%). However, the initial concentration of phenol does not exceed the standards.

TABLE V. TOTAL EFFICIENCY OF THE WWTP

Parameter	Unit	P1	P4	Efficiency (%)	Permissible Limit
BOD_5	mg/L	2050	26	98.7	85
COD	mg/L	7817.5	66.2	99.1	250
TDS	mg/L	483	143	70.4	2000
TSS	mg/L	1315	12	99.1	60
Phenol	mg/L	0.2035	0.179	12.0	0.5
Total Chrome	mg/L	< 0.0213	< 0.0213	-	1
Amonia total (NH_3-N)	mg/L	0.2463	0.1444	41.4	3
Sulphide (S)	mg/L	0.5218	0.291	44.2	0.3
Total Oil and Grease	mg/L	11	4.8	56.4	5
Temperature	ºC	29.1	29.1		±3ºC from air temperature
pH	-	7.2	7.2		6.0 - 9.0

V. CONCLUSION & RECOMMENDATION

The objective of this study was to make an evaluation of the performance of WWTP. Conclusions were drawn from the results of the sampling and its analysis. The main conclusion points of the study can be summarized into the following points: (1) the removal efficiencies of all parameters were acceptable according to the process guidelines; (2) all the effluents from every sampling points of the WWTP were in accordance with the Local Regulation of Special Region of Yogyakarta No. 7 of 2016 on Wastewater Discharged Standards; (3) the WWTP was feasible to be pilot project for batik SMEs.

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