Textile wastewater treatment: biodegradability on aerobic and anaerobic process

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Abstract. Textile wastewater, mainly generated from batik small and medium-sized enterprises (SMEs), is still becoming a serious problem to be tackled. Due to lack of treatment facilities and adequate knowledge and skill, many batik SMEs are disposing their wastewater directly to environment, include river, ditch, etc. “Batik Blimbing” Malang SMEs also has the same problem and eager to change the practice. This study aimed to investigate the potential of treating textile wastewater on aerobic or anaerobic condition. Aerobic biodegradability was carried out using a closed bottle test, while anaerobic biodegradability was tested using Biochemical Methane Potential (BMP) test. The results showed that treating textile wastewater can be potential option as seen by 80-85% BOD removal, or approximately 12-13% BOD/COD removal compared to that of the theoretical value of 15% BOD/COD removal. While, anaerobic digestion treatment indicating that a high COD concentration may inhibit the ability of microorganism consortia to degrade COD into biogas.

1. Introduction
Textile industries play a major role to Indonesia economy, specifically batik industries. Indonesia is globally well-known for its batik tradition and cloth. Many of batik producers in Indonesia are small and medium enterprises (SMEs). According to ministry of trade, republic of Indonesia [1], Indonesia exports batik with the income value of usd 51.15 million, mainly exported to Japan, USA and Europe. this leads to an increase in the number of batik smes in indonesia. it is predicted that the number of batik smes increased by 8% from the current unit of 50,000 SMEs with job placement of 100,000 labour [2]. According to Ministry of Trade, Republic of Indonesia [3] the income generation from batik was 9.86 billion IDR in 2012 and increased to 1.12 billion IDR in 2013. this indicated a huge economy potential from batik industry.

However, an increase in the batik industry leads to an increase in the amount of batik (textile) wastewater [4], mostly, textile wastewater is generated from washing and soaking process, in which approximately of 15-20 liter per day was produced from a batik SME [5]. The characteristics of textile wastewater in general include biological oxygen demand (BOD) of 1,099.22 mg/l and chemical oxygen demand (COD) of 1,310 mg/l, these values are exceeded the standard value of textile effluent discharge from the Governor of East Java no. 72 year 2013: BOD of 60 mg/l and COD of 150 mg/l [6].

Many of batik SMEs have no proper wastewater treatment. Mostly, batik SMEs directly disposed their batik wastewater to the nearby environment which may lead to water polution [4]. Batik
Belimbing Malang SMEs also have no adequate wastewater treatment due to lack of facilities, knowledge/skills and financial supports. Batik wastewater can be treated chemically, biologically or physically. Yet, biological treatment is preferable due to its operational cost consideration and impacts to environment [7], which can be carried out either aerobically or anaerobically. This study aimed to investigate the biodegradability of batik wastewater under aerobic and anaerobic condition.

2. Materials and Methods

2.1. Feedstocks and inoculums

Textile wastewater was freshly collected from ‘Batik Belimbing Malang’ SME. The sample was stored in 5-l plastic container and kept at room temperature upon arrival at Bioindustry Laboratory. The characterisation analysis of the initial textile wastewater include pH, BOD, COD, TSS, ammonia, sulfide, phenol, oil and grease, and total Cr. Inoculum for aerobic test was collected from communal domestic wastewater treatment plant in Tlogomas, Malang. While, inoculum for the BMP test was prepared from digestate taken from a full-scale mesophilic digester treating cattle slurry at Balai Besar Pelatihan Peternakan in Batu City. Digestate was collected in a 5-litre container. The digestate is then sieved through a 1 mm screen to remove larger particles. The inoculum was analysed for pH, temperature (°C), moisture content (MC), ash, total solids (TS), and volatile solids (VS).

2.2. Aerobic biodegradability test

The aerobic biodegradability test was carried out using Closed Bottle Test method. The samples composed of blank sample (inoculum only), control sample (inoculum and mineral medium) and the tested samples with the volume addition of 1, 2, 3, 4 and 5 ml textile wastewater, further named as P1, P2, P3, P4 and P5. Mineral medium was prepared in accordance to the guidance for closed bottle test in OECD Guideline for Testing of Chemicals [8]. Dissolved oxygen was measured on day 0, 7, 14, 21, and 28. The calculation of BOD removal and BOD degradation rate were as follows [8]:

\[
BOD = (DO_0 - DO_n) \times p
\]  

(1)

Where: DO_0 represents DO values on day 0 (mg/l), DO_n represents DO values on day n (7, 14, 21 and 28) (mg/l), and p is dilution factor.

\[
Biodegradation(\%) = \left(\frac{BOD - BOD_n}{COD}\right) \times 100
\]  

(2)

Where: BOD represents initial BOD concentration (mg/l), BOD_n represents BOD concentration on day n (7, 14, 21 and 28) (mg/l), and COD is initial COD concentration (mg/l).

2.3. BMP test set-up

BMP test was performed in a manual BMP system using water bath for 30 days. The test will be carried out at 37 °C in triplicates with an inoculum to substrate ratio (I/S ratio) in the range of 6. BMP test was carried out using 250-ml serum bottle with working volume of 40 ml. Three sets of blank samples are included in the test to measure the indigenous methane production from the inoculums. The positive controls (α-cellulose) are used to test the activity of the inoculum. Textile wastewater samples of 1, 2, 3, 4 and 5 ml were added in each reactor samples, further identified as S1, S2, S3, S4 and S5. The serum bottles were placed in a waterbath at 37 °C without shaking. Pressure was measured using a Digitron 2026P absolute pressure meter (Electron Technology, UK) on a daily basis.
2.4. Analysis
TS and VS determination was based on Standard Method 2540 G [9]. pH was measured using a digital pH meter, calibrated in buffers at pH 7 and 9.2. Biogas production was calculated by converting pressure readings to gas volume in the headspace at standard temperature and pressure (STP) of 273.15 K and 101.325 kPa.

3. Results and Discussion
3.1. Textile wastewater characteristics
The characterisation test indicated that textile wastewater from ‘Batik Belimbing Malang’ SME was high in BOD and COD concentration at values of 8,651 mg/l and 54,700 mg/l, respectively. A high BOD and COD concentration demonstrated a high organic content in textile wastewater [10]. Ammonia concentration was also very high (1,440 mg/l), exceeded the standard discharge value for textile wastewater (8 mg/l) [5]. The C/N ratio was 37,986:1, which was calculated based on COD and ammonia concentration. A high C/N ratio inhibits the biodegradation process [11].

3.2. Aerobic biodegradability test results
Figure 1 shows that on day 7, all samples have a sharp decrease in BOD concentration. The BOD concentration was then slowly decreased up to day 28, reaching the concentration of approximately within the range of 1,000-2,000 mg/l. The calculation of BOD removal shows a high degradation of organic material in the textile wastewater with the values of 86% (P1), 85% (P2), 84% (P3), 80% (P4) and 78% (P5), respectively. Yet, the final BOD concentration values of the sample was still higher than that of the standard values.

![Figure 1. BOD concentration after aerobic degradation test.](image)

Theoretical biodegradation percentage based on initial BOD and COD concentration is 15.8%. This study found that the biodegradation rate was in the range 12-13%, after 28 days, as shown in Figure 2. This indicating that the aerobic biodegradation of textile wastewater was possible for treating the textile wastewater.
3.3. BMP test results

The experimental results demonstrated that the cumulative biogas yield was lower than the biogas produced by the inoculum only sample. This causing the negative net biogas production as illustrated in Figure 3, which showing average values of net biogas production over the period of 30 days. The net biogas production was calculated from the cumulative biogas production of each tested samples substracted by the cumulative biogas production from blank sample (inoculum only).

The negative value of net biogas production indicates that no biogas is produced from the sample itself. Also, it showed an inhibition was occured during the AD process. The inhibition may due to a high concentration of BOD, COD, and C/N ratio. As reported by Rajeshwari et al. [11] and Miqueleto et al. [12] that a high C/N ratio may slower the biodegradation rate and reduce the biogas production. The optimal C/N ratio for AD process is in the range of 25-30 [13]. A study by Desiana and Setiadi [14] reported that methane production from textile mill effluent sample was 62-73% when its COD concentration was ranged in 1,040-1,424 mg/l. The methane production was reduced to 4-8% at a
very high COD concentration of 10,400 – 14,240 mg/l. This indicates that a high COD concentration can also inhibit the degradation process, and potentially create toxic conditions to the AD process. However, the pH values before BMP test were in the range of 7.5 – 7.7, and it slightly decreased to 7.2-7.4 after end of BMP test. Yet, these values were still within the ideal range of 6.8 – 8.0 for AD process [15]. A very little amount of biogas or methane production could be due to energy used to repair the cell during the process. However, further in-depth investigation is needed to show this possibility.

4. Conclusion
Characterisation analysis indicated that BOD, COD, TSS, phenol, oil and grease concentration of textile wastewater were exceeded that of the standard effluent of discharge. Therefore, adequate textile wastewater treatment is critical. Aerobic test demonstrated high BOD removal values of 80-85%. While, no biogas production throughout BMP test period indicating an inhibition in AD process occurred. Thus, aerobic treatment is potentially to have a superior performance than anaerobic treatment.

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