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THE EFFECTIVENESS OF ANAEROBIC BAFFLED REACTOR AND ROTATING BIOLOGICAL CONTACTOR IN BATIK WASTEWATER TREATMENT

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Abstract

Batik is one of popular arts of Indonesia. The batik industries in Sragen, Central Java, are prepared to compete in global market. In order to realize that objective, batik products should fulfill some qualifications, one of which is "environmental friendliness". As batik production is usually generating wastewater which pollutes the environment, the technology of wastewater treatment should be developed to solve the problem. This preliminary study has been done to assess the effectiveness of anaerobic baffled reactor (ABR) and rotating biological contactor (RBC) in batik wastewater treatment. In 40 days of treatment period, the ABR performance in reducing pollutants showed an effectiveness up to 75%, whereas RBC effectiveness was in the range of 15-57%. Concerning the quality standard of wastewater, the wastewater treatment system showed a good performance to decrease pH, whereas the COD was still high. Further optimization, then, is needed to improve the quality of effluent.

Keywords: anaerobic baffled reactor, batik, effectiveness, rotating biological contactor, wastewater

1. Introduction

Batik is one of Indonesian arts. Even today, batik has been assessed by UNESCO as the world's culture heritage. In addition, batik is an economics-supporting product of Central Java. The Sragen district is one of batik centers in Central Java. The batik industries in Sragen have been contributing about 32% of its total regional income. There are about 250 batik industries in this district, either in the form of micro, small, or medium-scaled industries [1]. They have been prepared to produce qualified products which can be sold in global market. In relation to this goal, those industries must fulfill some product qualifications set by global market. One of the qualifications is the environmental friendliness aspect of the product.

The batik industries in Sragen, however, face an environmental-relating problem. The industries discharge their wastewater approximately 3 m^3 per day. Their activities have been causing pollution due to the dyes and other chemicals which are contained in the wastewater. Moreover, this pollution threats people's health in a long term [1]. In addition to environmental damage and health hazards, the discharge of highly colored effluent causes another problem relating to aestethical aspect [2].

By understanding the effect of pollution to the environment and community, a solution to minimize the pollution is needed. The wastewater should be treated before it is discharged into the environment. By doing this step, pollution and its impacts can be minimized, as well as increasing the awareness of batik industries to produce environmentally friendly products.

As well as other textile industries, batik wastewater can be treated by a combination of anaerobic and aerobic processes. This method is chosen because of its efficient design compared to physicochemical and conventional methods [3]. Anaerobic process is needed to degrade long-chain organic matter into a simpler matter. In the next step, this matter is aerobically degraded into gas and water. Based on an experiment in a textile industry in Central Java, the combination of anaerobic and aerobic processes was proved to significantly reduce chemical oxygen demand (COD), biological oxygen demand (BOD), and color concentrations [3].

The combination of anaerobic and aerobic processes can be performed using anaerobic baffled reactor (ABR) and rotating biological contactor (RBC). ABR is a reactor which is used to treat wastewater anaerobically. This reactor consists of compartments which are separated by vertical layers [3]. This design gives a good contact between the wastewater and biological agent, such as activated sludge [4]. In addition to its simple design, ABR efficiently reduces COD, solids, and gives a lower operational costs, as reported by Dama *et al*. [5].

RBC is an aerobic reactor consisting of steel discs attached to a sylindrical tank. These discs are located on a horizontal axis. The spaces between the discs are filled with nylon nets for microbial growth. As it rotates, the microbes will absorb oxygen to oxidize organic matter. The RBC gives advantages because of its minimal maintenance, tool stability, and process consistency [6].

Sumantri *et al*. [4] reported that ABR can effectively reduce COD of batik wastewater. It also reduce pathogens, and decreases alkalinity, phosphate, and COD concentrations of municipal wastewater in the by 80-90%. The combination of ABR and RBC in laboratory-scale research was reported to efficiently reduce COD, nitrite, and sulphate [7]. However, the performance of the technology in a pilot-scaled research needs to be tested. Due to this reason, a preliminary study was performed to assess the effectiveness of ABR and RBC in batik wastewater treatment in Sragen.

2. Methods

The research was done in IKM Batik WTJ, Pilang village, Masaran Sub-district, Sragen, Central Java. The wastewater sample was analyzed in chemistry laboratory, the Faculty of Science and Mathematics, Satya Wacana Christian University, Salatiga.

The batik wastewater was obtained from IKM Batik WTJ. It was derived from dyeing, *lorot*, and bleaching steps. Prior to the treatment was wastewater characterization. This characterization was done to determine the concentration of physical and chemical pollutants which were contained in the wastewater. Its result was then used to determine physical and chemical parameters which would be measured in the wastewater treatment.

The physical parameters which were involved in characterization were color concentration, turbidity, total dissolved solids (TDS), and conductivity. The chemical parameters were BOD, COD, pH, alkalinity, sulphate, phenol, chromium, N-NH_3, and sulfide. Color concentration, turbidity, and alkalinity were assessed using HACH-spectrophotometer. HACH-TDS-conductivity meter was used to measure TDS and conductivity. The pH was measured by pH electrode. N-NH_3 was determined using Nezzlerization method, whereas sulphate concentration was assessed using turbidimetric method, both were based on Kruis [8]. The activated sludge was obtained from PT Timatex, Salatiga. It consists of microbes. Before the treatment, this sludge was adaptated to the wastewater.

The wastewater treatment reactors consist of a collecting tank, an ABR, an RBC, and a filter as shown in Figure 1. ABR was made in a capacity of 1000 litres. It consisted of eight compartments. Three compartments were filled with corals and charcoals to precipitate the solids, whereas the other compartments were filled with activated sludge to treat the wastewater.

The RBC was made from a sylindrical tank in a capacity of 1000 litres. There were steel discs in the tank. Some nylon nets were tied onto the discs for the microbes growth place. While they were rotating, the discs were exposed to the air. This process was done in order to provide oxygen for the microbes so they could degrade pollutants. After the treatment in RBC, the wastewater was then flowed into a vessel on the ground. In the next step, the wastewater was pumped into a collecting tank and then to the filter. The filter was made from a tank in a capacity of 200 litres. This tool was fulfilled by charcoals and gravels to filter the effluent. The effluent flowed out from the filte which was then analyzed to determine the concentration of pollutants.

Batik wastewater treatment was performed continuously. In the first step, the wastewater was collected in a tank of 4000 ml capacity which was placed underground. The wastewater was pumped into ABR by then. In addition to solid precipitation, in ABR the wastewater was also treated anaerobically. The effluent was then flowed into RBC to be treated aerobically, and it was flowed back to ABR to be retreated.

The treatment in ABR and RBC was repeated up to 72 hours. After this step, the wastewater was then flowed into the collecting tank and filtered in the filter. The wastewater samples were collected from ABR (inlet and outlet), RBC, and filter, and were analyzed by then.

The wastewater treatment was carried out for 40 days and was divided into three periods, i.e. 5–11 September (P.1), 16–25 September (P.2), and 9–19 October (P.3), respectively, based on continuous flows of batik waste-

Figure 1. Wastewater Treatment Reactors, i.e. ABR (A), RBC (B), Collecting Tank (C), and Filter (D)

water through the treatment system. The effectiveness of ABR, RBC, and filter was determined for each period using different change between post- and pre-treatment divided by pre-treatment and multiplied by 100%.

3. Results and Discussion

The result suggests that batik wastewater contains high concentration of color, turbidity, and TDS. Similar result was also shown for chemical parameters, i.e. pH, COD, alkalinity, sulphate, and N-NH3. The COD concentration of IKM Batik WTJ's wastewater is 1904 mg/L. This concentration was even higher than that of Melati industry, which was only in the range of 400–1,750 mg/L) [9]. However, phenol, BOD_5, and lead concentration of the wastewater were lower than those of textile wastewater quality standard which was assessed by the Central Java Provincial Government [10]. Due to this reason, the following measurement was focused on the high-concentrated pollutants, i.e. color, TDS, pH, alkalinity, COD, sulphate, and $N\text{-}NH_3$. The character of batik wastewater is shown on Table 1.

Table 2 shows a variation on effectiveness of ABR in reducing pollutants during the treatment period. The result indicated that ABR is effective to reduce turbidity, TDS, and color concentration. Its effectiveness was 61.7–71.8%. In addition, the effectiveness of ABR to neutralize pH, reduce alkalinity, COD, sulphate, and $N\text{-}NH_3$ ranged from 14.1–75.9%.

This phenomenon suggested that the effectiveness of ABR in reducing chemical pollutants was influenced by the type of pollutants. During this anaerobic treatment, the alkalinity decreased with 75.9% effectiveness, and 67% for $N\text{-}NH_3$. On the contrary, sulphate and COD reduction, as well as pH neutralization by ABR

Table 1. The Character of Batik Wastewater

Parameters	Concentration
Physical	
Color (PtCo)	1,496.00
Turbidity (FTU)	276.00
TDS (mg/L)	2,300.00
Conductivity (mS/cm)	3.58
Chemical	
BOD_5 (mg/L)	12.50
COD (mg/L)	1,904.00
pH	10.70
Alkalinity (mg/L)	1,120.00
Sulphate (mg/L)	176.00
$N\text{-}NH_3$ (mg/L)	4.68
Phenol (mg/L)	0.01
Cr^{+6} (mg/L)	0.05
Lead (mg/L)	0.45
Sulfide (mg/L)	0.55

Table 2. The Effectiveness of ABR in Batik Wastewater Treatment in Three Periods

Parameters	Effectiveness (%)			Average (%)
	P.1	P.2	P.3	
Physical				
Turbidity (FTU)	62.0 (78.8)	86.7 (52.8)	128.0 (83.7)	71.8
TDS (mg/L)	880.0 (66.3)	1260.0 (30.9)	1,068.0 (87.9)	61.7
Color (PtCo)	346.0 (78.0)	457.5 (45.1)	724.0 (72.3)	65.1
Chemical				
pH	8.7 (19.8)	9.0 (5.2)	9.4 (17.4)	14.1
Alkalinity (mg/L)	308.8 (74.0)	1,362.5 (5.6)	1,013.0 (77.8)	75.9
COD (mg/L)	754.7 (76.4)	1,026.7 (15.3)	872.0 (42.4)	45.4
Sulphate (mg/L)	138.7 (26.6)	130.0 (29.3)	205.3 (70.0)	41.9
$N\text{-}NH_3$ (mg/L)	1.98 (82.0)	3.40 (33.7)	1.50 (85.3)	67.0

Note:
P.1: Period of wastewater treatment between 5-11 September
P.2: Period of wastewater treatment between 16-25 September
P.3: Period of wastewater treatment between 9–19 October.
Number indicates measure value, while number in bracket indicates effectiveness (%). These notes are also used for Table 3.

Table 3. The Effectiveness of RBC in Batik Wastewater Treatment in Three Periods

Parameters	Effectiveness (%)			Average (%)
	P.1	P.2	P.3	
Physical				
Turbidity (FTU)	104.0 (10.3)	90.8 (39.5)	139.3 (8.4)	19.4
TDS (mg/L)	780.0 (69.0)	976.7 (28.1)	998.3 (73.5)	57.1
Color (PtCo)	572.0 (10.1)	444.2 (40.8)	810.0 (17.3)	22.7
Chemical				
pH	8.5 (21.6)	8.4 (8.6)	8.8 (18.7)	16.3
Alkalinity (mg/L)	323.8 (1.9)	1,020.8 (18.4)	963.3 (6.9)	27.2
COD (mg/L)	1,264.0 (4.8)	828.0 (34.9)	888.0 (5.9)	15.2
Sulphate (mg/L)	148.0 (11.9)	18.9 (37.6)	--	24.7
$N\text{-}NH_3$ (mg/L)	2.5 (19.4)	2.3 (58.2)	2.2 (8.3)	28.6

indicated a lower effectiveness than those of other parameters. The effectiveness of ABR in wastewater treatment is shown on Table 2. The effectiveness of RBC in batik wastewater treatment is presented in Table 3.

The effectiveness of RBC in reducing pollutants was lower than that of ABR. The RBC is effective to reduce TDS up to 57%, whereas its effectiveness was only 19.4-28.6% for other parameters. Table 4 presents the effectiveness of filter in batik wastewater treatment.

As well as the RBC, effectiveness of filter to reduce physical and chemical pollutants was also low. The effectiveness of filter in decreasing physical pollutants was in the range of 2–12%, and 8–38% for chemical pollutants. However, the filter could decrease the pH of wastewater to 7.3 (17% of effectiveness). This means that the pH value fulfilled the quality standard which has been assessed by the Provincial Government of Central Java [10].

Our findings showed that pollutants' concentration of batik wastewater decreased after the treatment. ABR was more effective to treat batik wastewater than RBC and filter were (Table 2, 3, and 4). ABR was effective to reduce color concentration up to 65%. Bell & Buckley [11] reported that the use of ABR to treat textile wastewater could reduce color concentration up to 86%. The decrease of color concentration was more effectively performed on ABR than RBC. It indicates that anaerobic condition is favorable for color removal, as reported by Dos Santos [12]. Similar results was also shown on the concentration of N-NH_3, alkalinity, turbidity, and TDS. The concentration of those parameters decreased most effectively on ABR. This fact suggested that degradation of pollutants in anaerobic condition was performed better than the aerobic ones.

Table 4. The Effectiveness of Filter in Batik Wastewater Treatment in the Third Period

Parameters	Effectiveness (%)			Quality standard
	Pre-filtration	Post-filtration	%	
Physical				
Turbidity (FTU)	146.0	140.0	4.1	-
TDS (mg/L)	1,167.5	1,020.0	12.6	-
Color (PtCo)	962.0	936.0	2.7	-
Chemical				
pH	8.8	7.3	17.1	6-9
Alkalinity (mg/L)	963.3	865.0	10.2	-
COD (mg/L)	888.0	712.0	19.8	150
Sulphate (mg/L)	262.7	161.3	38.6	-
N-NH_3 (mg/L)	2.28	2.08	8.8	8

Note: The quality standard is adopted from Provincial Government of Central Java [10].

Our findings showed that the combination of ABR and RBC can be used to treat batik wastewater. However, conditions that might support the microbial growth need to be increased in order to optimize the treatment process. Miao [13] stated that wastewater treatment by microbial activities needs an optimal condition for the microbial growth. Alkaline condition might inhibit the microbial growth. Coughlin *et al.* [14] reported that biodegradation of textile wastewater was performed optimally on pH 6.0-6.2. He *et al.* [15] also reported that color removal of Direct Scarlet 4BS by microbial consortia was optimally performed on neutral pH.

The microbial growth is also influenced by nutritional aspect despite pH. Batik wastewater does not contain the simple carbon source for microbes. This condition might lead to the inhibition of microbial growth. The research of Padmavathy *et al.* [16] indicated that some materials, i.e. starch, glucose, lactose, sewage and whey water supported the microbes on degrading textile wastewater. This result was similar to Setyaningsih [17], who reported that the addition of carbon source could increase color removal and reduce COD. The simple carbon source acts as an energy source and electron donor for color removal [18]. By understanding its importance, therefore, the carbon source can be suggested to be involved in the further treatment.

4. Conclusion

The effectiveness of ABR and RBC in batik wastewater treatment varies because of the type of pollutants. The ABR performance in reducing pollutants showed an effectiveness up to 75%, whereas RBC effectiveness was 15-57%. Concerning the quality standard of wastewater, the wastewater treatment system showed a good performance to decrease pH, whereas the COD was still high. Further optimization, then, is needed to improve the quality of effluent.

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