IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

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To cite this article: M Gunawan and T Wikaningrum 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **995** 012027

The Bacteria Addition Study to Batik Wastewater Industries In pH Performance, and Removal of Ammonia and COD

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Abstract. The production of batik generates a large volume of wastewater with complex nature and characteristics such as high temperature, pH, BOD, COD, and TSS. In Jababeka Industrial Estate, Wastewater from batik industries is treated by going through a facultative equalization tank before going to the next treatment units. Hypothetically, by optimizing the facultative equalization tank, it will improve the effluent quality and increase COD and Ammonia's removal efficiency. This research used 4 microbial products that are commercially available and can be applied easily in real-life operating conditions. The study aimed to determine the effect of bacteria addition and its removal efficiency for batik wastewater effluent from batik industries in Jababeka Industrial Estate. the parameters measured were pH, concentration of COD and ammonia. The addition of bacteria reduced COD and Ammonia concentration in the wastewater and changed the wastewater's pH and color. The result indicates that for high COD and ammonia loads, the M-Aerobic bacteria is the best type of bacteria with a removal efficiency of 63.39% and 99%, respectively. However, ANOVA analysis indicates that there is no statistically significant difference between the treatment groups. It is recommended for this experiment to be repeated in a continuous reactor.

1. Introduction

1.1. Wastewater From Batik Industries

As a country with a diverse culture, Indonesia has a lot of cultural heritage. Recognized by UNESCO in 2009, batik is one of the famous cultural heritage in Indonesia [1]. Generally, wastewater from the textile industry is very complex because of the use of different kinds of coloring agents and the use of other solvents for production processes. It is estimated that 80% of the total water consumption in the production process of textiles becomes wastewater [2]. Textile coloring substances are usually manufactured from non-biodegradable organic compounds, that accumulate readily in soils and waters. [3] The wastewater of the batik industry contains organic substances, suspended solids, colors, and also chromium (Cr), sulfide, ammonia, phenols, fat, and oils. [4]. In addition, Batik wastewater is alkaline and contains high organic content.

Directly discharging the wastewater into the river or other surface water will cause an increase in COD, BOD, TSS concentration [3]. The non-biodegradable compounds that exist in textile wastewater are highly toxic to aquatic life, carcinogenic, and mutagenic to humans [5]. Consequently, a High concentration of BOD, COD, and color in surface waters can adversely impact the balance of the natural ecosystem and lower the water quality index [6]. Therefore, untreated discharge of textile wastewater may affect the marine life, ecosystem, water resources, and productivity of the soil [7]. The complex nature of textile wastewater made it very difficult to treat the wastewater in a conventional process.

In the biological process, there are a variety of microorganisms that can be utilized, such as algae, fungi, and bacteria. Previous research conducted in 2019, utilized indigenous bacteria obtained from activated sludge. From the research, it was found that in the aerobic condition the treatment was able to reduce COD as much as 76,59% while in the anaerobic condition the treatment was able to reduce 69.43% of the COD [8]. Another research studies the effectiveness of biological pre-treatment by the addition of microorganisms and support media. The research isolated the microorganisms, *Aeromonas salmonicid*a, and *Pseudomonas vesicularis*. From the laboratory-scale experiments, it was found by detention time of 6 days, the COD was reduced by 33.3% for the control, 42.4% with microorganism addition, and 63.6% with both support media and microorganism addition. In addition, it was found that after 2 and 3 days from the start of the experiment the COD reduction stopped [9].

1.2. Case Study

In Jababeka Industrial Estate, Cikarang, Bekasi, West Java, there is the zoning of batik industries that operate a number of batik industries. The wastewater discharge from these industries needs to meet a certain quality standard set by the estate regulation. The quality standard for ammonia is 10 mg/L, COD 800 mg/L and pH is 6-9 [10]. The study of modeling for industrial estate environmental management showed that the first actor is the industrial estate manager, the industrial companies located in an industrial estate are the second actor and the local government is the third actor [11]. The sustainability study of environmental management in Jababeka showed that the management dimension has already been classified in the "sustain" level, but other dimensions of ecology, economy, and social and technology are still classified as "unsustain" [12]. Regarding the condition, the evaluating of batik zoning industries in Jababeka is significant to be studied. In the existing condition, the wastewater first goes through a facultative equalization tank before going to the next treatment units, as shown in Figure 1.

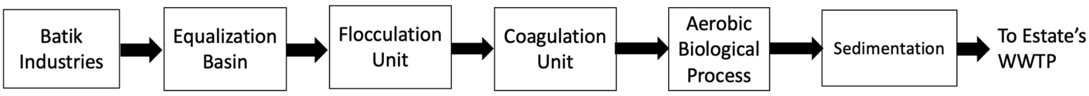

Figure 1. Batik Wastewater Treatment Train (Source: Jababeka Doc.)

The equalization tank has a flowrate of 2,000 m^3/d and a capacity of 6,000 m^3/d with a detention time of 3 days. The primary function of equalization tanks is to reduce the variation of the composition and flow rates of incoming wastewater [13]. For batik industries, the cyclic nature of production where each day there is a variation of the colour or design produced, equalization basin is especially important for equalizing the wastewater.

A 3-month report from December 2019 – March 2020 shows that the COD, ammonia concentration, and pH in the wastewater discharge exceeds the quality standard. The COD concentration in the wastewater ranges from 207 – 3185 mg/l with an average concentration of 1519 mg/L. While the ammonia concentration ranges from 76.3-708 mg/L with an average of 309 mg/L. The pH of the wastewater ranges from 8.22-12.6 with an average of pH 10.33

By optimizing the process in the facultative equalization tank through the addition of bacteria, it will improve the effluent quality and increase the removal efficiency of the key parameters. As a result, the load to the next treatment units can be reduced and the system can be more efficient. The purpose of the research is to find a treatment option that is easily accessible in the markets. Therefore, this study selected to use microbial products that are available and can be applied easily in real-life operating conditions in Indonesia. Because the equalization tank is facultative, therefore in this research both anaerobic and aerobic microorganism is tested. In this study, two types of brands are selected M and B brands.

The first objective of this research is to study the effect of bacteria addition, to the pH of wastewater Batik Industries in Jababeka Industrial Estate. The second objective is to know the percent removal of COD and ammonia that can be achieved by the lab-scale batch reactor. The last objective is to find out the best type of bacteria product for treating wastewater. This research is limited to analyzing the result of treatment in a lab-scale batch reactor and is a one-factor experiment.

2. Materials and Methods

This research uses both primary and secondary data. Secondary data that was used was 3 months report of wastewater quality obtained from Jababeka. The collection of primary data of water quality was taken through the experimental method by performing laboratory experiments. The independent variable in this experiment is the type of microbial products added to the wastewater. While the dependent variable is the concentration of the parameters COD, ammonia, pH in the wastewater. In order to find the bacteria product that yields the best result, three experiment runs were conducted. The details of each experiment are shown in Table I. The initial detention time was set for 3 days, following the conditions applied in the real-operation of the equalization tank. Although in the experiment runs, the detention time was extended until the time of which the parameters reach below the quality standard.

Table 1. Experiment details.

Experiment Details	Detention Time (Days)	Type of Bacteria Used	Dose
Experiment 1	4	M-anaerobic; M-aerobic; B-anaerobic; B-aerobic	250 PPM for brand M products; 80 PPM for brand B Products
Experiment 2	6	M-aerobic; B-anaerobic; B-aerobic	
Experiment 3	3	M-aerobic	

Four microbial products were used in this experiment from 2 different commercial brands. The dosing was taken from the recommendation given by the manufacturer. The batch-reactor was made using plastic basins that are marked at height 2.5 cm with the dimensions 21 cm x 28 cm, the total volume is 1.47 L.

For measuring ammonia, HANNA HI 96733 Ammonia High Range photometer and HI93733-01 ammonia high range reagents were used [14]. Next, the COD was measured using the USEPA-Approved dichromate COD method by using HACH DRB 200 Digital Reactor Block for digestion and Low range COD Digestion Vials with a range of 3-150 mg/L. A DR900 Multiparameter Portable Colorimeter was used to read COD values from the vials [15]. Lastly, the ATC pH-2011 digital pH meter was used to measure the pH of the wastewater [16]. The removal of pollutants in wastewater over a period of observation can be calculated as the removal efficiency. This study used One-way ANOVA to find statistical evidence that the associated population means are significantly different [17]. The One-Way ANOVA was conducted using Excel© software.

3. Results and Discussion

3.1. Experiment 1

For the first experiment, the pH was measured daily. The initial pH was 8.35 which was slightly alkaline. For almost all treatments, after the initial measurement, the pH continues to increase in value. Expect for the basin with M-anaerobic bacteria, where the pH slightly decreases in day 1. The pH quality still meets the quality standard of 6-9.

In this first experiment, the measured initial influent quality for COD was 200 mg/L COD. The COD was measured at day 0 and day 3. After 3 days, the removal efficiency of the control basin was 47.5%, while for the Anaerobic M-anaerobic, M-Aerobic, B-anaerobic, B-aerobic the removal efficiency was 42.5%, 40%, 50%, and 67.5% respectively. Compared to the control, both the B-anaerobic and B-aerobic bacteria performed better. While the M-anaerobic and M-aerobic bacteria have lower removal efficiency than the control basin and performed worst compared to other treatments. For low-load COD, the best result was obtained by wastewater with aerobic B-aerobic addition. For ammonia, the measured initial concentration was 143.96 mg/L. This is beyond the quality standard. After 4 days of observation, all the ammonia concentration reached below the quality standard of 10 mg/L. The M-Anaerobic M-Aerobic, B-Anaerobic, B-Aerobic has the removal efficiency of 97.05%, 99.02%, 99.02%, and 98.26% respectively. The control basin obtained a removal efficiency of 94.75% which is lower compared to wastewater that was treated with bacteria. Although there was not much difference.

3.2. Experiment 2

After the result of the first experiment, the number of bacteria was narrowed down to three types, M-Aerobic bacteria, B-Anaerobic bacteria, and B-Aerobic bacteria. The M-anaerobic bacteria was eliminated because it performed the worse in terms of ammonia removal, and was the second worse in terms of COD removal. Based on the observation of the first experiment. In the second experiment, the measurement frequency of pH is increased to every 8 hours over a period of 6 days. The aim is to find the time where the pH may start to rise. The initial pH value for the second sample is 9.71. From the result, it is observed that the pH value starts to rise at around hour 40 to 48. After that, the pH continues to rise slightly. This result is observed across all treatments including the control basin. At the end of the experiment, the pH quality for all treatments was slightly above the quality standard. In the biological process, the reduction of pH can be caused by the production of carbon dioxide in the process of degradation or by biodegradation of wastewater, such as the conversion of carbohydrate to glucose [18]. In addition, ammonia oxidizers can produce acidic metabolic compounds that can lower the pH as well [19]. The changes in pH are influenced by factors such as the production of an acidic or alkaline substance in the treatment process or the buffer capacity in the influent [20]. It is can also be affected by the equilibria of carbonic acid in the wastewater, relating to the concentration of carbon dioxide, bicarbonate, and carbonate [21].

The initial COD concentration of the second experiment was 1525 mg/L. Because of the higher COD value, the detention time was 6 days. The COD concentration was measured every 2 days. It was found that the M-Aerobic bacteria has the best COD concentration with 550 mg/L which is under the quality standard. On the other hand, the other treatments do not meet the quality standard. The removal efficiency of the control was 29.51%, while for the M-Aerobic, B-anaerobic, B-aerobic the removal efficiency was 63.93%, 29.51%, and 32.79% respectively. The B-Anaerobic bacteria have the same removal efficiency as the control with no treatments. For the control, by the second day, the COD concentration did not change. Compared to experiment 1, the removal efficiency is lower due to the higher COD load. At the end of the experiment, only the wastewater treated with M-Aerobic bacteria is able to meet the quality standard with a concentration of 550 mg/L, which is lower than the quality standard of 800 mg/L.

For the second experiment, the initial ammonia concentration was 679.68 mg/L after 5 days the ammonia concentration for the wastewater treated with M-Aerobic bacteria and B-anaerobic bacteria reaches below the quality standard of 10 mg/L. While the control and the one treated with B-aerobic bacteria still exceed the quality standard. The removal efficiency was found to be 96.88% for the control basin. The M-Aerobic, B-anaerobic, B-aerobic has the removal efficiency of 99.65%, 99.31%, and 96.88% respectively. Both the wastewater with M-Aerobic, B-Anaerobic addition has a higher removal efficiency compared to the control.

3.3. Experiment 3

Based on the previous experiments it was found that the M-Aerobic bacteria has the best performance compared to the other treatments. For the third experiment, the parameters tested were only ammonia and pH. In the previous experiments, there was no big difference in removal efficiency between the control basin and the treated basin. In this experiment, the fresh sample was mixed with the sample from experiment 2 where the bacteria were already acclimated. Acclimation is a process to adapt an organism to a new environment until a condition of steady-state is achieved [22]. The aim is to test whether or not there is a significant difference between the control and treated basin. The initial pH was 9.43. Similar to the second experiment the pH reduces from the initial point until around day 1-2 where it starts to rise again. In the third experiment, the initial ammonia concentration was 474.36 mg/L. After 3 days the wastewater treated with the M-aerobic bacteria reaches 0 mg/L. While the control basin ammonia concentration was slightly above the quality standard as shown in Fig. 10. The removal efficiency of the control basin was 97.51% similar to the result obtained in the second experiment. On the other hand, the wastewater treated with the aerobic M-aerobic bacteria was able to reach 100% removal.

3.4. Statistical Analysis Result

A one-way ANOVA between subject test was conducted to compare the effect of bacteria added to the pH value and concentration of COD and ammonia in the wastewater for wastewater with no bacteria addition as the control and wastewater with different kinds of bacteria addition. For ANOVA, the null hypothesis is that the mean of all populations is equal. The alternative hypothesis is that the mean of at least one population is different from at least one other population. If $P < 0.05$ then the null hypothesis is rejected. For the first experiment, the result of the one-way ANOVA showed a non-significant effect on COD concentration ($P= 0.995$), ammonia concentration ($P = 0.926$) and pH ($P = 0.982$). Similarly, for the second experiment, the result showed a non-significant effect on COD concentration ($P = 0.848$), ammonia concentration ($P = 0.999$) and pH ($P = 0.988$). Lastly for experiment 3 the One-way ANOVA test showed a non-significant effect for ammonia concentration ($P = 0.961$) and pH ($P = 0.708$). It implies that there is no statistical evidence that indicated that the addition of bacteria has an effect on pH, COD, and ammonia concentration.

4. Conclusion and Recommendation

In conclusion, it was found that:

1. The bacteria addition has an effect on the pH by decreasing its value around the first and second day after that the pH value rises. The changes in pH value are caused by the biological processes that occur in the wastewater.
2. The addition of bacteria in a lab-scale shallow batch reactor for batik wastewater was able to achieve a COD removal efficiency ranging from 29.5-67.5% Consequently, it also achieves a removal efficiency range of 96.8-100% for ammonia.
3. From the experiments, the result indicates that for high COD and ammonia loads the M-Aerobic bacteria is the best type of bacteria that yields the best results in this experiment. Using M-Aerobic bacteria, 63.39% COD was able to be removed and for ammonia, 100% was removed.

The addition of bacteria has the effect of degrading the organic matter and removing ammonia in batik industries wastewater. As observed in the change of concentration of ammonia and COD of batik wastewater. Although, there was no significant statistical difference between the groups including the control. This means that for batch reactor application of bacteria addition, although there was removal of the pollutants, the result does not conclude that there was a massive difference in the removal efficiency. It is recommended that this research be developed in a continuous basin to test whether or not bacteria addition can significantly optimize the process of batik wastewater treatment in a continuous system equalization tank. In addition, further testing could also be conducted using other parameters beyond COD and ammonia, such as carbonate and bicarbonate to facilitate further investigation on the changes of pH throughout the process.

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