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Analysis OF COD, Ammonia, and pH Reduction of Textile Industry Wastewater with Aeration System Based on Activated Sludge Concentration (Study Case: PT Jababeka Infrastruktur)

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Abstract: The batik industry is a sub-sector of the textile and clothing industry that can produce handicraft products, with a continuously growing market. With the increasing demand for batik production, the number of batik craftsmen in Indonesia is also growing, resulting in a significant amount of batik waste generated from its production. Batik wastewater contains high levels of COD, ammonia, and pH, as well as heavy metals, making it hazardous to discharge into rivers without prior treatment. Objectives: The purpose of this research is to determine the effectiveness of the concentration of activated sludge in biological treatment on the efficiency of reducing COD, ammonia, and pH levels in the treatment of batik wastewater at PT Jababeka. Method and results: The experiment was conducted using a batch system in the aeration process, utilizing aerobic bacteria derived from 2 (two) different types of activated sludge. The residence time of bacteria in wastewater biodegradation is

22.5 hours based on the maximum incoming wastewater discharge Conclusion: The concentration and composition of activated sludge used in the biological process, particularly in the aeration process, have an impact on reducing the characteristics of textile wastewater. The mixing of activated sludge types from the batik treatment system and sludge from the centralized process at PT Jababeka has shown better results in reducing the characteristics of textile wastewater. Biological treatment using aerobic bacteria from two different types of activated sludge in Sample 3 shows better efficiency in removing COD by 83.5% and NH3 by 99.45%, along with a pH reduction of 25.6%.

1 Introduction

The number of batik consumers in 2010 reached 72.86 million people [1]. The number of batik industries in Indonesia has grown due to increasing consumer demand. The expansion and development of batik industry centers in various regions of Indonesia are driven by the rising demand and consumption of batik. The increase in batik production is directly proportional to the amount of waste generated, especially in wastewater production.

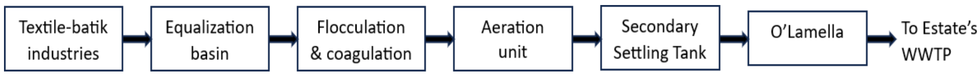
The expanding batik industry in Indonesia raises environmental concerns, particularly regarding the aquatic environment. The batik industry's processes generate waste with dye characteristics. These dyes are a byproduct of the dyeing and washing processes of batik cloth [2]. Since the batik industry is a part of the textile sector, which utilizes the greatest amount of water during manufacturing, the amount of wastewater generated equals 80% of the total water utilized in batik[3]. So it will produce wastewater that comes from the dyeing and washing processwhich can have a bad impact on the environment, especially water. a load of organic wastewater produced in Indonesia is 883 tons/day, of which 29% of the load comes from the textile industry [4]. Textile wastewater is generated from the process of releasing wax and washing batik cloth [5]. The compounds contained in textile wastewater are identical to the presence of heavy metals. The content of heavy metals in textile wastewater that enters water bodies generally exceeds water quality standards and has a negative impact on living things. This is because heavy metal particles are difficult to decompose (non-degradable) by microorganisms. Textile wastewater generally contains heavy metals from dyes derived from the dyeing process of batik cloth. The dyes used in the coloring process are generally complex aromatic compounds with characteristics that are difficult to decompose [6].

Based on the content of particles and other hazardous substances that are difficult to decompose, the textile industry business activities will have an impacton environmental damage. This is because there are still many textile industry producers who throw their wastewater into the river due to the well-known waste management process being expensive, while the batik industry is dominated by small-scale industries [7].

Jababeka has a total area of 5,600 ha and an industrial area of around 3,000ha which is occupied by ± 1,700 industrial companies from 30 countries which makes Jababeka one of the largest industrial estates in Indonesia. Many batikindustries are established in the Jababeka area so further waste treatment is needed before being discharged into the environment. One of the treatment systems is the Batik Wastewater Treatment Plant at PT Jababeka Infrastruktur, where from secondary data it is found that the average debit of textile-batik wastewater entering the treatment system is around 800 m3 / day with an average value of BOD 804 mg / l, COD 2,417 mg / l, Ammonia 939 mg / l and an average pH of 10.33 (PT Jababeka doc), where it will be harmful to the environment if no treatment is carried out. The flow chart of the batik waste treatment system at PT Jababeka can be seen in Figure 1.

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

This research focuses on increasing the removal efficiency of COD, Ammonia, and pH parameters by



utilizing the concentration and/or composition of activated sludge in biological treatment. According to [8] the efficiency of the results of reducing wastewater characteristics (COD, Ammonia) can reach around 70%-95%. Based on the acquisition and analysis of secondary data, the aerobic biological treatment unit at PT Jababeka has shown an average COD removal efficiency of 85% and ammonia removal efficiency of 57.6%. The SVI value stands at 73.87 g/mL,and the F/M ratio value is 0.156 mg/mg·d. A lower F/M ratio value causes microorganisms to tend to consume almost all organic matter in the incoming wastewater. Typical F/M ratios in a wide variety of activated sludge processes range from 0.04 to 2.0 mg/mg·d, while SVI in biological treatment typically falls within the range of 50 to 150 g/mL [9]. A low F/M ratio indicates that the microorganisms in the aeration tank are in a state of high activity, and the lower this ratio, the more effective the sewage treatment process.

Based on this, further research was conducted to enhance the removal efficiency of COD, ammonia, and pH in the treatment of batik wastewater at PT Jababeka in the biological treatment process, specifically in the aeration tank. In the aeration tank unit, activated sludge plays a vital role in degrading organic particles in wastewater. According to secondary data, the activated sludge is indicated to have a low SVI value and a high MLSS concentration, even up to twice the detention time. Therefore, the research was carried out through a dilution experiment by adjusting the composition of activated sludge and introducing two different types of activated sludge with the expectation that the activated sludge can function more optimally.

2 Method

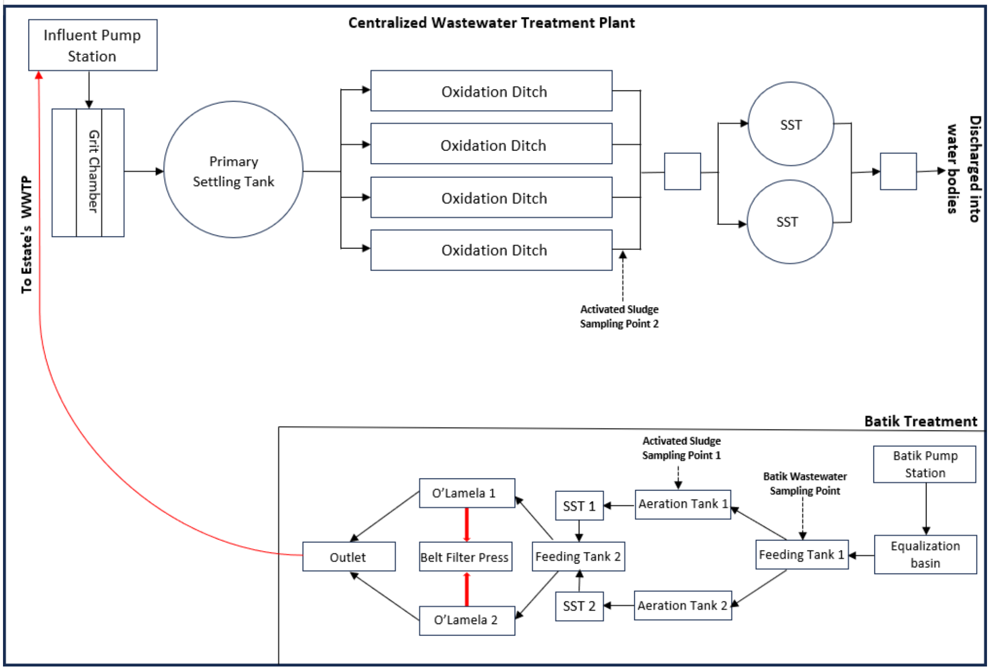
2.1 Population and Sample

The population in this study comprised textile wastewater and return-activated sludge from the Jababeka Wastewater Treatment Plant I. Samples for this study required ± 10 liters of textile wastewater, ± 6 liters of batik return-activated sludge, and ± 3 liters of WWTP return-activated sludge for the required sampling. Before using the samples for experiments, a homogenization process was conducted usingan Agitator Engine with a maximum speed of 4800 r/min.

2.2 Sampling Method

Samples of textile wastewater were collected from the feeding tank which is the outlet from the equalization tank and goes directly to the aeration tank. A sample of return-activated sludge is obtained from the discharge channel of the return sludge from the secondary tank to the aeration tank at Jababeka Wastewater Treatment Plant I, located in Cikarang at coordinates 6°16'26.82"S latitude and 107°7'37.78"E longitude. For more details, refer to the sampling point indicated in the flowchart of the textile wastewater treatment process in Figure 2. The samples were collected at 8 a.m. on March 16, 2023, following the guidelines outlined in SNI 6989.59: 2008, which pertains to Water and Wastewater – Section 59. This standard specifies the method for spot random sampling for wastewater, involving direct collection using a container and a rope.

Fig. 2. Flowchart of Batik Wastewater Treatment at PT Jababeka Infrastruktur (Source: Jababeka Doc.)



2.3 Experimental Method

2.3.1 Sample Preparation

The research instrument is a tool used in research activities, specifically for measurement and data collection by researchers through observation and experimentation. The quality of the data collected depends on the instrument used. The calculation for the required aeration time in this study is 22.5 hours with a residence time of 3 hours. To conduct the study, 1 liter of wastewater was mixed with activated sludge. Four sample treatments were used based on the conditions and secondary data: control samples (adjusted to match the conditions of batik wastewater treatment in the aeration tank unit at PT Jababeka), sample 1 (with reduced activated sludge concentration due to thick activated sludge based on secondary data from PT Jababeka's batik treatment), sample 2 (with a concentration adjustment based on sample 1, but with added activated sludge from centralized treatment for improved efficiency), and sample 3 (with activated sludge concentration adjusted based on the control sample and consisting of two different types of sludge). The composition of each treatment sample and the formula for calculating the required aeration time and residence time are provided below [10].

Max flow rate = 1200 m^3/d Volume of aeration tank = 1125

m^3Volume of SST = 150 m^3

Aeration detention time $= \frac{V}{Q} = \frac{1125\ m3}{1200\ m3/d} \times 24 =$ 22.5 hour

SST detention time $= \frac{V}{Q} = \frac{150\ m3}{1200\ m3/d} \times 24 =$ 3 hour

Table 1. Type and Composition of Treatment

Treatment	Batik Wastewater	Activated Sludge from Batik Treatment	Activated Sludge from Centralized Treatment
Control	20 %	80 %	-
Sample 1	50 %	50 %	-
Sample 2	50 %	40 %	10 %
Sample 3	20 %	40 %	40 %

2.3.2 Aeration Process

Aeration is one of the important methods in wastewater treatment systems. According to [11] and [12] the aeration method involves adding oxygen to wastewater to increase the dissolved oxygen levels, thereby providing a source of oxygen to decomposing microorganisms to reduce the organic matter in wastewater. The purpose of the aeration process is to maximize the contact between water and the air or atmosphere, increasing the dissolved oxygen inwastewater, which is essential for sustaining life. This ensures a more efficient transfer of substances/components from one medium to another, preventing stagnation at the interface between wastewater and air, which can impede the transfer rate.

In this research, the aeration method marks the initial stage. Following the aeration process, the study proceeds to investigate dependent parameters such as Ammonia, COD, and pH. Decomposing microorganisms are sourced from return- activated sludge. Two types of activated sludge with varying concentrations are employed in each experiment, along with control samples adjusted to conditions in Jababeka's textile wastewater treatment. The hydraulic retention time for aeration in this study is 22.5 hours, followed by a 3-hour settling period before analyzing thedesired parameters.

Fig. 3. Laboratory Scale Aeration Process

3 Results and Discussion

3.1 Characteristics of Wastewater After the Aeration Process

The textile industry is a vast and intricate sector that generates a substantial amount of wastewater due to the diverse types of wastewater produced during its manufacturing processes. Wastewater in the textile industry is easily identifiable due to the distinct colors resulting from the dyes used in the batik-making process [13]. Textile industrial wastewater is a potentially hazardous industrial waste due to its turbid physical condition, which results from the presence of dyes that can produce various colors, ranging from brownish-red, green, blue, to deep black, depending on the production process. The colorful wastewater generated during the textile dyeing process consists of synthetic chemical compounds with high COD

(Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) values, along with other dye components that can harm the environment [14].

In this study, textile wastewater entering the Jababeka textile effluent treatment system exhibits a deep blue color (blue-black) and a strong odor. The presence of such color and odor indicates that the waste contains high COD, BOD, and NH3 values. The appropriate treatment process involves a biological treatment system that utilizes aerobic bacteria to break down organic particles in the wastewater, thereby reducing the levels of COD, NH3, and color in the wastewater. Figure 3 depicts the results before and after the aeration process, highlighting the changes in color characteristics in textile wastewater.

Fig. 4. Textile Wastewater Before and After Aeration Process

From the figure, it can be concluded that the color in sample 4 is clearer because the concentration of activated sludge is higher and contains 2 different types of activated sludge so the bacteria in the sludge are more optimal in degrading organic particles in textile wastewater.

3.2 F/M Rasio Analysis Result

The aeration process is regulated by the amount of air supplied, sludge recirculation speed, proportion of sludge discharged, MLSS control, and F/M ratio. Based on the calculation of MLSS value and F/M ratio in each treatment sample, the results can be obtained as in Table 2.

Table 2. Type and Composition of Treatment

Sample	Flow Rate	Volume Aeration tank	F/M Rasio (mg/mg.d)	SVI (mL/gr)	MLSS (gr/L)
Control	1200 m^3/d	1125 m^3	0.122	79.05	10.15
Sample 1			0.186	153.49	5.22
Sample 2			0.184	140.15	5.72
Sample 3			0.119	70.85	11.29

According to Table 2, the SVI value in the control treatment sample is 79.05, with an MLSS value of 10.15 g/L (10,150 mg/L), closely matching the secondary data value. The Sludge Volume Index (SVI) is directly linked to the quantity and solids content of the sludge returned to the aeration basin. Under these conditions, the MLSS concentration of activated sludge exceeds the required range of 2,000-5,000 mg/L, with an F/M ratio value of 0.122. Due to the initially thick activated sludge, reducing the concentration of activated sludge in samples 1 and 2 resulted in less favorable outcomes than in the control treatment, considering bacterial conditions. Consequently, the removal efficiency of COD and ammonia parameters was lower than in the control treatment. The F/M ratio values were higher at 0.186 and 0.184 mg/mg·d, with MLSS values of 5.22 and 5.72 g/L, respectively. Typical F/M ratios in various adaptations of the activated sludge process range from 0.04 to 2.0 mg/mg·d. A low F/M ratio indicates that microorganisms within the aeration tank have a strong appetite, and the lower the F/M ratio, the more efficient the wastewater treatment [9]. In sample treatment 3, the F/M ratio value is lower than the control, which is 0.119 with an MLLS value of

11.29 gr/L where in this condition the bacteria in the activated sludge begin to starve so that they will degrade the organic particles in the wastewater.

3.3 Chemical Oxygen Demand (COD)

Table 3. Wastewater Quality Standards for Business and/or Activities Textile IndustrySample Before (mg/L)

	After (mg/L)	Efficiency (%)	
Initial Sample	1521.49		-
Initial Sample	1504.70		
Control 1	-	356.28	76

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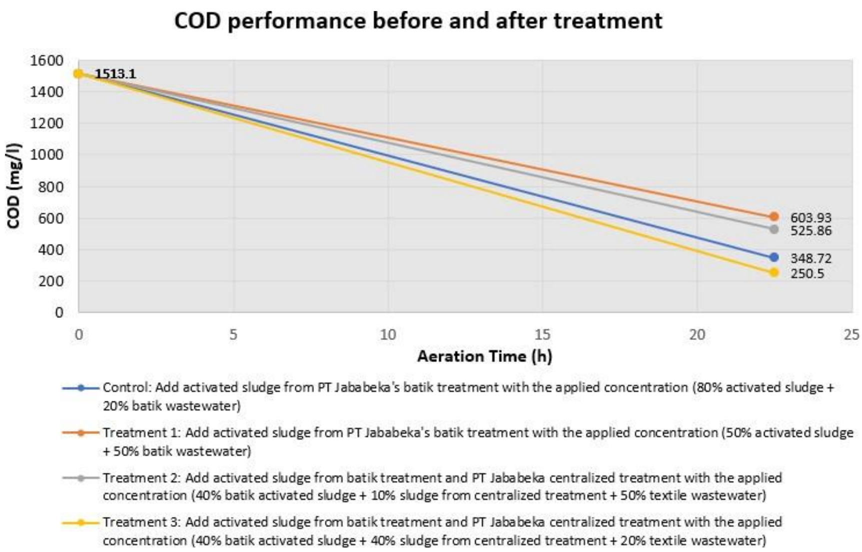
Sample	Before (mg/L)	After (mg/L)	Efficiency (%)
Control 2		341.17	77
Treatment 1-1	-	618.20	59
Treatment 1-2		589.66	61
Treatment 2-1	-	510.75	66
Treatment 2-2		540.97	64
Treatment 3-1	-	258.90	83
Treatment 3-2		242.11	84

Based on the table above, the average COD level before treatment is 1513 mg/land the average control value of COD level reduction after aeration treatment based on field conditions is 348.7 mg/l, this value is equivalent to the average value of COD level reduction based on the acquisition of field data shown in table 3.1with a percentage reduction of 76.5%. While in treatments 1 and 2, the results of the reduction in levels obtained were 603.9 mg/l and 525.8 mg/l. While sample 3 is a more significant decrease than the others, namely 250 mg/l with a percentage of 83.5%.

Fig. 5. Average COD removal result



Based on Figure 5, it can be seen that the COD content value in the Effluent of textile wastewater aeration results obtained is still above the quality standards of textile wastewater ready for disposal. The results of reducing the COD value in treatment 3 are better than the control sample even though it is still above the quality standard. With a COD content in Effluent of 250.51 mg/l with a removal efficiency of 83.5%, it shows a number that is not safe to be discharged into water bodies because the environmental quality standard set by the Minister of Environment Regulation No. 16 of 2019 on the COD value is 150 mg/l.

The percentage removal of COD values in treatments 1 and 2 decreased in efficiency compared to the control treatment. This decrease can be attributed to the reduction in the concentration of activated sludge during the aeration process. Consequently, aerobic bacteria, which are the primary microorganisms responsible for the activated sludge process, may not effectively oxidize the organic pollutants, whether in dissolved form or as particles present in the wastewater. Furthermore, the F/M ratio value influences the activity of microorganisms in degrading organic particles found in the wastewater.

The increased efficiency in COD removal observed in sample 3 is attributed to the precipitation resulting from the activity of microorganisms that form flocs. These flocs become larger as the number of colonies increases, leading to self- settlement. Additionally, the presence of bioball media acts as a filter to retain organic pollutants, which are subsequently degraded by microbes attached to the media. This results in a reduction in the chemical oxygen demand (COD) concentration in textile wastewater, as the amount of oxygen required for chemical oxidation decreases.

3.4 Ammonia (NH_3)

High ammonia conditions on the water's surface will be able to cause the death of organisms found in the waters. Therefore, the Ammonia parameter is also important to determine the level of pollution in wastewater that will be discharged into the waters.

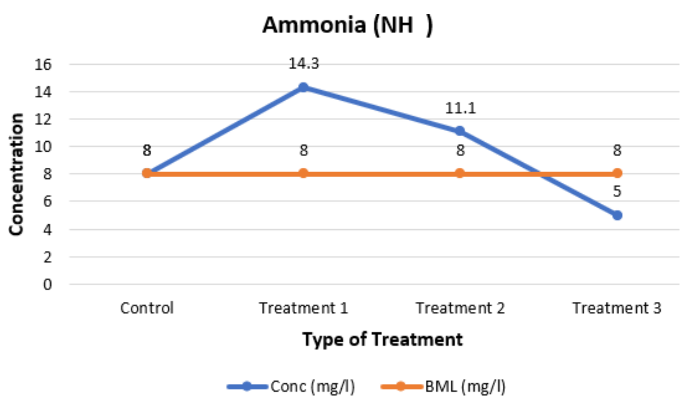
Table 4. Analysis Results of NH_3 Before and After Treatment

Sample	Before (mg/L)	After (mg/L)	Efficiency (%)
Initial Sample	914.63	-	-
Initial Sample	920.69		
Control 1	-	8.23	99.10

Sample	Before (mg/L)	After (mg/L)	Efficiency (%)
Control 2		7.90	99.14
Treatment 1-1	-	14.63	98.41
Treatment 1-2		13.96	98.48
Treatment 2-1	-	11.60	98.74
Treatment 2-2		10.59	98.85
Treatment 3-1	-	5.54	99.40
Treatment 3-2		4.53	99.51

The analysis of ammonia concentration in textile wastewater before and after treatment, as well as the effectiveness of concentration removal, is presented in Table 4 and Figure 6. From Table 4, it is evident that the average ammonia concentration in untreated textile wastewater reaches its highest value at 917.65 mg/l. However, in the treated wastewater, the ammonia concentration decreased to as low as 5.03 mg/l in treatment 3, corresponding to an impressive ammonia content removal percentage of 99.45%. The reduction in NH_3 concentration in this treatment meets the quality standards for textile wastewater discharge into water bodies.

Fig. 6. Average NH_3 removal results



Based on the graph showing the average ammonia removal concentration, it's evident that the ammonia content in the effluent of textile wastewater in treatments 1 and 2 exceeds the established environmental quality standards, making it unsafe for disposal. In the control treatment, the value meets the quality standard of 8 mg/l. However, in treatment 3, the ammonia removal value surpasses that of the control sample, reaching 5 mg/l with a removal efficiency of

99.5%. These results indicate that the textile waste is relatively safe for disposal, as it complies with the environmental quality standard set by Minister of Environment Regulation No. 16 of 2019, which stipulates a maximum NH_3 value of 8 mg/l.

The relatively low ammonia content in this wastewater effluent suggests that the sedimentation process is effective. Additionally, one of the factors influencing ammonia content is the aeration process. Proper aeration can contribute to reducing ammonia levels in wastewater

The addition of bacteria has the effect of degrading organic matter and removing ammonia in batik industry wastewater, as observed in the changes in ammonia concentration after the aeration process. The reduction in ammonia levels in textile wastewater demonstrates that the microorganisms involved in this treatment process are functioning optimally. The removal of ammonia occurs due to the activities of nitrifying microbes, which are aerobic and require oxygen to thrive. The higher the concentration of bacteria in the wastewater, the more organic material in the textile industry wastewater is decomposed, resulting in a higher percentage of ammonia reduction.

3.4 pH (Hydrogen Potential)

Table 5. Analysis Results of pH Before and After Treatment

Sample	Before (mg/L)	After (mg/L)	Efficiency (%)
Initial Sample	9.69	-	-
Initial Sample	9.69		
Control 1	-	7.93	18.2
Control 2		7.85	19
Treatment 1-1	-	8.25	14.86
Treatment 1-2		8.16	15.8
Treatment 2-1	-	7.43	23.3
Treatment 2-2		7.35	24.1
Treatment 3-1	-	7.25	25.2
Treatment 3-2		7.17	26

The results of the analysis of the pH values of batik wastewater before and after treatment are presented in Table 5 and Figure 7. Table 5 reveals that the average pH value of textile wastewater before treatment is 9.69, while the average pH value of wastewater after treatment is 7.67, indicating an efficiency of 20.81%. In the treatment of batik wastewater, the pH value has decreased to 7.2 in treatment 3, resulting in a removal percentage of up to 25.6%. These pH value reductions meet the quality standards for textile wastewater suitable for discharge into water bodies. According to Minister of Environment Regulation No. 16 of 2019, the maximum pH value that can be discharged ranges from 6 to 9.

Fig. 7. pH Removal

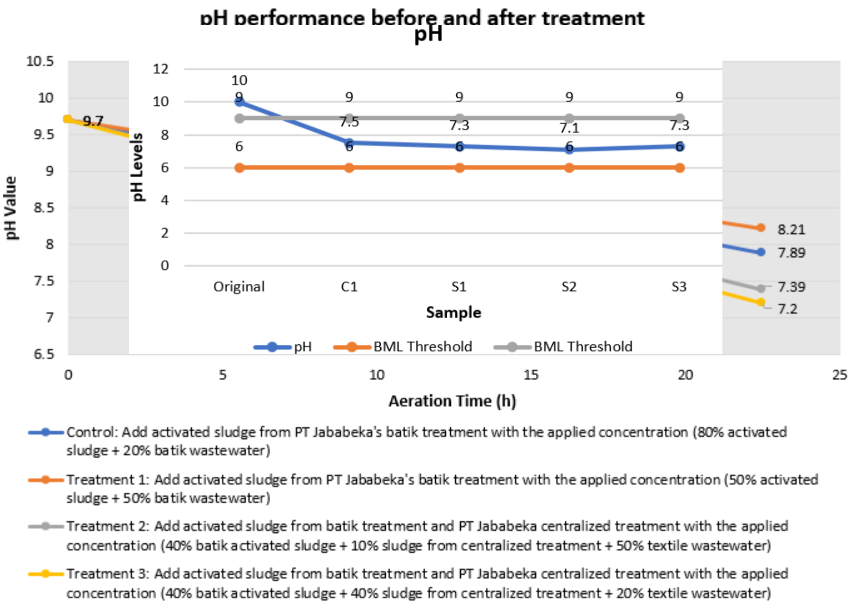


Fig. 8. Average pH Removal Result

In the pH graph presented above, the results of the average pH value in each treatment after the aeration process are still in normal conditions around 7-8. According to Astuti [15], bacteria can live in the pH range between 7-8. Most microorganisms grow best at pH values close to neutral, Microorganisms can grow well at normal pH so that substrate removal can take place well and the efficiency of COD removal can also be high.

From the graph above, it is evident that the pH value of textile wastewater, as a result of the aeration process, falls within a safe range for discharge into water bodies. According to the environmental quality standards established by Minister of Environment Regulation No. 16 of 2019, wastewater is considered safe fordischarge when its acidity level falls within the pH range of 6-9.

The establishment of a quality standard within the pH range of 6-9 is based on the principle that water within this range is considered neutral, neither too alkaline nortoo acidic. Water with extreme alkalinity or acidity in the treated effluent from the WWTP can harm the ecosystem of the receiving water body. Excessively acidic treated water can disrupt the stability of the water body's ecosystem, while excessively alkaline water can lead to elevated hardness, also affecting the stability of the receiving water body.

4 Conclusions

Based on the results of the research, analysis, and discussion, several conclusionscan be drawn relating to the research as follows:

1. The composition of activated sludge significantly influences the efficiency of reducing COD concentration values in batik wastewater at PT Jababeka. The control treatment sample can reduce the COD value by up to 76.5%. However, the sample treatment performed significantly better, reducing theCOD value by 83.5% compared to the control treatment.
2. The composition of activated sludge significantly influences the efficiency of reducing ammonia concentration values in batik wastewater at PT Jababeka. Treatments in samples 1 and 2 are less effective than the control treatment, which can reduce ammonia levels to 99.1%. In contrast, treatment 3 is

significantly more effective, reducing ammonia values by up to 99.5% compared to the control treatment.

3. The composition of activated sludge significantly influences the efficiency of reducing the pH value in batik wastewater at PT Jababeka. Sample 1 treatment results in a pH reduction of 15.3%, while the control treatment reduces the pH value by 18.6%. In contrast, treatments 2 and 3 are significantly more effective, reducing the pH value by 23.7% and 25.6% compared to the control treatment.
4. Based on the conducted research, it is recommended to improve the removal efficiency in the biological treatment of batik wastewater at PT Jababeka by transferring activated sludge from the secondary settling tank in the centralized wastewater treatment system to the biological treatment unit, specifically the aeration tank for batik wastewater treatment, by establishinga connecting pipeline.

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