Integrated System of the Biofilter and Constructed Wetlands for Sustainable Batik Industry

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Abstract— **Wastewater produced during the production process of batik contains toxic. Wastewater is generally an organic compound that causes environmental pollution, especially the aquatic environment. It is difficult to decompose the chemicals that increase pH, BOD, COD, TSS, and heavy metals. The effluent water from the boiling process of batik production does not meet the quality standards set by Regulation of the Minister of Environment of the Republic of Indonesia No. 5/2014 on wastewater quality standards. Natural wastewater treatment systems, such as constructed wetlands (CWs) and biological sand filters, are suitable options in treating wastewater due to its efficiency, cost, and operation. This research aims to provide and test alternative media to treat batik industry wastewater by using the biofilter and HSSFCWs integration. The results of the study showed decreases in the COD, TSS, and oil & fat parameters of 72.67-86.67%, 95.85-98.18%, and 79.47-90.04%, respectively. The statistical analysis showed a significant influence of the biofilter performance and the biofilter-HSSFCWs integration to the dependent variable, for three days, five days, and seven days period. As the quality of wastewater of batik's processing exceeds the established standards, it is not allowed to be discharged into water bodies and consumed by the community.**

Keywords— *industrial wastewater from batik, boiling, biofilter, constructed wetlands.*

1. Introduction

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Nowadays, water scarcity is becoming a global issue in most countries[1][2]. There are at least 3.6 billion people (almost half the world's population) who are experiencing water scarcity. The number is predicted to increase to reach 4.8-5.7 billion in 2050[3]. Most of them live in developing countries where small industries are the backbone of the economy. Small enterprises in developing countries still have limited knowledge, capital, and technology. They are not aware that their daily activities pollute the environment[4]. It happens when they get rid of the production waste, which includes liquid waste into the environment without undergoing treatment first.

Wastewater that polluted the environment comes from all sectors, such as pharmaceuticals, paper mills, paints, and the textile industry[5]. The largest textile industry in Southeast Asia is the batik industry[6]. In Indonesia, the batik industry is developing rapidly along with the stipulation of batik as a world cultural heritage by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) in 2009[7][8]. Based on the data from the Ministry of Industry in 2015, the value of the production and export of the industry reached US $ 178 million, an increase of 25.7% from the previous year[9]. However, this industrial growth is followed by environmental consequences through its wastewater.

Batik industry liquid waste is produced from the process of soaking, boiling, and rinsing[10]. The wastewater contains toxic chemicals, such as waxes, coloring agents, reinforcing substances[8], and synthetic materials that are difficult to degrade[5][7][11]. They cause increases in pH, BOD, COD, TSS, and heavy metals[6][10]. The increase in various pollutants, along with the rise in the production capacity and the number of batik industries in Indonesia, cause aquatic environmental pollution, which results in the death of aquatic organisms and triggers waterborne disease for humans[12]. Based on the above conditions, the development of a variety of natural dyes, which are more environmentally friendly, and sustainable technology, which is economically affordable, socially acceptable, and ecologically effective [13], are necessary. We need a simple technique to support the sustainable batik industry.

The use of the macrophytes or wetland systems is known for decades due to its high capability as a pollutant removal. It does not require much energy in its operation and low maintenance costs[1][14][15]. Therefore, the constructed wetland has a high potential to be applied in developing countries. It is an engineering system or artificial system in the form of ponds or shallow channels (less than 1 meter) that utilize natural processes that occur in wetland vegetation, media (rocks, gravel, sand), and microbial assemblages to treat wastewater[16].

The constructed wetlands are capable of processing various types of waste, such as urban, agricultural, animal, industrial, mine wastewater[17][18], petroleum wastewater[19][20][21], and also municipal wastewater[18][22][23]. However, they can be combined with other technologies to treat more complex types of wastewater and to obtain higher processing efficiency[24]. The weakness of constructed wetlands is that their performance decrease at low temperatures as the activities of the plants and microorganisms is little [25]. This condition can be improved by providing a larger area and longer retention time[26] by combining it with the filtration method. Filtration is one of the most important processes in wastewater treatment to produce high-quality waste for various purposes. All types of filters with biomass attached to the filter media (gravel, sand, plastic, and activated carbon particles) can be defined as a biofilter. The basic principle of the biofilter is biodegradation of pollutants by microorganisms that are attached to the filter media through the combination of biological oxidation, absorption, and filtration processes[27].

The biofilter eliminates various organic and inorganic pollutants, even for substances that are classified as compounds that are dangerous, toxic, and hard to biodegrade. The characteristics of the media that is used in the biofilter have an essential role in achieving the desired level of effectiveness to remove pollutants. The effectiveness of filter media is influenced by the type of material, shape, size, surface area, porosity, and surface roughness[28]. Sand and gravel are potential biofilter media for water treatment due to their abundant availability. Sand and gravel grains provide a more full-contact surface for attaching biofilms so that they improve processing efficiency. Some previous studies mention the success of the combination of biofilter as the pretreatment and constructed wetland as a subsequent treatment in domestic wastewater treatment[25]. Integrated system constructed wetlands (CWs) and biofilter are relevant alternatives in treating wastewater because they are efficient in terms of installation, operational, and maintenance aspects[31]. This study aims to determine the performance of a combination of the biofilter and constructed wetland treatment systems in treating batik wastewater.

2. Methodology

2.1 The raw batik wastewater

The untreated wastewater used in this study came from a small batik industry in Jetis, Sidoarjo Regency, East Java Province, Indonesia. Raw sewage was obtained from the boiling process. The sample from this process was chosen because it had higher contaminants compared to those of the other two methods, which are soaking and rinsing[10]. Samples were taken directly after the boiling process using 1,000 ml of glass bottles, as shown in Figure 1 for further characterization.

Figure 1. Wastewater sampling in the batik industry.

2.2 Characterization of raw batik wastewater

The parameters analyzed were the chemical parameters, including Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and oils and grease. The laboratory analysis was carried out according to the standard methods of APHA [10]. The measurements for TSS parameters and oils & grease used gravimetric analysis methods, while COD parameters used reflux methods.

Measurements were taken on the influent before being treated, to determine the initial characteristics of the batik wastewater, and after the treatment. The measurement results were then compared with the quality standards set by the Republic of Indonesia's Minister of Environment Regulation No. 5/2014 regarding the wastewater quality standards. The results of the analysis can be seen in Table 1.

Table 1. Characteristics of raw batik wastewater.

Parameter	Unit	Value	Effluent standard (*)	Analytical method
TSS	mg/L	3,180	50	Gravimetri
COD	mg/L	12,000	150	Refluks
Oil & Grease	mg/L	9,740	3	Gravimetri

* Regulation of the Minister of Environment of the Republic of Indonesia No. 5/2014 on wastewater quality standards.

2.3 Pilot system

2.3.1 Biofilter

The biofilter used is made of glass with dimensions of 20 x 20 x 80 cm. The filter material is significant for the biofilter and the constructed wetlands. The suitable material can improve pollutant removal in the biofilter [32]. The filter media used are 1-2 mm of sand, and 19-25 mm of gravel. These two media were chosen because of their local availability. Gravel was placed at the bottom with a height of 100 cm and the sand with a height of 500 mm. Free space from sand to the top surface of the glass was 200 mm. Gauze cloth was placed between sand and gravel as the insulation to prevent the mixing of media. The schematic diagram of the biofilter can be seen in Figure 3.

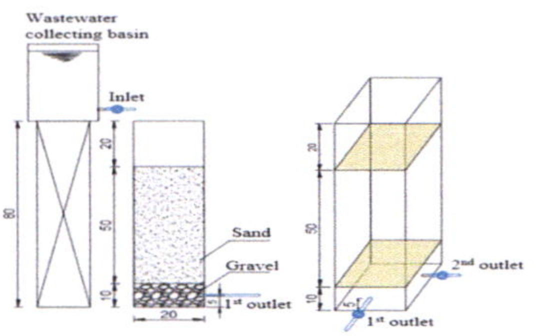

Figure 2. Schematic diagram of the biofilter.

The acclimatization process was carried out after the biofilter pilot system was completed by flowing raw batik wastewater continuously, with a sufficient rate of aeration into the biofilter for four weeks at 27-29 ° C, to grow the biofilm layer on the surface of the media. The layer serves to help reduce levels of wastewater pollutants in the biofilter[33][34][35]. The acclimation process aims to obtain a stable growth rate of microorganisms characterized by the removal efficiency of physical parameters and organic matter[33]. The biofilter system performance is shown by the efficiency of TSS, COD, and oil and grease removal. Samples are taken and tested for each hydraulic retention time and then analyzed in the laboratory using the standard procedure of APHA.

2.3.2 Constructed wetlands

The pilot system is made of glass with dimensions of 100 x 50 x 60 cm. The type of CWs used in this study is the horizontal subsurface flow (HSSF). The CW's design can be seen in Figure 3. The media used in CWs are gravel and sand. The first medium used was 150 mm of gravel with a size of 19–25 mm and a porosity of 0.6%[36]. The second layer above the first was 70 mm of coarse sand (filter media size was 1–2 mm) into which the macrophyte was planted[37]. Between the two media laid a gauze cloth that serves as a barrier so that the two media are not mixed. Here, the roots of the plant are not disturbed but still allows raw batik wastewater to pass through. Free space from sand to the top surface of the glass is 30 cm.

The macrophytes used in the HSSFCW must pay attention to several things, namely (1) have a high tolerance for high organic and nutrient loadings; (2) have many roots and rhizomes to provide substrate for attached bacteria and oxygenation (even very limited); and (3) have high aboveground biomass for winter isolation in cold climates. The plant used in this study was Hymenocallis littoralis. Hymenocallis littoralis or tiger lily is a plant species of the genus Hymenocallis, which is widely available in various tropical countries including Indonesia[17].

Hymenocallis littoralis is a plant that is used to observe the efficiency of reducing nutrients (total phosphorus: TP and total nitrogen: TN) in the surface flow constructed wetlands (SFCW)[38]. The use of Hymenocallis littoralis together with Canna siamensis and Heliconia spp are used in the constructed wetlands with seafood waste flowing and is capable of reducing BOD, SS, TN, and TP each by 91-99%; 52-90%; 72-92%; 72-77% [39]. Hymenocallis littoralis shows a high absorption rate of phosphorus (P) [38]. Data shows higher removal rates that correlate with faster growth and a greater biomass. Hymenocallis littoralis has high biomass compared to other rhizomatic root plants that make the average nutrient removal also high[32].

Plant density is needed to ensure the optimal processing performance of CWs. Plant density in general is 6 – 8 clumps/m2[40]. Based on the area of the pilot system HSSCWs of 0.5 m2 (0.5 m x 1.0 m), four plant units are used Hymenocallis littoralis. The acclimatization of the plants is carried out for 56 days until the plants grow well[41]. The plants are watered using PDAM water in the first two weeks, while the next is using raw batik wastewater with a concentration rate of 25%, 50% dan 75%.

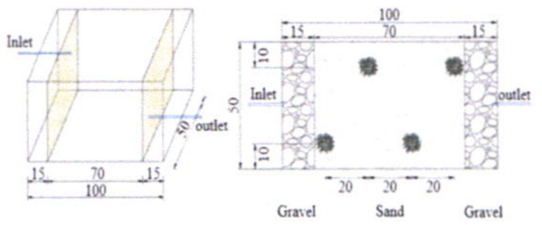

Figure 3. Schematic diagram of the HSSFCW.

2.4 Experimental setup and operations

The combination of the biofilter and HSSFCW technology is used to treat the batik industry's wastewater better. The Batik wastewater is pumped to the elevated water tank over the biofilter and then trickled down to the naturally aerated upper layer. Furthermore, the liquid waste flows towards the top layer and then entered the submerged lower layer. During the spatial alternations of aerobics and anoxic conditions in the biofilter, organics, nitrogen, and suspended solids are removed simultaneously. After biofiltration, batik wastewater was introduced into the HSSFCW to remove other residual pollutants. The schematic diagram of the combination of the two methods is shown in Figure 4.

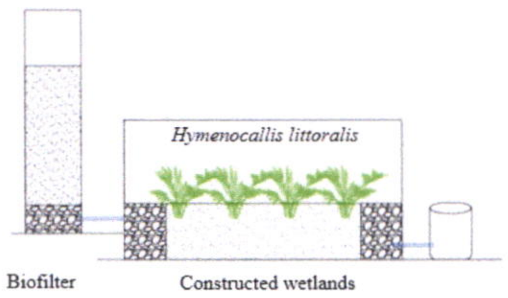

Figure 4. Schematic diagram of combined biofilter dan HSSFCW.

Both of these methods are operated in the batches, which are believed to provide better results than continuous feeding because they provide more oxygen in the processing system[42]. The opinion is also confirmed by Zhang et al. (2012), which compares the performance of subsurface flow treatment wetlands operated in the batch with that of the continuous feed. The result shows that the ammonia-nitrogen was removed with an efficiency rate of 95.2% in the batch mode system, which was significantly ($p < 0.05$) higher than the continuous mode's rate of 80.4% of the removal efficiency. In this study, the batik industry's liquid waste flowed in batches with a discharge rate of 5.2 mL/second and the hydraulic retention time of three days, five days, and seven days. The parameters observed consisted of TSS, COD, and oil &grease [43].

2.5 Data analysis

The data analysis technique used in this study is the inferential analysis. It includes the test of the research hypothesis using a test-multivariate analysis of variance (manova). Testing the hypothesis of the study by using SPSS version 22.0 for Windows. Manova test can be used in data if it meets two test prerequisites, namely normality and homogeneity. Data is considered normal and homogeneous if it has a significance value of more than 0.05. The normality test uses the Kolmogorov Smirnov one-sample test, while the homogeneity test uses the Lavene's Test.

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3. Results and Discussion

3.1 The characteristics of raw batik wastewater

The characteristics of raw wastewater, which is taken from the boiling process for later use as the influents, are all above the effluent standard, as determined by the Minister of Environment Regulation of the Republic of Indonesia No. 5/2014. The analysis results, as shown in Table 1, show the TSS value of 3.180 mg/l, COD of 12,000 mg/l, and oil and grease of 9,740 mg/l. The results are consistent with the previous research, which states that the COD of batik wastewater value shows the highest value. The value is close to the effects of previous studies, which says that the characteristics of batik wastewater after the boiling process amounted to 13.600 mg/L[10].

3.2 Removal efficiency on various parameters of batik wastewater

Parameter measurements were performed on the biofilter and the HSSFCWs with a hydraulic retention time (HRT) of three days, five days, and seven days. It aims to determine the effectiveness of each pilot system. The measurement results are in Table 2.

Table 2. Measurement results from effluent biofilter and HSSFCWs.

No.	Method	Parameter	Sample	Hydraulic retention time (days)		
				3	5	7
1	Biofilter	COD	BIO1	4,127	2,770	5,030
			BIO2	4,144	2,806	5,035
			BIO3	4,149	2,824	5,055
		TSS	BIO1	241	183	270
			BIO2	.253	199	278
			BIO3	262	206	298
		FO	BIO1	2,509	1,697	3,061
			BIO2	2,516	1,709	3,072
			BIO3	2,535	1,718	3,077
2	Biofilter-HSSFCWs	COD	HSSF1	1,583	2,547	3,261
			HSSF2	1,605	2,564	3,276
			HSSF3	1,612	2,569	3,303
		TSS	HSSF1	82	123	49
			HSSF2	91	133	60
			HSSF3	102	140	65
		FO	HSSF1	959	1551	1990
			HSSF2	966	1558	1998
			HSSF3	985	1571	2012

Manova test was conducted to determine the differences in the performance of the single methods and the combination methods. Based on Table 3 on the value of Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root, it shows a significance value <0.05. It means that there is a significant difference between the performance of the biofilter and the biofilter-HSSFCWs combination in the HRTs of three days, five days, and seven days. It proves that the two methods have different capabilities in processing COD, TSS, and oil &grease.

Table 3. Manovatest results

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	1.000	1231599.20[b]	3.000	10.000	.000
	Wilks' Lambda	.000	1231599.20[b]	3.000	10.000	.000

Effect		Value	F	Hypothesis df	Error df	Sig.
	Hotelling's Trace	369479.760	1231599.20^{b}	3.000	10.000	.000
	Roy's Largest Root	369479.760	1231599.20^{b}	3.000	10.000	.000
Technology	Pillai's Trace	1.000	57606.711^{b}	3.000	10.000	.000
	Wilks' Lambda	.000	57606.711^{b}	3.000	10.000	.000
	Hotelling's Trace	17282.013	57606.711^{b}	3.000	10.000	.000
	Roy's Largest Root	17282.013	57606.711^{b}	3.000	10.000	.000
HRT	Pillai's Trace	1.242	6.011	6.000	22.000	.001
	Wilks' Lambda	.000	508.711^{b}	6.000	20.000	.000
	Hotelling's Trace	17878.596	26817.895	6.000	18.000	.000
	Roy's Largest Root	17878.277	65553.681^{c}	3.000	11.000	.000
	Pillai's Trace	1.885	60.190	6.000	22.000	.000
Technology* HRT	Wilks' Lambda	.000	884.232^{b}	6.000	20.000	.000
	Hotelling's Trace	8140.110	12210.164	6.000	18.000	.000
	Roy's Largest Root	8132.393	29818.773^{c}	3.000	11.000	.000

a. Design: Intercept + Technology + HRT+ Technology * HRT

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha= .05

3.2.1 *Efficiency removal of COD*

The combination of the biofilter and the HSSFCW processing methods shows a decrease in the COD value of the HRTs of three days, five days, and seven days, as shown in Figure 5. The results of the combination of the processing methods show an efficiency rate of 86.67% in an HRT of three days, then decrease to 78.67% in an HRT of five days, and again decrease in an HRT of seven days to 72.67%. The results are different from the previous studies, which state that the processing of polluted river water using the biofilter is 30% in an HRT of three days. After seven days, the removal efficiency of organic matters increases to 80-90%. After 18 days of operation, organic removal efficiency is relatively stable at around 90%. At this point, the steady-state condition is reached that is characterized by the formation and the development of the biofilms by bacterial layers, which can be observed visually. Longer HRT allows raw water to have long contact time with the media and adequate oxygen supply, and thus accelerates the formation of the biofilms in the media[33].

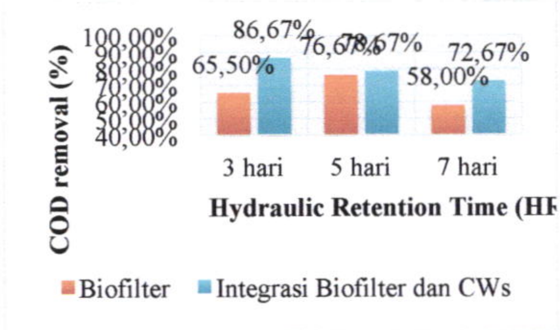

Figure 5. The efficiency of COD removal.

The differences in the results are due to the type of raw water treated and the media used. In this study, the efficiency of COD reduction by the biofilter and the HSSFCW combination is obtained from an HRT of three days. It means that the steady-state biofilter conditions are obtained from an HRT before three days and the same for the HSSFCW. Hymenocallis littoralis experiences saturation in deciphering various types of toxic pollutants in the liquid waste. Here, the most optimum HRT in treating batik wastewater is three days with a COD reduction efficiency value of 86.67%.

Other studies suggest that a combination of the biofilter and the HSSFCWs systems can eliminate the COD contaminants with an efficiency rate of 95%[25][44]. The higher performance was obtained by using a combination of two types of plants, namely Syzygium campanulatum and Ficus microcarpa, and pretreatment before the combination of the biofilter-HSSFCW method. Pretreatment is done to separate oil and grease[44]. Other studies suggest that COD reduction efficiency from 82.4 to 91.4% in the summer. The study used a double-layer biofilter with a combination of plants in CWs, namely C. alternifolius and Canna. CWs that use several types of plants will be more effective in reducing the cc-organic compounds, compared to the use of one type of plant[25].

In the biofilter, the decrease in COD occurs physically through the process of absorption. The absorption process is the concentration of pollutants on the surface of the filter media caused by the attraction between the filter media and pollutants. The filter media, such as gravel, can also help reduce COD by precipitating particulate material[39]. Organic contaminants absorbed by the filter media will be broken down by microorganisms[27][35][44]. The molecular breakdown is carried out through the process of fermentation, aerobic, and anaerobic respiration to use energy and carbon sources in supporting the growth of microorganisms. COD in the HSSFCW removal process occurs through the process of suspended solids filtration or sedimentation and the activity of microorganisms from aerobic and anaerobic bacteria. The macrophyte, Hymenocallis littoralis, provides aerobic conditions in the root zones of planted cells so that microorganisms can carry out microbiological degradation[45]. The aerobic condition occurs because the oxygen produced from the photosynthesis process in the leaves is transferred to the roots to support the growth of microbial degrading organic matters[46].

3.2.2 Efficiency removal of TSS

The combination of the biofilter-HSSFCW method in reducing TSS is very effective. It is evident from the result of a decrease in TSS that reaches above 90%, in which an HRT of three days is 97.12%, an HRT of five days is 95.85%, and in an HRT of seven days is 98.18%, as shown in Figure 6. The results are in line with the previous studies, but there are slight differences. The previous research has suggested that the combination of the biofilter and the HSSFCWs systems can eliminate TSS contaminants by 84.38%[44]. The difference lies in the use of the filter media, which uses sand and limestone. This study uses sand and gravel as filter media.

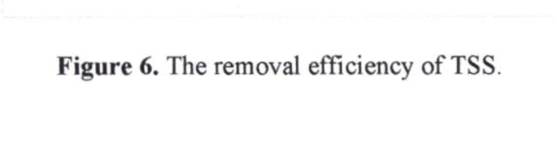

Figure 6. The removal efficiency of TSS.

The TSS pollutant removal process is caused by the physical filtration effect of sand and gravel. However, it is also possible for organic particles to be captured by gravel and sand as media, and degraded by microbes contained in the biofilm layer [33]. In the combination of these two methods, the HSSFCW has a more important role in the TSS elimination. In a previous study, it is mentioned that HSSFCWs is able to increase TSS removal to 43% when combined with the biofilter, which reduces TSS by 39%[44]. When batik wastewater was flown to HSSFCW, further entrapment and sedimentation of the solids, due to media that reduces the hydraulic surface loading rates, happen[47].

In the process, the media plays the most important role because it acts as a filtering media for contaminants in batik wastewater[48]. The sedimentation process causes wastewater to retain in the pores of the substrate due to the low water velocity and retention time. Wastewater replaces the air cavities contained in the substrate. The presence of plants in the HSSFCWs increases sedimentation by slowing down the water velocity, thereby allowing suspended material to settle[31].

3.2.3 Efficiency removal of oil and grease

The presence of oils and fats in water bodies causes the formation of oil layers which triggers various impacts that include the following: 1) decreased light penetration which can cause disruption of photosynthesis of aquatic plants and other organism activities; 2) cause blockages in various pipelines and pumps thereby increasing maintenance costs; 3) excess oil and grease content in wastewater causes difficulty in sludge generated from the treatment plant unit will be challenging to compact; 4) disrupt the biological aerobic wastewater treatment process by reducing the rate of oxygen transfer; 5) causes underarm optimization in the anaerobic treatment process by reducing the transport of soluble substrate to bacterial biomass; and 6) cause turbidity, aesthetic disorders and unpleasant odors[49]. Therefore, oil and grease must be treated so that it does not cause water pollution.

In the process of decreasing oil and grease content that uses the biofilter and the HSSFCW combination method with various HRT, the results are 90.04% in an HRT of three days, then in an HRT of five days efficiency decreased to 83.98%, and in an HRT of seven days efficiency is 79.47%, as shown in Figure 7. It shows that for the decrease in oil and grease parameters, an optimal HRT is three days. The decrease is due to the character of oil and grease as a hydrocarbon compound, which is an organic material with long and complex carbon chains[50][51]. The complex and long carbon chains in oil and grease cause the slow degradation of microorganisms. Lack of penetration of sunlight and dissolved oxygen that occurs due to the presence of oils & fats also affects the slow performance of organisms. The slower performance of microorganisms causes a decrease in the removal efficiency of oil and grease from an HRT of three days to seven days.

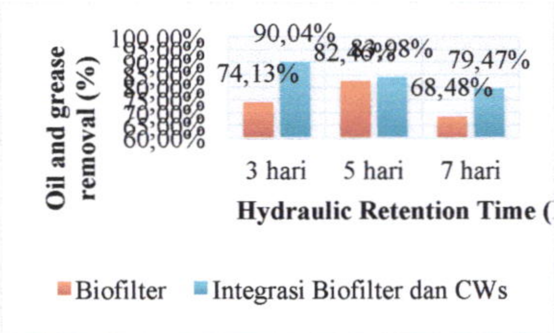

Figure 7. Efficiency removal of oil and grease.

The high oil and grease removal efficiency that is up to 90% is due to the main role of the biofilter. The efficiency depends on the contact time (HRT), column length, and the thickness of the media. Previous research shows the efficiency of the industrial waste treatment that uses absorption is 67% at slow flow rates. The maximum efficiency can reach 80% at higher flow rates of 200 cm of column length. The length of this column is very influential in decreasing oil and grease. It will increase the efficiency of oil transfer and the concentration of oil and grease, due to longer contact between wastewater and the filter media[52].

3.3 Effluents from combinations biofilter-*HSSFCWs*

The results of the batik wastewater treatment using the integration of the biofilter and the HSSFCWs cannot reduce batik liquid waste pollutants to meet effluent standards stipulated in the Regulation of the Minister of Environment of the Republic of Indonesia No. 5/2014. It means that effluents generated through a combination of the HSSFCWs biofilter treatment methods cannot be discharged directly into water bodies. The effluent also does not meet the standards for various designations referring to Government Regulation No. 82/2001regarding the management of water quality and water pollution, which can be seen in Table 4.

Table 4. Comparison of the biofilter-HSSFCW processing results.

Parameter	Combined biofilter-HSSFCW HRT (days)			Class*			
	3	5	7	I	II	III	IV
TSS (mg/L)	64	132	58	50	50	400	400
COD (mg/L)	1.600	2.560	3.280	10	25	50	100
Oil and grease (mg/L)	970	1.560	2.000	1.000	1.000	1.000	(-)

* Government Regulation (PP) No. 82 of 2001 (Government Regulation Number 82 of 2001 concerning Management of Water Quality and Water Pollution Control)

Table 4 shows that treated water still exceeds the predetermined class limits, which are class I, class II, class III, and class IV. The three parameters, namely TSS, COD, and oil & fat, exceed all class limits, except for the oil & fat parameter in an HRT of three days. The oil & fat parameter in an HRT of three days is at 970 mg/l that is below the specified class limit of 1,000 mg/l. However, other parameters indicate values that exceed the water class limit. It can be concluded that treated water should not be intended for the community, whether class I, class II, class III, or class IV.

The results showed that the treated water still exceeds the specified quality standards, especially for the COD parameters and oil & fat. It causes the need for pretreatment before it flows into the integration of the biofilter and CWs. Some studies also use pretreatment to help reduce levels of pollutants. The pretreatment includes the use of oil & grease separator[44], membrane filtration[53] or flotation[54]. Dissolved Air Flotation (DAF) is the most widely used floatation type because of its flexibility to reduce oil and grease significantly[55].

4 Conclussions

Batik wastewater generated from the boiling process has COD, TSS, and oil and grease values of 12,000 mg/l, 3,180 mg/l, and 9,740 mg/l, respectively. They exceed the quality standards set by the Regulation of the Minister of Environment of the Republic of Indonesia No. 5/2014 on the wastewater quality standards. Wastewater is not allowed to be discharged into water bodies because of the potential to cause environmental pollution. The combination of the biofilter and the HSSFCWs method shows a COD reduction efficiency of 72.67-86.67%, TSS of 95.85-98.18%, and oils & grease of 79.47-90.04%. There was a significant difference in $p < 0.05$ between the biofilter method and the combination of the biofilter and the

HSCCFCWs method. The highest reduction efficiency was obtained in the removal of TSS, while the optimum HRT value is three days for all observation parameters. However, although the performance of the biofilter-HSSFCWs combination method is quite high in reducing various parameters in wastewater, it still does not meet the effluent standards set by the government for various purposes. Therefore, pretreatment is needed in advance to reduce COD pollutants and oil and grease before the batik industry wastewater enters the biofilter and the HSSFCWs unit combination.

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