



Phytoremediation of Batik Industry Effluents using Aquatic Plants (*Equisetum hyemale* and *Echinodorus palaefolius*)

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Abstract

Batik industries generate effluents with high COD and BOD concentration. The conventional wastewater treatment plants which are commonly used to treat the effluents still have some shortages. Those plants do not generally degrade the pollutants and cause sludge accumulation thus creating disposal problems. In addition, these methods are relatively expensive and unaffordable by batik small and medium enterprises. In this study a laboratory experiment was conducted to investigate the capabilities of some aquatic plants to remove different pollutants in wastewater. The objectives of this study were to evaluate the feasibility of phytoremediation using some aquatic plants to treat batik industry effluents as a cheaper and simpler alternative to treat batik industry effluents. This research compared *Equisetum hyemale* and *Echinodorus palaefolius* in two different reactors to treat several kinds of batik effluents which have been pre-treated in a wastewater treatment plant. The plants were planted on sand, gravel and activated carbon media for 15 days to get acclimated. The batik effluents were contacted in batch system. The *Equisetum hyemale* removed COD and BOD until 86.96% and 88.53% in variation of effluents concentration after 14 days of contact, while *Echinodorus palaefolius* COD and BOD removal efficiencies are 88.22% and 90.22%. *Equisetum hyemale* showed the best performance in effluents from wax removal tank and *Echinodorus palaefolius* were best in removing COD and BOD from effluents of sedimentation tank. It was observed that 7 days of contact time were optimal for removing pollutants in batik effluents.

Keywords: phytoremediation, batik, wastewater, BOD, COD, *Equisetum hyemale*, *Echinodorus palaefolius*

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1. Introduction

Textile industry such as batik industry consumes large amounts of discharged effluents during dyeing and finishing operations [1]. Since UNESCO recognition of batik as Intangible Cultural Heritage of Humanity in 2009, Indonesia's batik industries has rapidly grown, contributing significantly to Indonesia's economic growth. The increase of batik demands has caused batik

manufacturers to increase their production capacity which in turn also caused greater effects to the environment.

As a part of textile industry, batik is also processed using large amount of water and variety of chemicals [2]. The chemicals reagent used in batik manufactures are diverse in chemicals composition ranging from inorganic to organic [3]. Around 80% of water used in the production is discharged as effluent [4]. In Indonesia, batik is mostly produced by Small and Medium Enterprises (SMEs). They usually build their processing units in alongside the river, in residence areas or other places not designed as industrial areas. Therefore the facilities to treat their industrial effluents are not available. The SMEs usually discharge the effluents into a special vessel or directly into a river or drainage system after minimal or no treatment [3, 5]. The locals used traditional methods for producing batik thus the untreated effluents contain dyes, waxes, heavy metals [6] with high total dissolved solids (TDS), total suspended solid (TSS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) contents [7]. The effluents are known to be one of the most difficult to treat due to the recalcitrant nature of dyes [6].

Batik effluent is conventionally treated using a series of treatment with physical, chemical and biological methods [7]. However those methods do not generally degrade the pollutants and cause sludge accumulation thus creating disposal problems [2]. In addition these methods are relatively costly and unaffordable by SMEs. This financial burden might be the key reason which slow down efforts to control pollution predominantly in underdeveloped and developing countries including Indonesia [8].

In recent years, some researches have been focused on phytoremediation for wastewater treatment. Phytoremediation is a method to remove pollutants from the environment, heavy metals from soil, wastewater and sludge by using plants [9]. It has more advantages over conventional treatment methods including: low cost; high efficiency; minimization of chemical and biological sludge [10]. Studies have been done to investigate the capabilities of some aquatic plants to remove different pollutants in wastewater.

Equisetum hyemale and *Echinodorus palaefolius* (Figure 1a and 1b) are aquatic plants often used to treat domestic and industrial wastewater. *Equisetum hyemale*, also commonly known as scouring rush or horsetail, is considered effective as phytoremediation agent because it can survive in extreme to moderate conditions, can be found almost any time of the year and has a deep root system [11]. It has shown good performance in removing heavy metals such as lead and chromium from leachate [11] and TSS, COD, phosphate and LAS from laundry wastewater [12]. *Echinodorus palaefolius* or Mexican sword plant is easily found in tropical area like Indonesia, can grow in any part of a garden and regenerates quickly [13]. Some studies has demonstrated its ability to reduce COD and BOD such as in leather tanning [14] and medical [15] wastewater.

The objectives of this study are to evaluate the feasibility of phytoremediation using *Equisetum hyemale* and *Echinodorus palaefolius* to reduce COD and BOD in batik industry effluents.



Figure 1. a) *Equisetum hyemale*; b) *Echinodorus palaefolius*

2. Experimental

2.1. Materials

The aquatic plants used in this study are *Equisetum hyemale* and *Echinodorus palaefolius*. The plants were collected from local fresh water. Each plant was around 5 months of age at the beginning of the experiment and consisted of 10 to 15 stems. The collected plants were washed and initially acclimatized by placing them in a small plastic box filled with normal tap water for 15 days to achieve vigorous and dense root system to be used further in the experiments. In addition, the boxes were also filled with sand, gravel and activated carbon with 10 cm in height for each layer as illustrated in Figure 2. The water was maintained at room temperature.

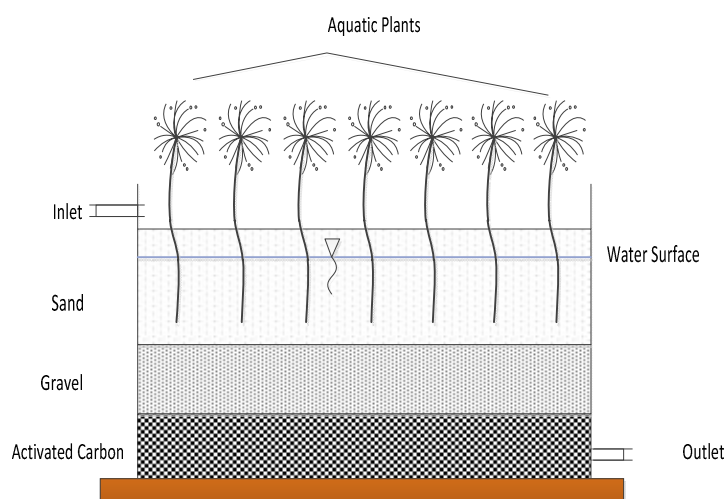


Figure 2. Phytoremediation Reactor

The batik industry effluent samples were collected from the wastewater treatment plant of Center for Handicraft and Batik in Yogyakarta, Indonesia. The WWTP consists of several units: wax removal, sedimentation, coagulation-flocculation, anaerobic filter, and adsorption. The samples used in this study were taken from four sampling points: the outlet of wax removal tank (P1), outlet of

sedimentation tank (P2), outlet of coagulation-flocculation tank (P3) and outlet of the WWTP (P4). The sampling points are illustrated in Figure 3.

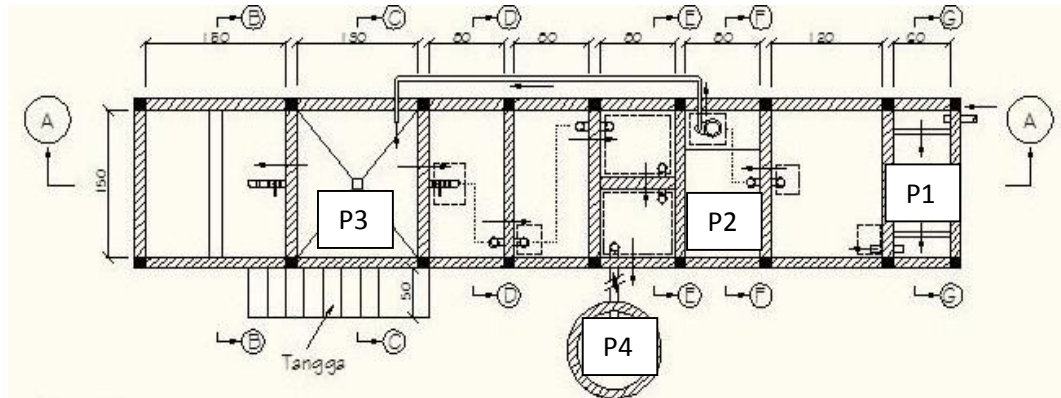


Figure 3. Layout of WWTP and the sampling points

The samples were taken using clean sealed bottles and then transported to Environmental Laboratory for analysis of initial COD and BOD.

2.2. Phytoremediation Experiments

For the experiments, the aquatic plants were introduced after acclimatization into the four types of effluents in the experimental tanks and examined for 14 days of period. The samples from each tank were taken and analyzed every 7 days.

The concentrations of COD and BOD in the batik effluents before and after phytoremediation were determined as per the standard procedure stipulated by Indonesian National Standards. Closed reflux system was used to determine COD, and Wrinkler method was employed to examine BOD.

The percent removals of those parameters by aquatic plants were calculated by using the following formula:

$$\%Removal = \frac{C_1 - C_2}{C_1} \cdot 100\%$$

In which C_1 is the concentration of the parameter before treatment and C_2 is the concentration of the parameter after treatment.

3. Results

3.1. Effluents Characteristics

The effluent from batik industry was collected and analyzed for BOD and COD parameters. Results are shown in Table 1. Based on the analysis, the BOD (285 mg/L) and COD (704.4 mg/L) values at the outlet of wax removal tank (P1) exceed the permissible limit based on Local Regulation No. 7 of 2016, namely 50 mg/L for BOD and 100 mg/L for COD. After being treated in sedimentation tank (P2), BOD and COD decreased significantly, reaching below the standards.

However in the outlet of coagulation-flocculation tank (P3) the two parameters increased sharply into 180 mg/L for BOD and 404 mg/L for COD. The anaerobic filter and activated carbon adsorption reduced the BOD reaching 26 mg/L and COD 66.2 mg/L.

Table 1. Initial concentration of batik effluents

Effluents	BOD (mg/l)	COD (mg/l)
P1	285	704.4
P2	180	404
P3	29.2	83.9
P4	26	66.2

Dyeing and printing processes produce effluent containing toxic organic compounds such as phenols, heavy metals like copper, chromium and also impart highly concentrated color.

Batik effluents containing mixture of dyes generally have high BOD [16]. High concentration BOD could be explained by the fact that desiring step in textile process contributes 50 % increase of BOD load. Biodegradable organic compounds like synthetic and natural polymers in water bodies cause deficiency of dissolved oxygen and found to have a significant impact on aquatic life [16].

3.2. COD Removal Efficiency

Chemical oxygen demand (COD) is the overall oxygen concentration utilized to chemically oxidize all of the organic compounds in an effluent sample [17]. The samples were taken on the seventh and fourteenth day. The results of the COD analysis for each reactor are shown in Figure 4 and Figure 5.

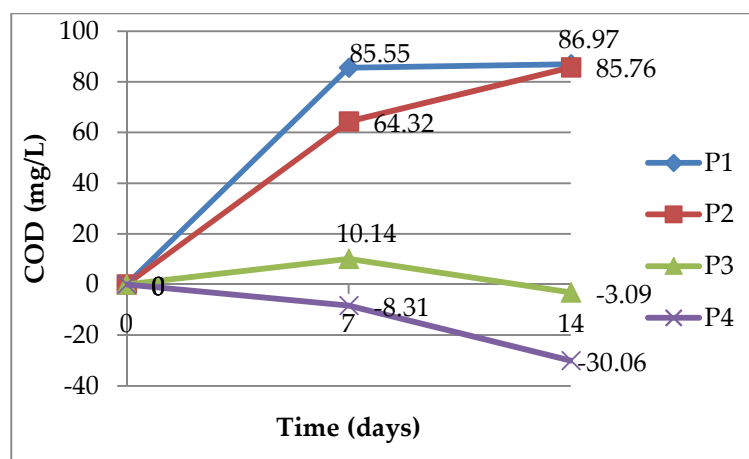


Figure 4. COD Removal Efficiency by a) *Equisetum hyemale*

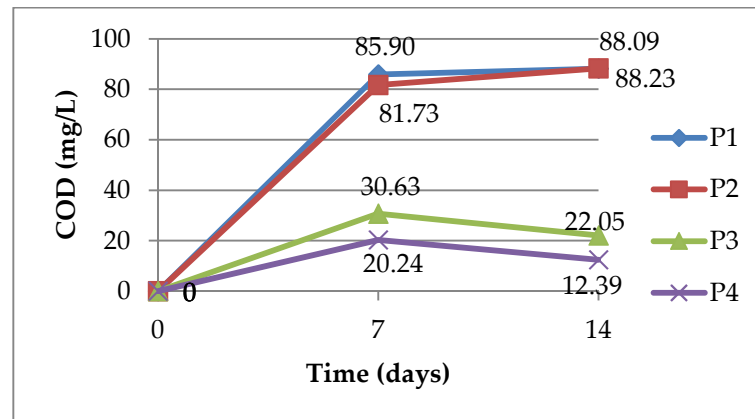


Figure 4. COD Removal Efficiency by *Echinodorus palaeifolius*

3.3. BOD Removal Efficiency

BOD (Biological Oxygen Demand) is the concentration of oxygen consumed during the biodegradation of organic compounds in the wastewater [17]. BOD analysis is usually conducted to determine the severity of pollution from domestic and industrial effluents into water bodies [18]. The samples were taken from the reactors on the seventh and fourteenth day of the experiments. The results were illustrated in Figure 5 and Figure 6.

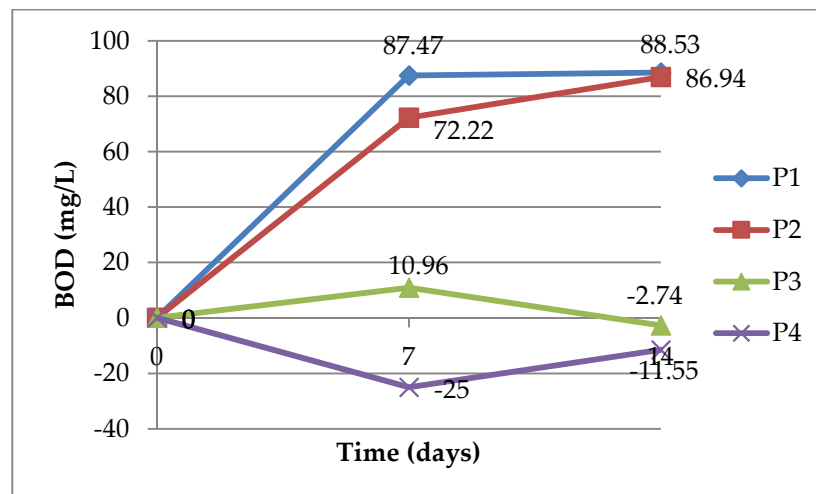


Figure 5. BOD Removal Efficiency by *Equisetum hyemale*

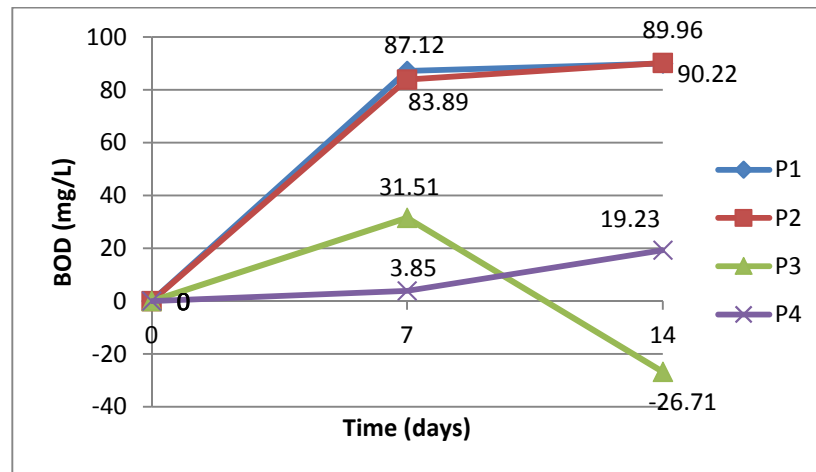


Figure 6. BOD Removal Efficiency by *Echinodorus palaeifolius*

4. Conclusion

The phytoremediation experiments were conducted in batch system. The aquatic plants were acclimated before being used in the experiments to help them adapt to the effluents condition.

4.1. COD Analysis

During the first seven days, in the reactors employing *E. hyemale* as phytoremediation agent, the removal efficiencies increased for samples from P1 (85.55%), P2 (64.32%), P3 (10.13%), and decreased for sample from P4 (-8.3%). On the fourteenth day the efficiencies slightly increased for P1 (86.96%) and P2 (85.75%), and decreased for P3 (-3%) and P4 (-30%). Our results for P1 are in agreement with a study of COD removal from laundry effluents using *Equisetum hyemale* where the efficiency ranged between 74–95% for 876.92 mg/l of initial COD value [12].

For the reactors using *Echinodorus palaeifolius*, similar trend was observed. The highest efficiency was obtained in samples from P1, followed by P2, P3 and P4 respectively. On day seven the removal efficiencies increased for all samples, namely: P1 (85.90%), P2 (81.72%), P3 (30.63%), and P4 (20.24%). On day fourteen the COD removal efficiencies slightly increased for P1 (88.09%) and P2 (88.23%), and decreased for P3 (22.05%) and P4 (12.39%).

The most probable COD removal mechanism was by uptaking the organic matters into the roots [18]. Apart from that, the media could produce a bio-film which could increase the removal of organic matters [12]. The degradation by microbial processes also occurred in the roots and rhizomes [19]. The COD removal was also attributed to the filtration by the sand, gravel and activated carbon media [12]. The results show that for P1, P2 and P3 in *Equisetum hyemale* reactor and all *Echinodorus palaeifolius* reactors the optimal process occurred during the first period. It indicates that the microbes on the roots zone have grown during the acclimatization period; therefore they were already reached the optimal numbers and growth when being introduced to the effluents.

During the next seven days, microbial growth has slowed down thus the total removal efficiency either slightly increased or decreased. For P3 in *Equisetum hyemale* reactor the removal efficiency was negative which means the COD concentration has increased from the initial condition. Samples from P3 have been treated in sedimentation and coagulation-floculation tank, therefore the COD loading (83.9 mg/L) was relatively low. After seven days, the nutrients from organic matters have decreased further and the microbes has reached stationary phase where the cell growth rate balanced the death rates and the bio catalytic activities gradually decreased [20]. Those dead cells contributed to the increase of the COD. The decrease of efficiency after 14 days might be also due to the clogging of the media which inhibited the filtration processes.

The COD concentration in the effluent from P4 has increased on the seventh day and increased further on the fourteenth day. The COD concentration has been very low since the beginning of the process. This lack of nutrients could not support the microbial growth so it entered the stationary phase and eventually the death phase where the dead cells might create toxicity and deactivate remaining cells [20].

The highest efficiency of *Equisetum hyemale* was achieved in the COD removal process of samples from the outlet of wax removal tank (P1) after 14 days which reached 86.96 %, while the removal efficiency of *Echinodorus palaefolius* was achieved in COD removal from effluent of outlet of sedimentation tank (P2) after 14 days which was 88.23%.

4.2. BOD Analysis

During the first seven days, in the reactors employing *Equisetum hyemale* as phytoremediation agent, the removal efficiencies increased for samples from P1 (87.47%), P2 (72.22%), P3 (10.96%), and decreased for sample from P4 (-25%). On the fourteenth day the efficiencies slightly increased for P1 (88.53%) and P2 (86.94%), and decreased for P3 (-2.74%) and P4 (-11.54%).

On the seventh day the BOD removal efficiency in *Echinodorus palaefolius* reactors significantly increased for P1 (87.47%) and P2 (72.22%), slightly increased for P3 (10.95%) and decreased for P4 (-25%). On day fourteen the COD removal efficiencies slightly increased for P1 (89.96%), P2 (90.22%) and P4 (19.23%), and decreased for P3 (-26.71%) This trend was similar to that of COD in the same reactor.

BOD removal occurred due to the microbial activities to break down biodegradable organics in the effluents, resulting in the lower BOD concentration. Organics were also removed by physical settling, and most of the organic matter was enmeshed within the sludge and settled within the media zone [21]. In phytoremediation the degradation of pollutants is the results of synergy between microbes and the plants in utilizing the organics in the effluents [22].

Almost similar to observed results for the COD removal, for effluents with lower organics loads the removal efficiencies were lower. The lack of nutrients provided by the effluents caused the slow growth rate of microbes attached on the roots of the plants. The highest efficiency of *Equisetum hyemale* was achieved in the BOD removal process of samples from the outlet of wax removal tank (P1) after 14 days which reached 88.53%, while the removal efficiency of *Echinodorus palaefolius* was

achieved in COD removal from effluent of outlet of sedimentation tank (P2) after 14 days which was 90.22%.

Generally, the removal efficiencies of *Echinodorus palaefolius* are higher than *Equisetum hyemale* for all effluents. BOD and COD removal mechanisms are also affected by plants activities. *Echinodorus palaefolius* have wide leaves, thus the photosynthesis rates are faster than *Equisetum hyemale* where the photosynthesis occurred in the stems. The organics degradation products by the microbes are utilized by the plants for photosynthesis processes. Therefore, the faster photosynthesis rate, the faster organics intake rates by the microbes [18].

5. Conclusions

The *Equisetum hyemale* removed COD and BOD until 86.96% and 88.53% in variation of effluents concentration after 14 days of contact, while *Echinodorus palaefolius* COD and BOD removal efficiencies are 88.22% and 90.22%. *Equisetum hyemale* showed the best performance in effluents from wax removal tank and *Echinodorus palaefolius* were best in removing COD and BOD from effluents of sedimentation tank. The optimal contact time for removal of pollutants in batik was 7 days.

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