PHYTOREMEDIATION POTENTIAL OF *Cyperus alternifolius* IN DIFFERENT SOURCES OF PALM OIL MILL EFFLUENT

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ABSTRACT

Phytoremediation was emerging technology recently due to the potential of various aquatics plant in, domestics and industrial effluent treatment. In order to enhance the water quality of the POME pond, the phytoremediation potential of Cyperus alternifolius (C. alternifolius) or also known as umbrella sedge was studied using different sources and concentration of POME. The plant was selected due to their tolerance in the high concentration of pollutant, extensive root systems and their aesthetic appearance as an ornamental plant. The C. alternifolius growth was tested in a 6L bucket with aerobic pond, facultative pond and polishing pond POME for 4 weeks of batch treatment. For aerobic pond POME, the removal can achieve 94.7% of TSS, 95.5% of COD, 92.7% of ammonia, and 99.3% of total phosphorus. While for facultative pond POME, the removal of TSS, COD, ammonia and total phosphorus was 86.5%, 85.6%, 90.7% and 99.5%, respectively. The removal for polishing pond POME was slightly lower than aerobic and facultative removal except for phosphorus which polishing pond shows the great removal of phosphorus with 99.8%. The study suggested Cyperus alternifolius plant as vegetation in the phytoremediation treatment of POME with promising potential.

Keywords: Aquatic plant; *Cyperus alternifolius*; palm oil mill effluent; phytoremediation; water quality.

INTRODUCTION

Indonesia and Malaysia were the largest producers of crude palm oil. The extraction process produces solids and liquid waste called palm oil mill effluent (POME). With impressive production of crude palm oil, the effluent becomes the main sources of water pollution with estimation about 60 million tons of POME generated in 2009 [1]. In Malaysia, the national production rate of POME is 0.67 cubic meters per ton of fresh fruit bunch processed [2]. POME produces from three sources which are from sterilizer condensation, hydro cyclone separation, and sludge separation process [3] in 9:15:1 ratio [4].

The ponding treatment systems are the most popular method for POME treatment where a series of ponds were utilized includes acidification pond, cooling pond, anaerobic pond, aerobic pond, facultative pond and polishing pond [1]. About 85% of palm oil mill in Malaysia utilize the ponding treatment systems. However, these methods operated in long hydraulic retention time (HRT 40-200 days), required large land areas, create a foul smell and emitted greenhouse gases [5]. The systems also inconsistently to meet the discharge standard regulated by Department of Environment Malaysia since the stringent limit [6]. Therefore, the palm oil industries player faces huge challenges to achieve the stringent discharge limit.

The phytoremediation research to treat POME had been done by several researchers using various species of plant. Hadiyanto *et al.*, (2013) studied the potential of *Eichhornia crassipes* (water hyacinth) and *Nymphaea spp.* (water lily) in anaerobic pond POME with a combination of algae phytoremediation. Water hyacinth able to reduce 50% COD, 88% total nitrogen, and 64% total phosphorus while water lily shows less effective with 44.5% COD, 83.5% total nitrogen and 58% of total phosphorus. Hadiyanto *et al.*, (2014) reported the phytoremediation potential of *Pistia stratiotes* (water lettuce) in the POME treatment. The study found that the COD could reduce to 59.66% and total nitrogen and total phosphorus 30.78 and 18.46%, respectively. Research by Ng & Chan, (2016) using *Salvinia molesta* in the pre-treated POME from sequencing batch reactor (SBR) is able to reduce 39% of COD and 95% phosphate. Only Darajeh *et al.*, (2014) used emergent type plant which is vetiver grass in the diluted and undiluted POME. The results show the vetiver grass was able to reduce BOD up to 90% and COD 94% in diluted POME while 60% BOD and 39% in undiluted POME.

Therefore, the potential of another emergent plant will be studied which known as *Cyperus alternifolius* or umbrella sedge. The plant species shows a great potential in effluent treatment such as landfill leachate, municipal and industrial wastewater [11]. *Cyperus alternifolius* also tolerance in hypereutrophic and saline condition [12-13]. The plant has the fast growth rate with the strong and complex root systems. It is easily propagated using cutting techniques [14]. It is a perennial herb which grows in humid and tropical areas. In addition, the plant also functions as an ornamental plant in the landscaped pond or water garden [15]. However, there is no reported research using Cyperus alternifolius in the palm oil mill effluent. Hence, the study aims to determine the potential of *Cyperus alternifolius* in the treatment of palm oil mill effluent. The different sources of pond effluent will be tested in order to choose the suitable pond effluent for the plant phytoremediation.

METHODOLOGY

Experimental plant and setup

The *C.alternifolius* plants used in this study were bought from a local nursery and propagated for the growth of new plant using the cutting technique in the 3 L plastic pots using tap water for 4 weeks to get the young plant for the experiment. Palm oil mill effluent samples were collected from the aerobic pond, facultative pond and polishing pond from United Oil Palm

Industries, Nibong Tebal, Pulau Pinang, Malaysia. For each effluent type, two sets of the bucket were used as replicate and the study was carried out for 25 days of batch treatment. Three rooted plants of *C. alternifolius* were transferred in the bucket and filled with 3 L of the POME samples. The experiment was conducted in the controlled environment at School of Civil Engineering, Universiti Sains Malaysia, Nibong Tebal, Pulau Pinang, Malaysia.

Plant Growth and Analysis

Plant growth analysis was carried out through observation of the plant and determining the plant height and the number of plants. The plant height was determined every five days by measuring the average height of the plants from the surface of the water to the top leaf and only with good plant condition. The number of plant growth counted at only at the plant without showing chroloris condition.

Pollutant Removal Analysis

The pollutant removal efficiency was evaluated by measuring organics, nutrients and suspended solid. The samples were collected and analyzed in two-day interval until the end of the experiment. The influent and effluent of each POME pond samples were analyzed for COD, TSS, TP, and NH_3-N according to standard method examination of water and wastewater [16]. The effluent samples were collected in two days internal and analyzed immediately after samples collection. The removal efficiency of the pollutant was used the following equation:

$$R\ (\%) = \frac{C_t - C_0}{C_0} \times 100 \tag{1}$$

where R (%) is the removal efficiency in percentage (%), C_t is the concentration of the effluent in t, time, C_0 is the concentration of the influent.

RESULTS AND DISCUSSION

Plant Growth Analysis

C. alternifolius were chosen as experiment plant in this experiment due to their characteristics that high tolerance and resistance in high pollutant load. In addition, the plant shows complex root zone and aesthetic appearance as a landscape plant. In this experiment, the growth of plants was observed every five days to measure the increment of plant height and number of a healthy plant. The plant height shows a static height in aerobic pond POME and a slower increase of the plant height in facultative and polishing POME. The number of the plant in the aerobic and facultative POME showing reduced number until the end of the experiment. Only in polishing POME, *C. alternifolius* was able to survive without showing the chlorosis altering.

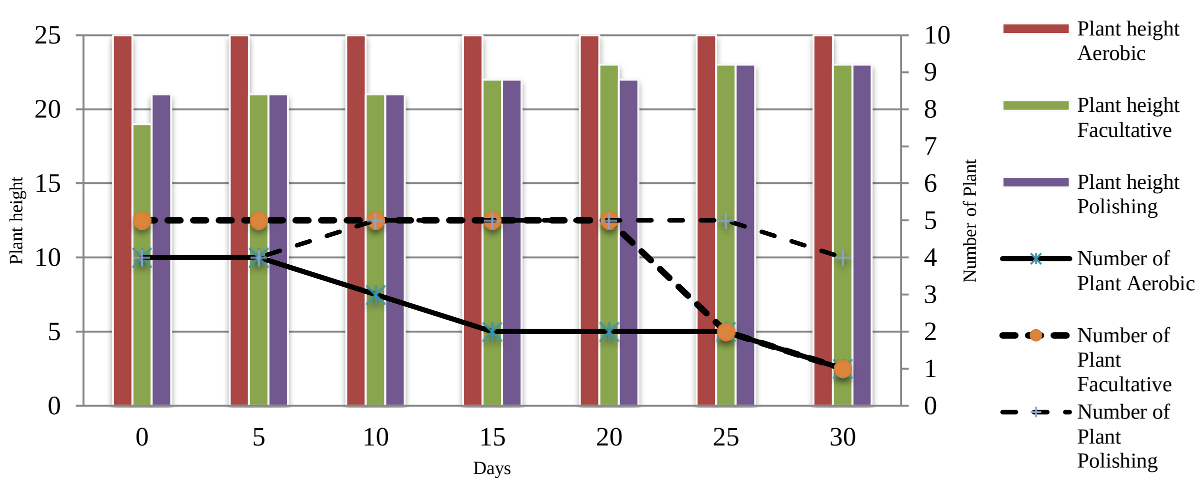

Figure 1. Plant growth and number of plants

Removal Efficiency of Pollutant

The removal efficiencies of different POME samples illustrated in Figure 2 for TSS, COD, ammonia (NH_3-N) and total phosphorus (TP) removal efficiency (%). The replicate batch experiment was run along the experiment to get the average result throughout 25 days of experiment duration. The effluent pollutant concentration should follow the Environmental Quality Act regulation regulated by Department of Environment Malaysia for crude palm oil as in Table 2. Discharge limit for mixed industrial effluent of Standard A also listed as a comparison to the standard with a more stringent limit.

The organics (COD) and solids (TSS) removal efficiency was used to study the water quality of POME phytoremediation. In terms of TSS removal, the maximum removal efficiency achieved only after 18 days of treatment and slightly fluctuates until the end of treatment duration. The TSS removal mechanisms in the phytoremediation process are via plant root filtration and sedimentation of the solid particles. The root of *C.alternifolius* is strong and complex that can filter the suspended solid materials [11]. The density of POME results the settlement of the particles to the bottom of bucket treatment

[17]. According to [18], the higher root density of umbrella sedge influence the filtering mechanism of TSS and increase the sedimentation around the roots. The effluent of aerobic, facultative and polishing POME was meet the Discharge Limit of Crude Palm Oil for suspended solid. Only polishing effluent conformed the discharge limit for mixed effluent regulation of 50 mg/L.

For organics removal, the COD removal efficiency also increased in the early days of an experiment to achieve the maximum efficiency and fluctuates until the end of treatment while the facultative and polishing effluent efficiency fluctuates and decrease until the end of the experiment. The organics removal mechanism by plants includes microbial degradation in the rhizosphere, phytovolatilization, plant uptake, filtration, and sedimentation. The plant roots provide the environment and root surface for microbial growth and activities [19]. The oxygen released by the macrophyte rhizome also aided the biodegradation process through heterotrophic bacteria [14]. With regards to effluent discharge standard, all effluent sources were below the discharge limit of crude palm oil, 1000 mg/L and none of them meet the mixed effluent discharge limit, 80 mg/L. The COD and TSS removal efficiency show a significant difference between sources of POME ($P<0.05$).

Nitrogen (ammonia and nitrate) and phosphorus are the essential macro nutrients for the aquatic plant growth. In this study, only ammonia (NH_3-N) and total phosphorus were studied. For NH_3-N removal efficiency, the percentage achieved the maximum percentage in the 12 days of treatment with 86%, 90% and 92% of polishing, facultative and aerobic pond POME, respectively and showing slightly decreasing at the end of treatment days. The NH_3-N removal efficiency was not significantly different between the sources of POME ($P >0.05$). The process involves in decreasing the ammonia concentration includes nitrification, ammonia volatilization and effect of the plant. High ammonia removal efficiency indicates the good nitrification process where nitrifying bacteria at the root plants converting ammonia to nitrate. The nitrate presence from the nitrification process will be uptake by the plant as sources of nutrients. The effluent ammonia level in all sources of POME was below the discharge limit of crude palm oil, 100 mg/L and none of them meet the discharge standard of mixed industrial effluent, 10 mg/L. In addition, the influent of polishing POME already in the acceptable limits.

The phosphorus removal efficiency for facultative and polishing pond POME showing different trends from aerobic pond POME where the aerobic POME uptrend to a maximum percentage (99%) at 12 days and showing decreasing trend until the end of treatment. The removal efficiency of the total phosphorus shows insignificant differences between the sources of POME ($P>0.05$). The main mechanism of phosphorus removal is due to plant uptake and adsorption process since phosphorus as essential macro nutrients required for plant growth [13]. The uptake of phosphorus is in the form of phosphate and stored in the plant tissue. In the aerobic POME, the removal efficiency lowered after achieved maximum may be due to the release of phosphorus by the dies plant. Therefore, the dies plant should be harvested to prevent this occurrence [13]. For the effluent concentration, the both discharged standard not listed phosphorus in the regulation.

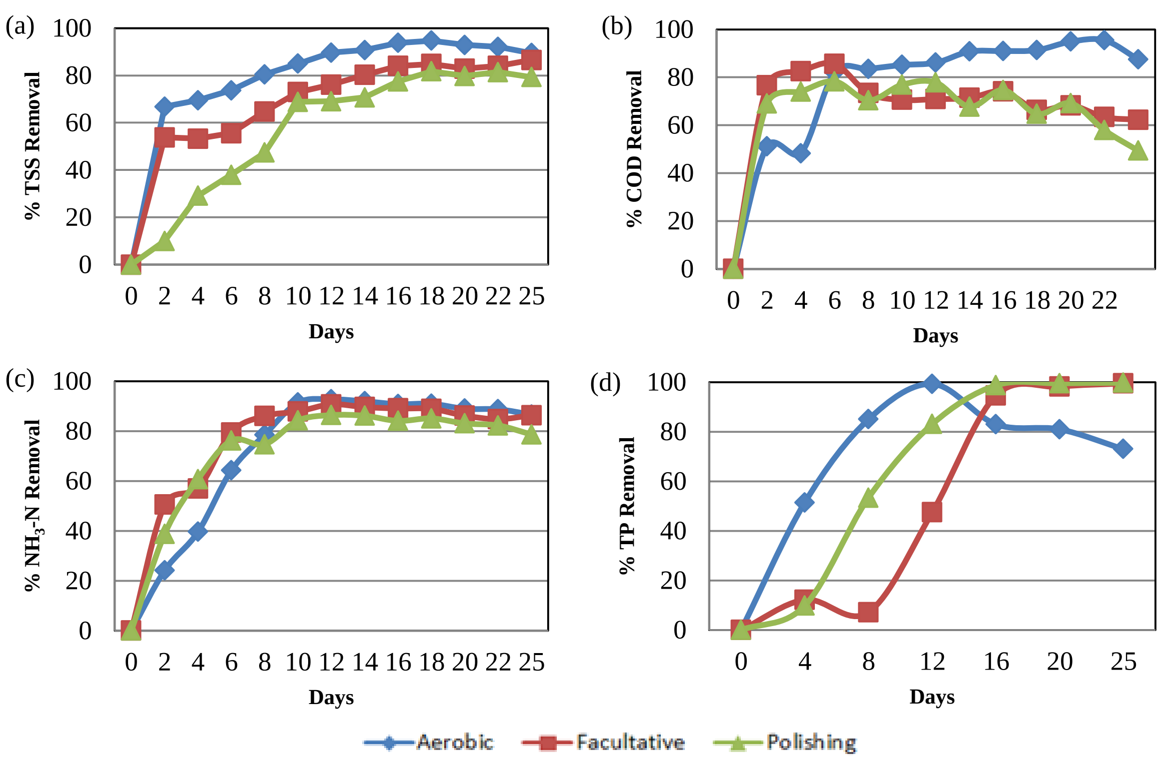

Figure 2. Removal efficiencies of the CWs during 25 days of treatment (a) TSS, (b) COD, (c) NH_3-N, (d) TP

Table 1. The concentration of different sources of POME treatment using *Cyperus alternifolius* phytoremediation as compared to the discharge standard

Sources of POME	**Unit**	**Aerobic**		**Facultative**		**Polishing**		**Discharge Limit of Crude Palm Oil***	**Discharge Limit for Mixed Effluent*'***
Parameters		Influent	Effluent	Influent	Effluent	Influent	Effluent		
Turbidity	NTU	244.4	39.5	187.00	6.93	97	10.5	-	-
TSS	mg/L	1544	81.5	379	51	191	35	400	50
COD	mg/L	14840	673.0	2160	310	1580	342.50	1000	80
NH_3-N	mg/L	188.75	13.75	152.00	14.10	76.09	10.35	100	10
TP	mg/L	41.5	0.3	13.9	0.07	31	0.07	-	-

*Sources: [6]
**Standard A

The aerobic POME with higher pollutant load showing the best removal efficiency compared to facultative and polishing POME. Pollutants loading are one of the factors that need attention in the phytoremediation treatments. Saeed & Sun, (2012) and Kantawanichkul, Kladprasert, & Brix, (2009) reported the higher removal rate with the increase of pollutant loading. However, the overloading effect will cause a negative effect such as excessive substance accumulation, decreasing hydraulic conductivity, hydraulic malfunction and blocked transportation oxygen thus reducing the pollutant concentration reduction especially organics and microbial degradation [22].

Previous research using Cyperus alternifolius run by several researchers includes [14, 18, 23, 24, 25] used Cyperus alternifolius in domestic wastewater treatment using coal slag bed as a substrate. The effluent analysis reported TSS, COD, NH_3-N, and TP with 78.82%, 63.58%, 50.51% and 37.89%, respectively. [18] run the pilot scale research in the secondary treatment of urban wastewater and reported 47% of TSS, 66.6% COD, 38.3% NH_4-N and 31.7% TP removal. [25] also utilized Cyperus alternifolius in municipal wastewater treatment and presented 83% COD, 47% of NH_4-N and 10% of PO_4-P removal. Meanwhile, [23] showed about 84%, 74%, 36% and 70% of TSS, COD, NH_3-N and PO_4-P removal, respectively.

CONCLUSION

The plant used showed good removal efficiency of the pollutant, shows *C. alternifolius* as a potential plant in the phytoremediation treatment of POME in different sources of POME. With the use of *C. alternifolius* plant in the polishing effluent, the removal efficiency achieved 81.4% TSS, 78% COD, 86.4% NH_3-N and 99% TP, consequently meet the crude palm oil discharge limit regulated by Department of Environment, Malaysia. Therefore, the use of the plant in polishing treatment pond was considerable.

In future research, it is suggested to measure the nutrients (N and P) and organics accumulation in the plant tissue, to determine the plant uptake of *Cyperus alternifolius* and determine the total biomass by measuring the fresh weight before and after the experiment.

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