SUITABILITY OF *IPOMOEA AQUATICA* FOR THE TREATMENT OF EFFLUENT FROM PALM OIL MILL

Siti Kamariah Md Sa'at
School of Civil Engineering, Universiti Sains Malaysia, Engineering Campus,
14300 Nibong Tebal, Pulau Pinang;
School of Bioprocess Engineering, Jejawi 3 Industrial Complex,
Universiti Malaysia Perlis, 02600 Arau, Perlis
Email: sitikamariahms@gmail.com

Nastaein Qamaruz Zaman
School of Civil Engineering, Universiti Sains Malaysia,
Engineering Campus, 14300 Nibong Tebal, Pulau Pinang
Email: cenastaein@usm.my

ABSTRACT

The phytoremediation technology has been used in industrial effluent treatment such as palm oil mill effluent (POME) as the recent technology since the last two decades with the great potential and as a sustainability approach technology. However, the phytoremediation usually used as polishing treatment due to high organics and suspended solid concentration of the raw POME. The treatments previously run using various species of floating aquatic plants such as water hyacinth, water lettuce, and duckweed. In this research, another species of aquatic plant were used which is water spinach (Ipomoea aquatica) in the bucket treatment using different sources of POME, which from aerobic and anaerobic pond POME. The potential of I.aquatica evaluated in term of percentage removal and first order removal rate constant (k) of chemical oxygen demand (COD), nutrients concentration (ammonia, nitrate, total phosphorus) and the total suspended solid (TSS). The result shows the I.aquatica are able to increase the plant height from 28cm to 38 cm in the aerobic POME samples with 80% of COD, 90% of TSS and 99% of nutrients removal at the end of 25 days of treatment. While the I.aquatica in the anaerobic POME, were unable to survive where the plant started to wilting and completely death after 5 days of treatment I.aquatica plants were shown their potential of the POME treatment with best prospective especially as a polishing treatment for industrial effluent.

Keyword: Phytoremediation, Palm oil mill effluent (POME), *Ipomoea Aquatica*

Introduction

Malaysia was the second largest producer of crude palm oil in the world. Palm oil mill effluent (POME) were liquid waste from palm oil mill with foul smell effluent, have high biological oxygen demand (BOD), chemical oxygen demand (COD) and suspended solid concentration (Ahmed, Yaakob, Akhtar, & Sopian, 2015). These characteristics will contribute serious aquatic environment degradation if not properly treated. The current treatment in the palm oil mill with the ponding treatment systems need to meet the crude palm oil discharge standard regulated by Department of Environment, Malaysia. In order to enhance the treatment performance of the current treatment, the phytoremediation treatment with aquatic plant was studied.

Phytoremediation technology involves the use of green plants to control and remove the contaminant. This technology had been used in domestic and industrial effluent and wastewater treatment in removing heavy metals, nutrients, organic chemicals, sewage and air pollutants (McCutcheon & Schnoor, 2003). The application of phytoremediation in the wastewater treatment offers cost-effective treatment alternatives, aesthetic appearances, and sustainability concern. Plants provide a substrate for microbial growth and uptake of nutrients and heavy metals in the wastewater. Therefore the plant's selection should be a concentration aspect before implementation of phytoremediation. The plant species should have high uptake of pollutant, fast growth rate, high tolerance in polluted water, adapted to the climate and easily control in dispersion (Ali, Khan, & Sajad, 2013). In addition, the treatment efficiency also depends on plant species and their ages, the root zone interaction and the type of wastewater (Tahir, Yasmin, & Khan, 2015). The younger plants tend to grow faster and uptake more nutrients than older plants (Rezania, Ponraj, Talaiekhozani, Sabbagh, & Sairan, 2015). The mechanism of pollutant removal by phytoremediation technology includes phytoextraction, phytodegradation, phytovolatilization, phytostabilization and phyto filtration (Farraji, 2014).

Floating aquatic plant have been reported to have achieved high nutrients removal due to high nutrients uptake potential, fast growth rate and high biomass productivity (Guittonny-Philippe *et al.*, 2014). Previously the selective number of the plant had been used in the POME treatment includes *Eichhornia crassipes*, *Pistia stratiotes*, vetiver grass and *Salvinia molesta* (Darajeh *et al.*, 2014; Hadiyanto, Soetrisnanto, & Christwardhana, 2013; Hadiyanto *et al.*, 2014; Innocent *et al.*, 2014; Ng & Chan, 2016). POME also has satisfy the nutrients concentration (eg. N, P, K, Mg, Ca) that can be used by aquatic plants and act as a medium for plant growth (Hadiyanto, Soetrisnanto, & Christwardhana, 2014). Therefore, the POME can be utilized as sources of plant nutrients.

Water spinach (*Ipomoea aquatica*) are a green leafy vegetable plants grown throughout tropical Asia countries, Africa and Australia and have commercially growth especially in Malaysia, Indonesia, China, Hongkong and Singapore (Manvar & Desai, 2013). This plant was chosen in this study due to their fast growth rate, flourishing root zone and local availability. Research by Yu, Li, Zhao, & Li, (2013) on water spinach floating bed for pig farm biogas reactor wastewater treatment showed 99% of COD, and over 90% removal of total phosphorus, total nitrogen and nitrate within 4 months of growth season. While Endut, Jusoh, Ali, & Wan Nik, (2011) study of water spinach in aquaculture wastewater treatment was able to remove up to 85% ammonia, 87% nitrate and 85% of orthophosphate. According to Rane *et al.*, (2016) on pre-treated textile effluent, about 76%, 87%, 34%,63% and 56% of BOD, COD, total solid, total nitrogen and total phosphorus reduction, respectively can achieved and suggested that water spinach as best plant with effective treatment of the effluent. Water spinach also had been used in cadmium, and chromium phytoremediation (Kashem, Singh, Huq, & Kawai, 2008; Weerasinghe, Ariyawnasa, & Weerasooriya, 2008). Since heavy metal is not the main concern dealing with POME, therefore, the main objectives of this research are to investigate the effectiveness of *Ipomoea aquatica* (*I.aquatica*) phytoremediation for POME treatment in term of TSS, COD and nutrients removal (ammonia, nitrate, and total phosphorus).

METHODOLOGY

POME Collection and Analysis

POME samples were collected from United Oil Palm (UOP) Industries palm oil mill, Nibong Tebal, Pulau Pinang. The POME samples were collected from the second pond of the aerobic pond and second pond of the anaerobic pond in the 20 L plastic bottle.

Aquatic Plant

In this study, water spinach (*Ipomoea aquatica*) was selected as aquatic plants as this plant were growth nearby the palm oil mill treatment pond. The plants were washed from debris attached to the plant and then the plants were acclimatized for 2 weeks using tap water to allow their roots dense and before used in the phytoremediation experiment.

Experiment setup

The experiment was conducted in the controlled environment structure at School of Civil Engineering, USM Engineering Campus, Nibong Tebal, Pulau Pinang. The initial concentration POME samples were analyzing for chemical oxygen demand (COD), total suspended solid (TSS), total phosphorus (TP), ammonia (NH_3-N) and nitrate (NO_3-N).

The POME samples were directly used after collected from palm oil mill in the 6L bucket where four (4) plants were planted in each bucket at different concentration. The volume of POME samples was 3 L and gravel were used as a medium for plant root growth. The phytoremediation experiment conducted for 25 days of the batch experiment. The analyses of water quality were done every five days. The water spinach plants growth and their survival were measured every five days based on the number of leaves and plant height as Rane *et al.*, 2016 and Kersten, Majestic, & Quigley, (2017) The survival of plants was shown as healthy roots or leaves. Only the healthy leaves were counted, not the shriveling and showing chlorosis leaves.

Pollutant removal

In this study, the pollutant removal efficiency was analyzed based on following equation approaches:

$$\text{Removal efficiency (\%)} = (1 - C/C_o) \times 100 \qquad \text{(Eq. 1)}$$

And the pollutant removal performance of the phytoremediation systems was developed using first-order plug flow kinetic model (Kadlec & Knight, 1996). The higher the k-value has the better the performance of the treatment. The first-order plug flow kinetic model equation:

$$C/C_o = e^{-kt} \qquad \text{(Eq. 2)}$$

Where Co=influent pollutant concentration (mg/L), C = effluent pollutant concentration (mg/L), t = nominal hydraulic retention time (day), k = first-order removal rate constant (day^{-1})

RESULT & ANALYSIS

The plant growth analysis was based on a number of leaves and plant height. Table 1 shows the *Ipomoea aquatica* plant growth in both aerobic and anaerobic POME while Figure 1 shows the *I. aquatica* plants at initial stages and at final stages. The *I. aquatica* were able to growth in the aerobic POME but not in the anaerobic POME. The survive plant with a limited number of leaves growth. The plant heights also increase at the end of 25 days of treatment.

Table 1: The plant growth

POME types	Parameter/Day	0	5	10	15	20	25
Aerobic	No of leaves	45	13	14	16	16	15
	Plant height (Avg)*	28.33	-	-	-	-	38
Anaerobic	No of leaves	45	Death	Death	Death	Death	Death
	Plant height (Avg)*	31.3	-	-	-	-	-

*Unit in cm

(a) (b)

Figure 1: *Ipomoea aquatica* growth (a) Initial (Day 0) (b) Final (Day 25)

Figure 2 illustrates the percentage removal trend of COD, TSS, TP, NH_3-N and NO_3-N for aerobic pond POME. After 20 days of phytoremediation treatment, the COD reduced 87.5% from 1292 mg/L to 161mg/L while the suspended solid (TSS) reduced 92.6% from 73,300 mg/L to 5400 mg/L. For nutrients removal (phosphorus, ammonia, and nitrate) can achieve their best removal at 10 days of treatment with 100% of total phosphorus and nitrate and 82.7% removal of ammonia. Figure 3 illustrates the first-order removal rates trend. Only COD, TSS and ammonia follow the first-order removal where TSS shows the best removal performance with removal rate constant, k = 0.132 followed by ammonia (k=0.089) and COD (k=0.077).

The COD concentration can be reduced by plants by the phytodegradation mechanism where the breakdown of organics contaminant through plant metabolic activities or through plant enzymes (Al-Baldawi, Abdullah, Suja, Anuar, & Mushrifah, 2013; Yu *et al.*, 2013). The microbial around the roots zone of the plant can enhance the purification process. The roots of water spinach can provide a medium for the microbial growth. Thus the organic matter can be removed effectively (Lee, 2013). The suspended solid particles may be filtered by extensive root zone of water spinach through phytofiltration which the extensive root systems sequestration of pollutants from contaminated water by the plant (Ali *et al.*, 2013). The solids also filtered by the gravel and reduced the suspended solid concentration.

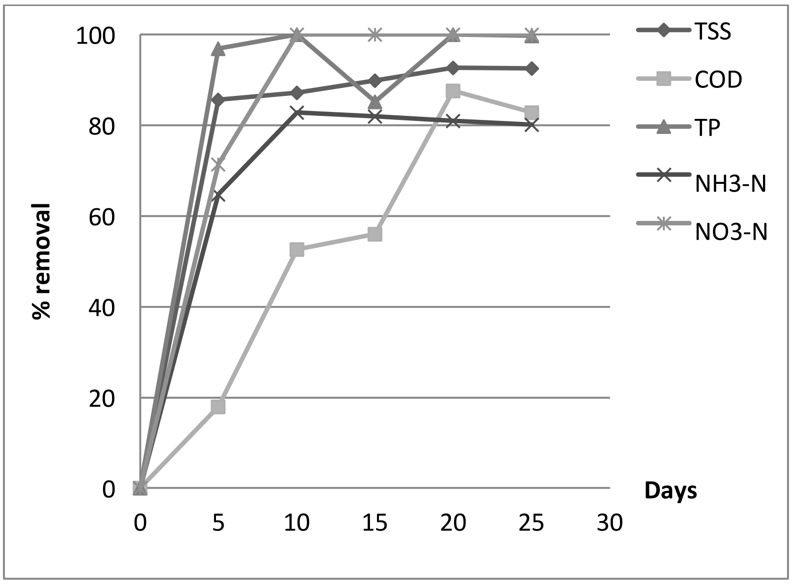

Figure 2: The pollutant removal

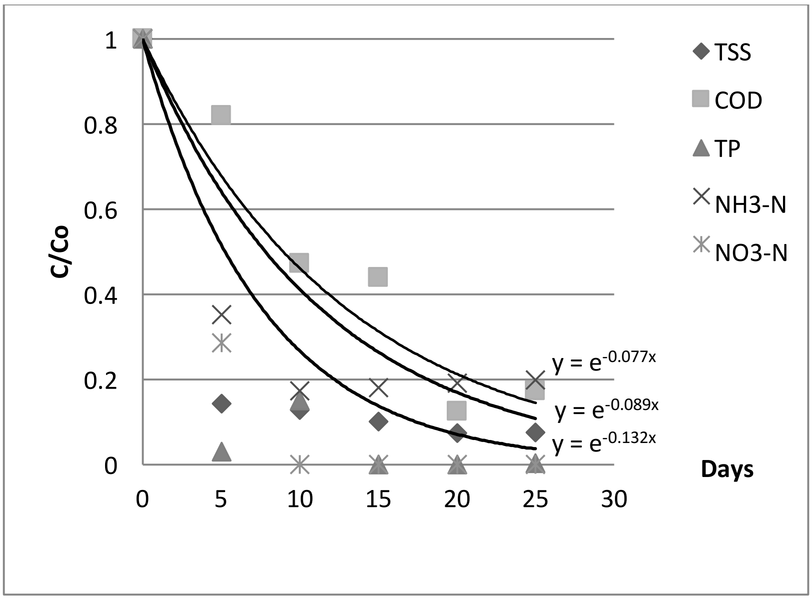

Figure 3: First-order removal rate

The phosphorus is one of the essential nutrients for plant and microorganism growth and needed during photosynthesis process. Phosphorus help for energy and biochemistry reaction and also plays an important role in coenzyme formation (Hadiyanto *et al.*, 2014). The phosphorus removal mechanism includes sorption, precipitation, complexation, assimilation by plant biomass and microorganism (Zhang, Achal, Xu, & Xiang, 2014). Removal of phosphorus in the systems may because of the photosynthesis activity occur and the adsorption of phosphorus by the gravel media. According to Zhang *et al.* (2014), the removal mechanism of phosphorus by water spinach was mainly through plant absorption.

The nitrogen is an essential macronutrient required by plant more than phosphorus. The nitrogen in the form of N-organic converted to ammonia via ammonification and then converted to nitrite and nitrate by bacteria in nitrification process (Saeed & Sun, 2012). The nitrite will be uptake by the plant for photosynthetic reaction (Hadiyanto *et al.*, 2014). The nitrate reduction maybe due to denitrification process occurs to reduced nitrate to nitrogen gas. The nitrate that needs by the plant will be uptake and therefore the nitrate will be removed. The plant also provided the surface of microorganism growth in the rhizosphere and enhances nitrification thus enhancing the organics and nitrogen removal (Saeed & Sun, 2012). The main mechanism for the ammonia and nitrate removal by water spinach were by nitrogen microorganisms comprising of ammonifying bacteria, nitrifying bacteria and denitrifying bacteria (Zhang *et al.*, 2014).

The final effluent must conform to the Malaysian Department of Environment (DOE) standard for palm oil mill effluent discharge standard. From the result of phytoremediation treatment using *I.aquatica* for POME treatment as listed in Table 2, only final ammonia concentration below the discharged standard. The experiment failed to fulfill the required discharged standard. Nevertheless, the phytoremediation treatment has shown the best performance in term of best percentage removal for all parameter.

Table 2: Initial and final concentration palm oil mill effluent

Parameter	Initial concentration (Day 0)	Final concentration (Day 25)	Limit**
pH	7.95	9.00	5 to 9
BOD	-	-	100
COD	1292	223	-
Suspended Solids (SS)	73,300	5500	400
Ammoniacal Nitrogen (NH_3-N)	121	24	150

*All units in mg/L except pH
**Source: (MPOB, 2014)

CONCLUSION
The phytoremediation of *Ipomoea aquatica* was able to reduce the COD concentration, nutrients and suspended solid of the aerobic POME up to 80% of all parameter by the end of 25 days of treatment. The greatest pollutant removal by *I.aquatica* showed their potential in phytoremediation for industrial effluent treatment like POME, suggested the utilization of the plant in polishing treatment pond to enhance the pollutant removal prior to discharge to nearest river and to meet the discharge standard. In future works, the potential of *Ipomoea aquatica* can be further explored for their nutrients accumulation in plant parts (leaves, stem and root).

ACKNOWLEDGEMENT

This work is funded by Universiti Sains Malaysia under Iconic grant scheme (Grant no. 1001/CKT/870023) for research associated with the Solid Waste Management Cluster, Engineering Campus, Universiti Sains Malaysia.

REFERENCES

Ahmed, Y., Yaakob, Z., Akhtar, P., & Sopian, K. (2015). Production of biogas and performance evaluation of existing treatment processes in palm oil mill ef fl uent (POME). *Renewable and Sustainable Energy Reviews*, *42*, 1260–1278. https://doi.org/10.1016/j.rser.2014.10.073

Al-Baldawi, I. A. W., Abdullah, S. R. S., Suja, F., Anuar, N., & Mushrifah, I. (2013). Comparative performance of free surface and sub-surface flow systems in the phytoremediation of hydrocarbons using Scirpus grossus. *Journal of Environmental Management*, *130*, 324–330. https://doi.org/10.1016/j.jenvman.2013.09.010

Ali, H., Khan, E., & Sajad, M. A. (2013). Phytoremediation of heavy metals-Concepts and applications. *Chemosphere*, *91*(7), 869–881. https://doi.org/10.1016/j.chemosphere.2013.01.075

Darajeh, N., Idris, A., Truong, P., Aziz, A. A., Bakar, R. A., & Man, H. C. (2014). Phytoremediation Potential of Vetiver System Technology for Improving the Quality of Palm Oil Mill Effluent, *2014*.

Endut, A., Jusoh, A., Ali, N., & Wan Nik, W. B. (2011). Nutrient removal from aquaculture wastewater by vegetable production in aquaponics recirculation system. *Desalination and Water Treatment*, *32*(1–3), 422–430. https://doi.org/10.5004/dwt.2011.2761

Farraji, H. (2014). Chapter 7 :Wastewater Treatment by Phytoremediation Methods. In *Wastewater Treatment by Phytoremediation TechnologiesWastewater Engineering : Types , Characteristics and Treatment Technologies* (pp. 205–218).

Guittonny-Philippe, A., Masotti, V., Höhener, P., Boudenne, J.-L., Viglione, J., & Laffont-Schwob, I. (2014). Constructed wetlands to reduce metal pollution from industrial catchments in aquatic Mediterranean ecosystems: A review to overcome obstacles and suggest potential solutions. *Environment International*, *64*, 1–16. https://doi.org/10.1016/j.envint.2013.11.016

Hadiyanto, H., Soetrisnanto, D., & Christwardhana, M. (2013). Phytoremediations of Palm Oil Mill Effluent (POME) by Using Aquatic Plants and Microalgae for Biomass Production. *Journal of Environmental Science and Technology*. https://doi.org/10.3923/jest.2013

Hadiyanto, H., Soetrisnanto, D., & Christwardhana, M. (2014). International Journal of Engineering Phytoremediation of Palm Oil Mill Effluent Using Pistia Stratiotes Plant and Algae. *International Journal of Engineering (IJE)*, *27*(12), 1809–1814. https://doi.org/10.5829/idosi.ije.2014.27.12c.02

Innocent, O., Fauziah, S. H., Redzwan, G., Chukwunonso, O. I., Fauziah, S. H., & Redzwan, G. (2014). The Utilization of Water Hyacinth (Eichhorniacrassipes) as Aquatic Macrophage Treatment System (AMATS) in Phytoremediation for Palm Oil Mill Effluent (POME). *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, *13*(No. 2), 31–47. Retrieved from http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Kashem, M. A., Singh, B. R., Huq, S. M. I., & Kawai, S. (2008). Cadmium phytoextraction efficiency of arum (Colocasia antiquorum), radish (Raphanus sativus L.) and water spinach (Ipomoea aquatica) grown in hydroponics. *Water, Air, and Soil Pollution*, *192*(1–4), 273–279. https://doi.org/10.1007/s11270-008-9654-7

Kersten, G., Majestic, B., & Quigley, M. (2017). Phytoremediation of cadmium and lead-polluted watersheds. *Ecotoxicology and Environmental Safety*, *137*(December 2016), 225–232. https://doi.org/10.1016/j.ecoenv.2016.12.001

Lee, J. H. (2013). An overview of phytoremediation as a potentially promising technology for environmental pollution control. *Biotechnology and Bioprocess Engineering*. https://doi.org/10.1007/s12257-013-0193-8

Manvar, M. N., & Desai, T. R. (2013). Phytochemical and pharmacological profile of Ipomoea aquatica. *Indian Journal of Medical Sciences*, *67*, 49–60. https://doi.org/10.4103/0019-5359.121115

MPOB. (2014). Oil Palm & The Environment (updated March. *Internet*.

Ng, Y. S., & Chan, D. J. C. (2016). Wastewater phytoremediation by Salvinia molesta. *Journal of Water Process Engineering*. https://doi.org/10.1016/j.jwpe.2016.08.006

Rane, N. R., Patil, S. M., Chandanshive, V. V., Kadam, S. K., Khandare, R. V., Jadhav, J. P., & Govindwar, S. P. (2016). Ipomoea hederifolia rooted soil bed and Ipomoea aquatica rhizofiltration coupled phytoreactors for efficient treatment of textile wastewater. *Water Research*, *96*, 1–11. https://doi.org/10.1016/j.watres.2016.03.029

Rezania, S., Ponraj, M., Talaiekhozani, A., Sabbagh, F., & Sairan, F. (2015). Perspectives of phytoremediation using water hyacinth for removal of heavy metals , organic and inorganic pollutants in wastewater. *Journal of Environmental Management*, *163*, 125–133. https://doi.org/10.1016/j.jenvman.2015.08.018

Saeed, T., & Sun, G. (2012). A review on nitrogen and organics removal mechanisms in subsurface flow constructed wetlands: Dependency on environmental parameters, operating conditions and supporting media. *Journal of Environmental Management*, *112*, 429–448. https://doi.org/10.1016/j.jenvman.2012.08.011

Tahir, U., Yasmin, A., & Khan, U. H. (2015). Phytoremediation: Potential flora for synthetic dyestuff metabolism. *Journal of King Saud University - Science*. https://doi.org/10.1016/j.jksus.2015.05.009

Weerasinghe, A., Ariyawnasa, S., & Weerasooriya, R. (2008). Phyto-remediation potential of Ipomoea aquatica for Cr(VI) mitigation. *Chemosphere*, *70*(3), 521–524. https://doi.org/10.1016/j.chemosphere.2007.07.006

Yu, X., Li, Z., Zhao, S., & Li, K. (2013). Biomass Accumulation and Water Purification of Water Spinach Planted on Water Surface by Floating Beds for Treating Biogas Slurry, *2013*(November), 1230–1235.

Zhang, Q., Achal, V., Xu, Y., & Xiang, W. N. (2014). Aquaculture wastewater quality improvement by water spinach (Ipomoea aquatica Forsskal) floating bed and ecological benefit assessment in ecological agriculture district. *Aquacultural Engineering*, *60*, 48–55. https://doi.org/10.1016/j.aquaeng.2014.04.002