VETIVER SYSTEM TECHNOLOGY FOR PHYTOREMEDIATION OF PALM OIL MILL EFFLUENT (POME)

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Abstract

Phytoremediation is a cost effective green technology suitable for environmental protection. Successful phytoremediation depends on various factors such as plant behaviour, high uptake of both organic and inorganic pollutants, grow well in polluted water and are easily controlled in quantitatively propagated dispersion. Vetiver grass (*Chrysopogon zizanioides L.Roberty ex Vetiveria zizanioides*) which was first developed for soil and water conservation has great potential as a tool for this technology because of its characteristic tolerance to high pollutant levels. As Malaysia is one of the world's largest producer of palm oil, large amounts of palm oil mill effluent (POME) is generated and often discharged to local stream, causing severe pollution. The aim of the project is to demonstrate the potential of Vetiver grass in reducing the Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and nutrients (Nitrogen and Phosphorus) from POME.

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The research was conducted under hydroponic conditions in both aerobic and anaerobic set up, growth of Vetiver plant and changes in POME characteristics were monitored over the period of four weeks. The results showed that Vetiver was able to reduce the BOD, COD, N, and P up to 93,70, 94, 70% for aerobic and 25,35, 55, and 50% for anaerobic condition respectively, while Control treatment only reduce BOD,COD, N, and P at 37,12, 22, and 25 % in aerobic and 7,2, 3, and 10 % for anaerobic condition.

These results showed that Vetiver System Technology is effective in reducing COD and nutrient levels in POME. Although the aerobic treatment is superior to the anaerobic one, but the former will incur higher operating and maintenance cost.

Key words: Phytoremediation, Vetiver, Palm oil mill effluent, wastewater, COD, BOD.

INTRODUCTION

Pollution of soil and water with wastewater is one of the major global threats that our environment is facing today. For the treatment of these wastewaters rich in nutrients and other toxic chemicals has mainly been done using conventional wastewater treatment systems such as activated sludge and biological nutrient removal technologies or otherwise by several chemical methods. These technologies are very expensive and dependent on skilled personnel or impossible to carry out, as the volume of contaminated material is very large (Dhanya & Jaya, 2013).

PALM OIL INDUSTRY

Palm oil is one of the world’s most rapidly expanding equatorial crops. Indonesia and Malaysia are the two largest oil palm producing countries and is rich with numerous endemic, forest-dwelling species. Malaysia has a tropical climate and is prosperous in natural resources.

While the oil palm industry has been recognized for its contribution towards economic growth and rapid development, it has also contributed to environmental pollution due to the production of huge quantities of by-products from the oil extraction process (Rupani et al., 2010; Singh et al., 2010).

PALM OIL MILL EFFLUENT (POME)

Huge quantities of waste are produced in the palm oil mill industry. The process of oil extraction results in generation of liquid waste commonly named as palm oil mill effluent (POME). Discharging the effluents or by products on the lands may lead to pollution and might deteriorate the surrounding environment. There is a need for a sound and efficient management system in the treatment of these by products in a way that will help to conserve the environment and check the deterioration of air and river water quality. Treatment of POME is essential to avoid environmental pollution (Rupani et al., 2010). Characteristics of palm oil mill effluent depend on the quality of the raw material and palm oil production processes in palm oil mills (Latif Ahmad et al., 2003). POME is considered as non toxic, but it is identified as a major source of aquatic pollution by depleting dissolved oxygen when discharged untreated into the water bodies (Khalid & Mustafa, 1992). However it also contains appreciable amounts of N, P, K, Mg and Ca (Muhrizal et al., 2006) which are the vital nutrient elements for plant growth (Rupani et al., 2010).

PALM OIL MILL EFFLUENT TREATMENT TECHNOLOGIES

Several researchers have studied the various aspects of palm oil mill effluent treatment (Rupani et al., 2010). Land application of palm oil mill effluent (POME) is one of the disposal alternatives. Discharging the POME on the land results in clogging and water logging of the soil and kills the vegetation on contact. The cheapest way of discharging of POME is to release it into the river, since POME is a non toxic oily waste, but discharge of effluent into water bodies causes water depletion of oxygen and results in aquatic pollution (Hwang et al., 1978). Some other methods such as anaerobic digestion (Tay, 1991; Ma et al., 1993), membrane technology(Ahmad et al., 2007), aerobic activated sludge reactor (Vijayaraghavan et al., 2007) and evaporation method (Ma et al., 1997), which all are expensive and depend on power source and skilled personnel.

PHYTOREMEDIATION TECHNOLOGY

Phytoremediation is an emerging, cost effective, aesthetically pleasing, and low cost technology that directly uses green plants to degrade, or render harmless various environmental contaminants including organic compounds or heavy metals from the environment in their tissues (Macek et al., 2004; Paz-Alberto & Sigua, 2013).

The principal application of phytoremediation is for lightly contaminated soils and waters where the material to be treated is at a shallow or medium depth and the area to be treated is large. This will make agronomic techniques economical and applicable for both planting and harvesting. Suitable plant species used for phytoremediation should have high uptake of both organic and inorganic pollutants, grow well in polluted water and be easily controlled in quantitatively propagated dispersion. Moreover, the plants should not only accumulate, degrade or volatilize the contaminants, but they should also grow quickly in a range of different conditions and lend themselves to easy harvesting (Wagner et al., 2003; Truong, 2008). The scientific research conducted in the last years has clearly demonstrated that vetiver grass is also one of the most effective and low-cost natural methods of environmental protection (Truong et al., 2008).

VETIVER GRASS TECHNOLOGY

Vetiver grass (*Chrysopogon zizanioides L.)* belongs to the same grass family as maize, sorghum, sugarcane, and lemon grass. Vetiver grass is a perennial grass growing two meters high, and three meters deep in the ground. It has a strong dense and vertical root system. It grows both in hydrophilic and xerophytic conditions. The leaves sprout from the bottom of the clumps and each blade is narrow, long and coarse. The leaf is 45 - 100 cm long and 6 - 12 cm wide. Vetiver grass is highly suitable for phytoremedial application due to its extraordinary features. These include a massive and deep root system, tolerance to extreme climatic variations such as prolonged drought, flood, submergence, fire, frost, and heat waves. It is also tolerant to a wide range of soil acidity, alkalinity, salinity, sodicity, elevated levels of Al, Mn, and heavy metals such as As, Cr, Ni, Pb, Zn, Hg, Se, and Cu in soils (Truong et al., 1998).

In central China Vetiver was used to treat polluted river water, the removal percentage of total P was 93.7% after two week and more than 99% after three weeks. The removal percentage of total N was 58% after two weeks, and 71% after four weeks. Phosphorous is usually considered to be a key element in water eutrophication (Zheng et al., 1997). Wagner et al. (2003) carried out a pot experiment to determine the maximum capacity of vetiver for N and P uptake in soil supplied with N and P at rates of 8,000 kg/ha/year and 1000 kg/ha/year respectively. Results showed that vetiver grass has a very high capacity of absorbing N at elevated levels of N supply. Vetiver growth will respond positively to N supplied at rates of up to 6000 kg/ha/year, with no adverse growth effects apparent up to 10,000 kg N/ha/year. These features make vetiver highly suitable for treating wastewater and other waste materials high in Nitrogen.

Vetiver grass when compared with other plants, is more efficient in absorbing certain heavy metals and chemicals due to the capacity of its root system to reach greater depths and widths

(Truong et al., 1998). As confirmed by Roongtanakiat and Chairoj (2001), vetiver grass was found to be highly tolerant to an extremely adverse conditions. Therefore, vetiver grass can be used for rehabilitation of mine tailings, garbage landfills, and industrial waste dumps which are often extremely acidic or alkaline, high in heavy metals, and low in plant nutrients.

MATERILAS AND METHODS

Treatments

POME used for this study was directly obtained from the Labu Palm Oil Mill in Labu, Negri Sembilan, Malaysia. POME was put in to the plastic container 32*22*30 cm (length× width× height).

Experimental design included three POME concentrations treated with and without aeration. The POME concentrations were:

1. 100% POME (Pure POME)
2. 50% POME + 50% distilled water (Half POME)
3. 25% POME + 75% distilled water (Quarter POME)
4. Control (without plant)

Aeration was carried out by using air pump in to the containers.

Plants Preparation

Planting stocks were obtained from a commercial nursery HUMIBOX (M) SDN. BHD,

Plants were too small for start the experiment, at the first the dried leaves were separated, then washed the leaves, so they were transferred to commercial hydroponic solution (N, P, K, 18:18:18) until adequate roots and shoot development ready for experiment. After five weeks vetiver plants with roughly the same sizes, were removed from the hydroponic solution and transfer to the POME containers. The shoots were cut back to approximately 20 cm height to reduce transpiration. Polystyrene was used to floating Vetiver on the container.

Analytical Method

The levels of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) Total Nitrogen (TN) and Total Phosphorus (TP) in POME were measure in beginning of the process (Table 1).

Table 1: POME Characteristics

Parameter	Unit	Measurement Method	Value
pH	_	pH Meter	7
COD	mg/l	Spectrophotometry	1414
BOD	mg/l	Manometric/respirometric	300
Total Nitrogen	mg/l	Macro kjeldahl	210.6
Total Phosphorus	mg/l	Ascorbic acid	11.65

RESULTS AND DISCUSSION

Effect of Aeration:

Biochemical oxygen demand (BOD) is defined as the amount of dissolved oxygen (DO) that is consumed by microbial activity for the biochemical degradation of organic matter in a water sample. The high level of BOD indicates the pollution strength of the wastewaters and low oxygen availability for living organisms in the wastewater when utilizing the organic matter present in the wastewater.

After four weeks of remediation result showed that, up to 93% of BOD concentrations have been removed from the aerobic system, while in anaerobic showed lower BOD reduction up to 25% (Figure 1).

Chemical Oxygen Demand (COD) is the need of oxygen to decompose organic materials in to CO_2 or water through chemical pathway. High COD level indicates the toxic condition and the presence of biologically resistant organic substances. Vetiver grass in aerobic set up reduced the COD up to 70%, while phytoremediation in anaerobic condition showed lower COD reduction up to 35% (Figure 2).

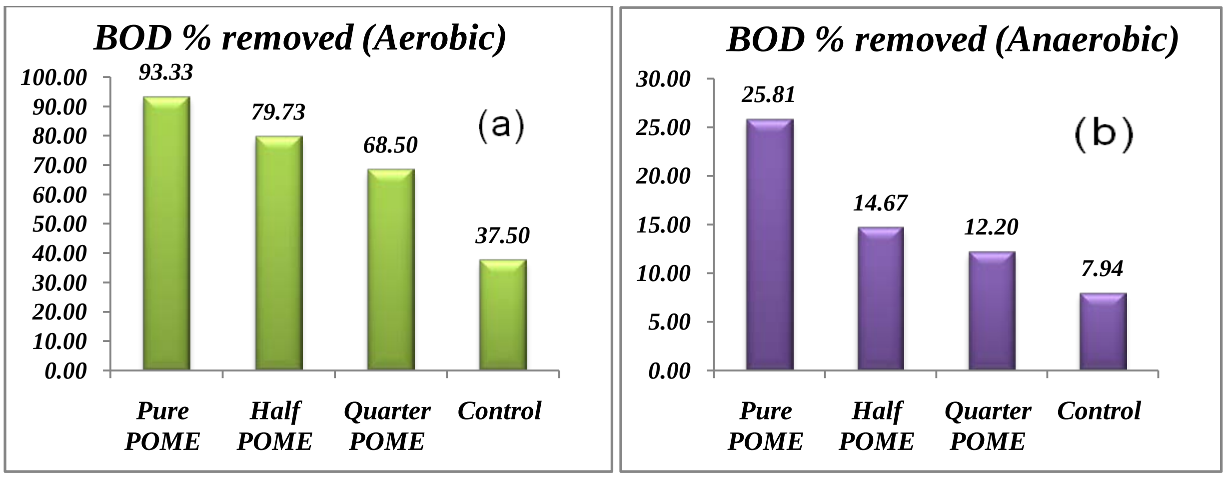

Figure 1: (a) Reduction of BOD in Aerobic set up (b) Reduction of BOD in Anaerobic condition.

Phytoremediation in aerobic set up was more effective than anaerobic condition as it shows more reduction of BOD, COD, Total N and Total P in POME during remediation.

During the entire time series analyses it can be shown that the concentration of BOD and COD of experimental sets planted with vetiver were lower than the control set. This clearly shows that the beneficial effect of vetiver in treating POME.

Christwardana and Soetrisnanto (2013) showed that water hyacinth (*Eichhorniacrassipes*) and water lily (*Nymphaea sp.*) was able to reduce COD, N and P up to 50, 88 and 64 % respectively in POME. Result showed that BOD and COD reduction is slightly higher than result obtained by Njau and Mlay (2003) who used Vetiver grass and *Phragmites mauritianus* to reduce BOD up to

67 % and 61 % and COD 46% and 37% for Vetiver grass and *Phragmites mauritianus* respectively in textile wastewater.

Effect of various concentrations

The level of contaminants will affect its uptake by Vetiver plant, as shown in Figure 2 in both aerobic and anaerobic conditions.

The highest removal BOD was for aerobic set up in pure POME (no diluted) by 93.33 % removed and for anaerobic condition also for pure POME with the reduction of 25.8 % of BOD. There is not significant different between the two other dilution POME to reduction of BOD in anaerobic set up (Figure 1).

The highest removal COD was for aerobic set up in pure POME (no diluted) by 70.6 % removed and for anaerobic condition also for pure POME with the reduction of 35.8 % of COD. There is not significant different between the two other dilution POME to reduction of COD in both aerobic and anaerobic set up.

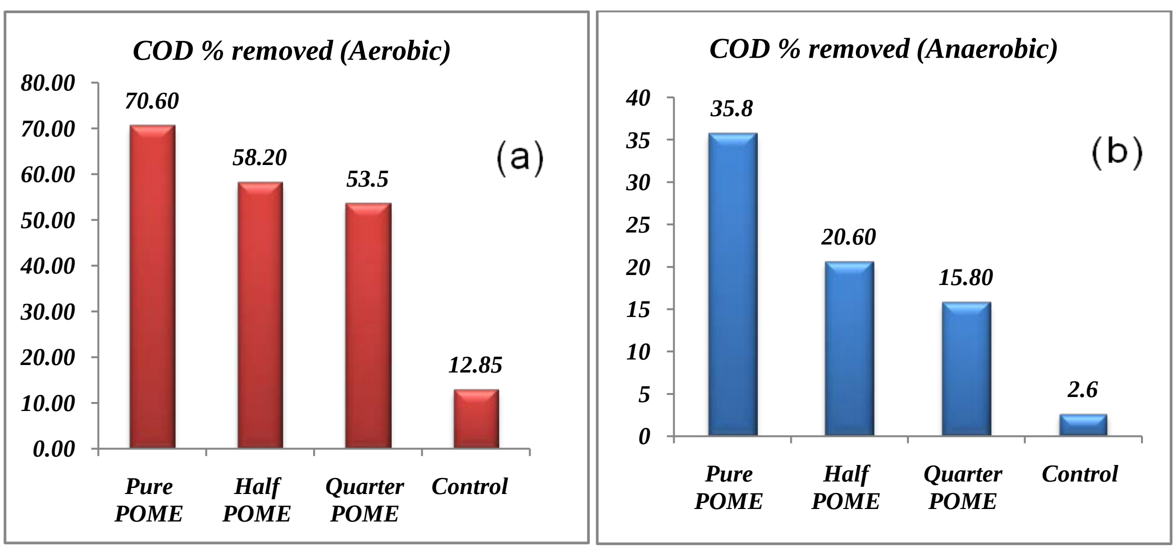

Figure 2: (a) Reduction of COD in Aerobic set up (b) Reduction of COD in Anaerobic condition.

Nutrients Removal by Vetiver Plant

The high concentration of TN indicates pollution of the environment that was rapidly converted to ammonia and creates odour problem and toxic to aquatic life. Nitrogen in wastewater consists of three forms of ammonium, nitrate and organic nitrogen. Figure 3 shows that total nitrogen reduction is 94%, this is slightly higher than the one obtained by Christwardana and Soetrisnanto (2013) who used water hyacinth (*Eichhorniacrassipes*) and water lily (*Nymphaea sp.*) to reduce nitrogen up to 88 % in POME.

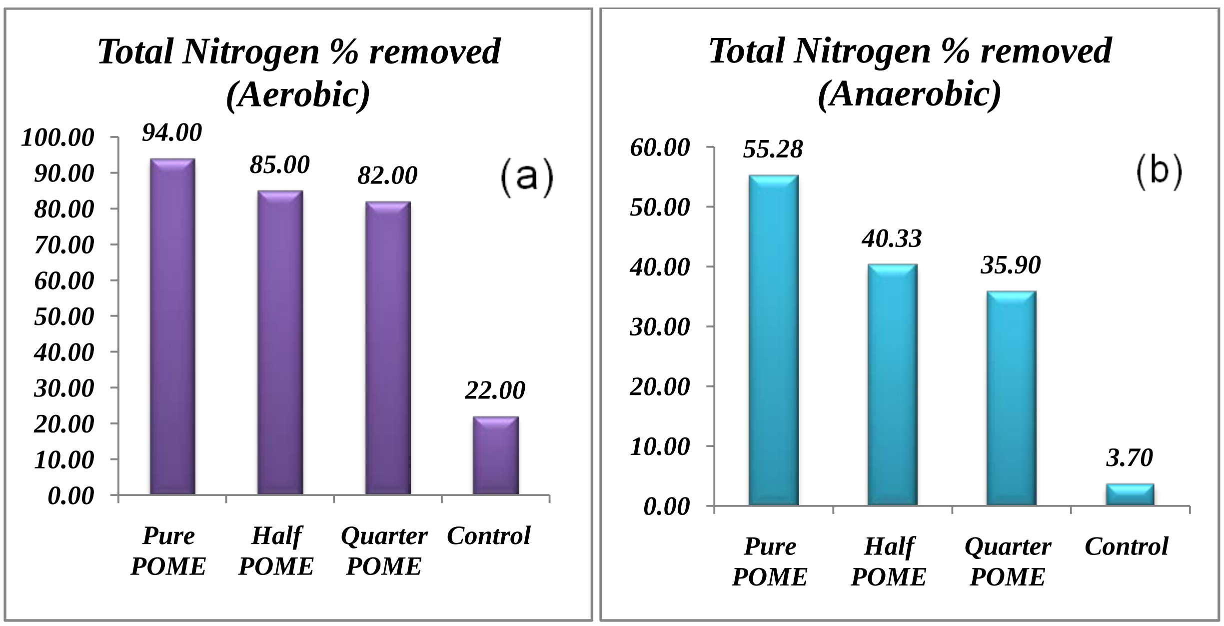

Figure 3: (a) Reduction of Total Nitrogen in Aerobic set up (b) Reduction of Total Nitrogen in Anaerobic condition.

The observed phosphorus removal might be due to absorption by vetiver, sedimentation in the container and the ability of a particular group of micro-organisms (Acinetobacter) to take up and store excessive amounts of phosphate. These micro-organisms, collectively known as phosphate accumulating organisms (PAO), store the phosphate internally as polyphosphate polymers (Lee et al., 2001). As shown in Figure 4 phytoremediation using aeration shows a highest reduction rate of phosphorus for pure POME with 70% reduced and 50%for anaerobic set up in the pure POME. This is slightly higher than the one obtained by Christwardana and Soetrisnanto (2013) who used water hyacinth (*Eichhorniacrassipes*) and water lily (*Nymphaea sp.*) to reduce phosphorus up to 64 % in POME.

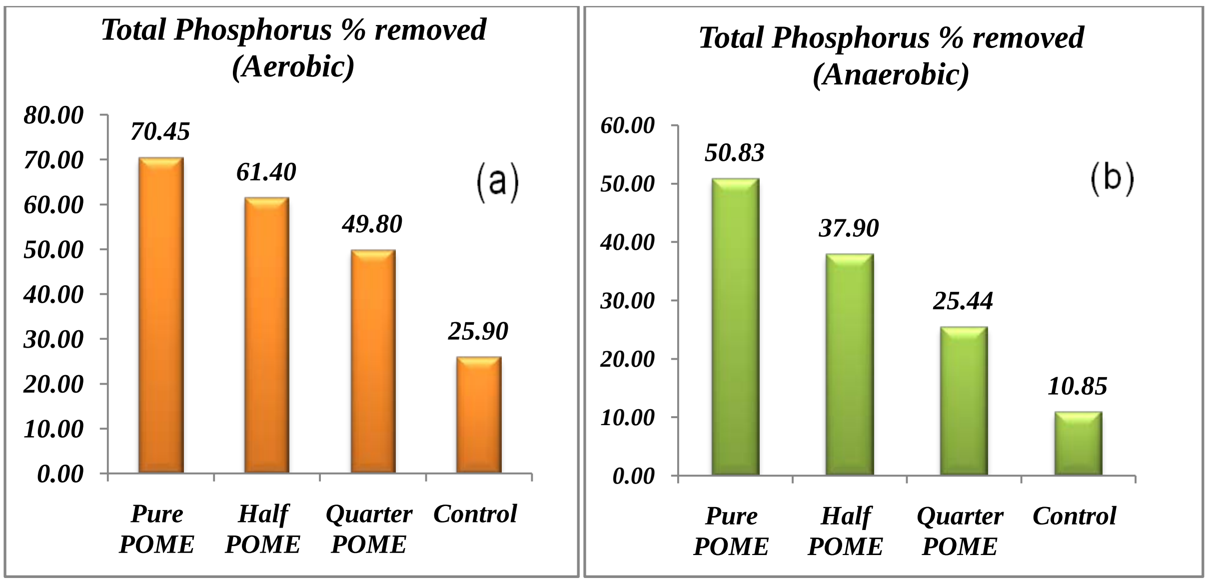

Figure 4: (a) Reduction of Total Phosphorus in Aerobic set up (b) Reduction of Total Phosphorus in Anaerobic condition.

Results obtained for TN and TP are roughly same as those reported in the literature review. Liao (2000) were reported 20% removal of ammonia nitrogen and 18% removal of TP after four days discharging the piggery wastewater in the field. Truong and Hart (2001) were reported 99% removal of TN and 85% removal of TP after five months discharging the domestic effluent from a septic tank into five row of vetiver field, and 94% removal of TN with 90% removal of TP after four days hydroponic treatment in the field. Hart et al. (2003) were reported 87.50% removal of TN and 11.47% removal of TP after fourteen days hydroponic treatment. Furthermore, Boonsong and Chansiri (2008) were reported 63.85% removal of TN and 36.34%

removal of TP at a HRT of seven days after eight weeks hydroponic treatment from domestic wastewater in the green house. Thus, the observed differences in the TN and TP removal efficiencies with different literatures could be due to differences in method of vetiver application such as soil as a growing medium and hydroponic with no supporting medium. Furthermore another factor could be affected the result such as, the variation of wastewater concentration or source of wastewater, setting up the hydroponic system in an open space or green house, hydraulic retention time (HRT), quantity of vetiver applied and temperature.

CONCLUSION

These results showed that Vetiver System Technology (VST) is effective in reducing BOD, COD and nutrient levels in POME. Although the aerobic treatment is superior to the anaerobic one, but the former will incur higher operating and maintenance cost.

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