Start-up treatment of palm oil mill effluent (POME) final discharge using Napier Grass in wetland system

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Abstract. Average of about 53 million m³ POME is being produced yearly in Malaysia. The treated palm oil mill effluent (POME) will be discharged to the river. However, the POME final discharge still contains high oxygen demand (COD) and suspended solids (SS) that potentially to cause environmental issues. Therefore, the aim of this study is to treat the POME final discharge with Napier grass (Pennisetum purpureum) in the constructed wetland system. This study has been carried out to investigate the feasibility of the Constructed Wetland in polishing the final discharge according to river quality index. Besides, the propagation of Napier grass in the POME final discharge was evaluated. Four different physicochemical parameters such as chemical oxygen demand (COD), total suspended solid (TSS), ammonia and colour were analysed based on standard laboratory methods and procedures. Results revealed that the reduction of COD level by 71.57 %, TSS by 83.59 %, ammonia by 85.97 % and colour reduced by 87.62 % after 15 days treatment time. In term of propagation of plant, Napier grass showed an excellent propagation in POME final discharge by 13.94% increment. The overall results indicated that treatment of POME final discharge by using Napier grass constructed wetland was successful to reduce the concentration of the contaminants.

1. Introduction
Malaysia has abundant natural resources for commercial cultivation of crops such as rubber and palm oil. Malaysia is the second largest producer of palm oil in the world [1], the third largest for rubber and fourth largest for cocoa [2] Since palm oil industries are the largest industries in Malaysia, more than 13 million tonnes of crude palm oil is being produced yearly, covering 11 % of Malaysian land for plantation area.

The byproduct of the crude palm oil (CPO) production are, oil palm trunks (OPT), empty fruit (EFB), oil palm fronds (OPF), palm pressed fibres (PPF), palm kernel shells, palm kernel cake and liquid
discharge palm oil mill effluent (POME) [2]. From the biomass mentioned above, POME is the most expensive and difficult waste to manage since it is generated in large volume in tonnes at a time [3]. POME is considered among the harmful waste that giving the detrimental impact to the environment if it is discharged untreated [2,4]. POME is treated to final discharge and released to the nearby land or river since it is the easiest and cheapest way for disposal [3]. Although the treated POME released to the rivers meets the standard discharge limit set by the government [6], it still contains relatively high chemical oxygen demand (COD) and suspended solids (SS) content compared to the receiving water body [7]. The POME final discharge quality still does not meet the river water quality index as shown in Table 1. Thus, the discharge of POME final effluent wastewater may potentially cause the environmental problem if it is not being treated properly [4].

Table 1. Characteristic of raw POME, POME final discharge and river water [8].

| Parameter | Raw POME (mg/L) | POME Final Discharge (mg/L) | River water (mg/L) |
|-----------|-----------------|-----------------------------|-------------------|
| BOD₅      | 10,250-25,020   | 65                          | 8                 |
| COD       | 15,000-59,700   | 520                         | 30                |
| SS        | 5000-18,000     | 217                         | 40                |

A wetland system can be suggested to treat POME final discharge. A wetland system is more compatible as compared to another system to treat the POME final discharge. The advantage of wetland system is more cost efficient with fewer side effects compared to other the biological and chemical approaches [9]. Wetland is an area that is saturated with water and an area between land and water that have characteristics of a distinct elements. Wetland has many benefits such as food or habitat for wildlife, flood protection, improve the water quality and can act as recreation site [10]. Wetland also can consider as natural environmental water treatment and it also environmental friendly [11].

Constructed wetlands are widely used in wastewater treatment throughout the world and vegetation from these systems can be used for raw material production [12]. Plant from constructed wetland should has ability to accelerate the development of microbial communities and promote ‘‘living’’ environments around roots (i.e., aerobic and anaerobic alternant environments). It is also assumed that plant play a central role in the sludge treatment wetlands (STWs) by preventing clogging, favouring dewatering and improving sludge mineralization [13]. The wetlands, either natural or constructed, is effective in treating biochemical oxygen demand (BOD), suspended solids, nitrogen, and phosphorus, and also for reducing concentrations of metals, organics, and pathogens [14]. Constructed wetlands have many advantages compared to conventional treatment techniques such as lower total lifetime costs and capital costs, environmentally friendly, tolerate fluctuating in flow and pollutant concentrations, capable of treating multiple or mixed contaminants, provide flood protection, have lower water and air emissions and secondary wastes, can be built to fit into the landscapes, provide habitat for plants and wildlife, provide educational and recreational opportunities [15].

Phytoremediation is a process that uses plants to degrade and remove contaminants from the environment [16]. Generally, phytoremediation of contaminants by a plant involves the following steps: uptake, translocation, transformation, compartmentalization, and sometimes mineralization [17]. Phytoremediation can degrade, remove, transform, or immobilize toxic compounds located in soils, sediments, and more recently in polluted ground water and wastewater in treatment wetlands [18]. The phytoremediation is recognized as a better green remediation and a possible method for the removal of wastewater pollutant [19]. Phytoremediation technology has been used successfully for the remediation of wastewater contaminated and soils contaminated with various pollutants [20]. Phytoremediation is increasingly used as a technological complement for treatment of polluted water in different types of
treatment wetlands [21]. Plants that are chosen to be used in the phytoremediation technique must possess several characteristics such as having high uptake of both organic and inorganic pollutants, and must be able to grow well and quickly in a range of different conditions of the polluted water conducted by (Darajeh et al., 2014) [22] such as *Pennisetum purpureum* (Napier grass). Napier grass (Figure 1) is perennial grass species found in the tropical and subtropical area around the world. This plant contains high morphological variation within the species and known as the fastest growing plant.

![Napier Grass (common Napier)](image)

Napier grass was introduced in Malaysia in 1921 from the East Africa and this grass currently the most popular fodder grass in the dairy and also in feedlot production systems [23]. A study has been conducted by Tayade et al., (2005) [24] where Napier Grass (*Pennisetum clandestinum*) was planted together with broadleaf cattail (*Typha latifolia*) in a horizontal subsurface flow system for the primary-treated municipal wastewater treatment. The objective of this study was to reduce the residual pollutants from biologically treated POME final discharge using the constructed wetland according to river water quality index. The reductions in COD, BOD, TSS and ammonia values have been recorded to determine the effectiveness of constructed wetland.

2. **Materials and method**

2.1. **Start-up of wetland system using Napier grass**

The wetland system was set up as shown in Figure 2. Each tank was constructed from a plastic box approximately 57.5 cm in length, 40.5 cm in height and 38.5 cm in width. These tanks were filled with stones, coarse sand and fine sand with ratio 1:1:1 according to the finding in the parallel study. The ratio is referred to the volume of each sand. The wetland system effluent was collected for the analysis. Napier grasses have been chosen to be observed and to monitor the efficiency of the constructed wetland system in order to remediate and treat the POME final discharge. The planting stock was obtained from the UPM’s farm and was planted at the Biomass Technology Laboratory, UPM. After 2 months, the Napier grass was transferred to the wetland systems. Unless stated otherwise, the study was done in triplicate.

2.2 **Sampling**

POME final discharge was collected from final process of POME treated ponds, Felda Pasoh Palm Oil Mill in Negeri Sembilan. The collected sample was stored in air tight plastic bottles at 4 °C in the chiller to prevent any microbial biodegradation that can affect the experimental result. The POME FD Wetland tanks were topped up with 5L of POME final discharge every day. Whereas the control was set up with
the rain water as the feed 5L every day. The outlet from the system was collected periodically from each tank on the sampling day 3, 6, 9, 12, 15 and 18. The measurement of Napier grass growth evaluation was carried out once per week.

2.3 Analytical procedure
All the water samples were analysed based on the APHA Standard Method for the Examination of Water and Wastewater [25]. COD was measured using COD Digestion Reagent vial. 2 ml of aliquot sample was added into the COD Digestion Reagent vial (Low range or High range were used). The vials containing sample were heated and refluxed for 2 hours. The vials were allowed to cool and measured using HACH DR2800 spectrophotometer (HACH, USA). TSS measurements were carried out by using a spectrophotometer DR 2800 (HACH, USA). 2 ml of sample was poured into sample cell and was measured at wavelengths of 810 nm. Colour measurements were carried out with a spectrophotometer DR 2800 (HACH, USA) at wavelength 455 nm. 2 ml of sample was added to the cell and the absorbance was taken. The amount of ammonia was determined by using Nessler method. 25 mL of the sample was filled to 25 mL of volumetric flask. 3 drop of each Mineral Stabilizer and Polyvinyl Alcohol Dispersing Agent were added to each flask. The sample and blank in the volumetric flask were inverted several times in every addition of reagent. Then 1.0 mL of Nessler Reagent was pipetted into the flask containing the sample. The flask was inverted again. 10 mL of the sample solution was poured into the sample cell and was inserted into the DR 2800. The wavelength used to measure the concentration of ammonia was 425 nm (HACH, USA). The Napier grass plants were evaluated on its growth efficiency by measuring their height.

3. Results and discussion
The system was run for 21 days, with sampling interval of 3 days. After 21 days, the system was stopped and the data were analysed. Figure 3 shows that the concentration of COD reduced from 453 mg/L to 128.8 mg/L from day 3 to day 15. The ability of Napier grass to reduce the concentration of COD has been proved by Klomjek et al., [26] with the removal efficiency of 64 ± 6 %. In this study, the removal was 71.57 %. More interestingly with the addition of the same final discharge everyday, the concentration of COD keeps on reducing. This suggested that there was an increase in the performance of the wetland system in removing the COD.
Furthermore, it was reported that the use of Napier grass in the constructed wetland to treat sewage have reduced COD by 77.51 % [27]. Others also suggested that there was 42 % and 34 % of COD reduction in domestic wastewater for first and second of Napier constructed wetland over a three-month period [28]. The presence of microbes in the system could help to reduce the COD concentration. Previous works discovered that *Pseudomonas* sp is one of the microbes that can be found in the POME [29]. According to Abdirahman Elmi H. [29], the presence of *Pseudomonas aeruginosa* reduces to 58 % of COD value. Besides, the ability of *Pseudomonas* sp. to reduce COD concentration was also proved by Sonune *et al.*, [30] where 60 % of COD reduction from municipal wastewater was achieved.

![Reduction of COD, TSS and Colour](image_url)

**Figure 3.** Reduction of COD, TSS and Colour after 21 days of treatment using constructed wetland system.

There is a reduction in the TSS values. It was shown that the concentration of TSS was consistently reduced from its initial values. The ability of Napier grass to reduce TSS in wastewater was proved by Dhulap *et al.*, [27], which reported that the use of Napier grass in the constructed wetland to treat sewage have reduced TSS by 55.17 %. Furthermore, there are 74 % and 82 % of TSS removal in domestic wastewater for first and second of Napier constructed wetland over a three-month period [28]. According to Vymazal *et al.*, [31], the removal mechanism for the suspended solids in the constructed wetland was by sedimentation and filtration. The particulates were filtered mechanically as water passes through the root masses of the Napier, sand and stones that have been constructed.

The concentration of colour also reduced from day 1 to day 21. The concentration of colour represent in Platinum-Cobalt (Pt-Co) At first, the concentration was recorded at 547.89±94.8 Pt-Co and it reduced to 67.83±33.706 Pt-Co that gave 87.62% removal of colour. Treatment of sewage through constructed wetland using Napier grass had successfully removed the colour and treated the water sample [27]. It was predicted that the colour removal is caused by a non-degradable organic material such as tannin that giving a tea colour to water sample [32] and by using wetland treatment, suspended solid was filtered out resulted in the concentration of colour. In addition, the presence of microbes in the system also helps to reduce colour level. This study was supported by previous study where 60 % of colour removal from POME was achieved by using *Pseudomonas aeruginosa* [29].
Figure 4 shows that the reduction of ammonia after treated in constructed wetland from 0.777 ± 0.102 mg/L to 0.109 ± 0.040 mg/L. This may be caused by nitrification process of the aerobic bacteria in the soil. The microbial metabolic pathways provide a wealth of processes that form or consume N₂O [33].

The aerobic bacteria convert ammonia to nitrate. The process by the microorganism and contributes to the movement of nitrogen through the biogeochemical nitrogen cycle. Ammonia-oxidizing bacteria first oxidize ammonia to nitrate, followed by the oxidation of nitrate by the nitrite-oxidizing bacteria [34]. The nitrates produced by the oxidation of ammonia are a good fertilizer for the plants. This study proven that Napier Grass has shown better growth with the treated POME compares to the rainwater. Figure 5 shows that Napier grass with treated POME has increment in height by 13.94 % compares to rainwater that increases to 11.22 % after 21 days treatment. The element such as nitrogen, phosphorus, potassium, magnesium and calcium which is the vital elements for the plant growth can be obtained in the POME final discharge [35] thus increasing the growth of Napier Grass. The effluent characteristic after the constructed wetland shows the higher reduction of COD, TSS, ammonia and colour with approximately 71.57 %, 83.59 %, 86.03 % and 87.62 % as summarized in Figure 6. All the studied parameters meet the river water quality index except for the COD. In future, the period of the system should be extended to see the efficiency of the treatment system to reduce the COD value to river water quality index.
4. Conclusion
In this study, reduction of pollution concentration in POME final discharge through constructed wetland using Napier grass was performed. Four different physicochemical parameters were analyzed by using standard laboratory methods and procedure which are chemical oxygen demand (COD), colour, total suspended solid and ammonia. Results revealed that this system shows better water quality by reducing the level of COD by 71.57%, TSS by 83.59%, ammonia by 85.97% and colour reduce by 87.62%. The overall results indicated that treatment of treated POME by using Napier grass constructed wetland was successful to reduce the concentration of the contaminant. Besides, the propagation of Napier grass in the treated POME was evaluated. In term of propagation of plant, Napier grass showed an excellent propagation in treating POME and it could be vital elements for the plant growth. All the objective was achieved since all the pollutants were reduced and meet river water quality index except for COD. For recommendation, the system should be run in longer time to reduce the COD.

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Figure 5. Percentage increment of plant height.

Figure 6. The initial and final concentration of COD, TSS, ammonia and colour. All value expressed in mg/L except for Colour that expresses in PtCo.
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