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TREATMENT OF PALM OIL MILL EFFLUENT FINAL DISCHARGE USING NAPIER GRASS WETLAND SYSTEM

NOR FARHANA AZIZ UJANG

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NOR FARHANA AZIZ UJANG

Thesis submitted to School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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Chaiman : Ahmad Muhaimin Roslan, PhD
Faculty : Biotechnology and Biomolecular Sciences

Palm oil mill effluent (POME) is the one of most difficult waste to manage since it is being generated in a large volume most of the time. Treated POME (POME final discharge, POME FD) usually will be discharged to a nearby land or river since it is the easiest and cheapest method to disposal. However, it is common to find that POME final discharge quality does not meet the standard A discharge limit, resulted in unintended pollution towards the rivers. This study has two objectives. The first objective is to determine the effectiveness of constructed wetland system incorporated with the Napier grass to treat POME FD to standard A discharge limit. Second objective is to relate the bacterial community in the constructed wetland system after the treatment of POME FD to physicochemical properties in the effluent of the constructed wetland system. In order to reduce the pollutants level, a modified constructed wetland system with *Pennisteum purpureum* (Napier grass) as phytoremediation agent was introduced in this treatment process. This system is expected to reduce the contaminant in the POME FD to the standard A discharge limit. In this system, Napier grass was chosen due to its fast, rapid regrowth rates and strong responds to nutrient supply. The wetland system was designed to have a combination of 3 layers of soil, sand and rocks. The reason for this combination is to achieve different removal and performance since stone or gravel at the bottom layer served as the supporting layer, coarse sand used in the second layer was main substrate layer. Meanwhile, fine sand at the upper layer was used to facilitate the dispersion of wastewater and growth of plants. From this study, COD, TSS, colour, and ammonia nitrogen were removed by 51.61%, 91.44%, 72.72% and 63.09%, respectively. With this removal, the wastewater successfully achieved standard A limit set by DOE. Reduction of trace elements in POME FD resulting in the better growth of Napier grass in the treatment system. Trace elements such as silica, caesium, rubidium, strontium, magnesium,

manganese and copper reduced by 80.51%, 71.17, 66.07%, 35.56%, 56.81%, 20.81% and 59.27%. Napier grass also managed to reduce the nutrient (macro-nutrient) in the POME FD, such as total nitrogen, phosphorous, potassium and sodium by 54.6%, 91.8%, 75% and 58.46% respectively. From microbial analysis, *Anaerolineaceae* uncultured, *Cyanobacteria* norank, *Acidobacteria* norank and *Nitrosomonadaceae* uncultured were detected in the samples of POME FD and treated POME FD. *Anaerolineaceae* uncultured increased from 0.67% to 13.21%. *Cyanobacteria* norank also shows the increment in the CWs. It increased up to 93.9% in the CWs. At the beginning of this experiment, *Acidobacteria* norank shows only 0.06%, but after 102 day, the population of *Acidobacteria* norank increased to 2.44% that give total 97.54% increment. Lastly is *Nitrosomonadaceae* uncultured. This genus increased from 0.07% to 1.1% and this increment showed a strong prove that nitrification process has occur in the CWs that lead to the decrement of ammonia nitrogen and total nitrogen inside POME FD. As the conclusion, CWs can be used as a treatment method for POME FD since the system is capable to reduce the pollutants level in POME FD down to standard A discharge limit. On the other hand, this research also found that the shift of bacteria from *Nitrosomonadaceae* genus might be supporting the phytoremediation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

RAWATAN PELEPASAN AKHIR EFFLUEN KILANG SAWIT MENGGUNAKAN SISTEM TANAH BENCAH DENGAN RUMPUT NAPIER

Oleh

NOR FARHANA AZIZ UJANG

Februari 2020

Pengerusi : Ahmad Muhaimin Roslan, PhD
Fakulti : Bioteknologi dan Sains Biomolekul

Pelepasan akhir efluen kilang sawit merupakan diantara bahan buangan yang paling sukar untuk dilupuskan kerana ia dihasilkan dalam jumlah yang besar pada sesuatu masa. Pelepasan akhir efluen kilang sawit yang telah dirawat biasanya akan dilepaskan ke kawasan yang berdekatan dengan sungai kerana ia merupakan cara yang mudah dan murah untuk melupuskan pelepasan akhir efluen kilang sawit. Bagaimanapun pelepasan akhir efluen kilang sawit yang dirawat masih tidak mencapai tahap piawaian air sungai dan ini menyebabkan berlakunya pencemaran yang tidak diingini di sungai. Kajian ini mempunyai dua objektif. Objektif pertama ialah untuk mengetahui keberkesanan sistem tanah becah yang dibina dengan kerjasama rumput Napier untuk merawat pelepasan akhir efluen kilang sawit hingga mencapai had pelepasan standard A yang telah ditetapkan oleh jabatan alam sekitar (JAS). Objektif kedua adalah untuk menghubungkan bakteria komuniti didalam sistem tanah becah selepas marawat pelepasan akhir efluen kilang sawit dengan karakteristik yang ada didalam efluen sistem tanah becah. Untuk mengurangkan tahap pencemaran tersebut, sistem tanah bencah buatan manusia dengan proses fitoremediasi telah diperkenalkan dalam kajian ini untuk merawat efluen tersebut. Sistem ini dijangka dapat mengurangkan kekotoran yang ada didalam pelepasan akhir efluen kilang sawit ke had pelepasan standard A. Rumput Napier dipilih kerana sifat dan kemampuanya untuk tumbuh dengan pantas. Selain itu rumput Napier juga mampu bertindak balas dengan bekalan nutrisi untuk pokok. Sistem tanah bencah ini direka dengan kombinasi tiga jenis tanah iaitu batu, pasir kasar dan pasir halus. Antara sebab kenapa kombinasi ini direka adalah untuk mencapai pelbagai pengurangan kotoran didalam sisa air. Ini kerana batu yang diletakkan di bahagian paling bawah berfungsi untuk memberi sokongan fizikal kepada sistem ini. Selain in pasir kasar pula digunakan sebagai bahagian paling utama dalam sistem ini dan yang terakhir sekali

pasir halus. Pasir halus ini digunakan sebagai pertumbuhan pokok yang menyebarkan air ke seluruh sistem. Daripada kajian ini, COD, TSS, warna dan nitrogen ammonia dapat dikurangkan hingga 51.61%, 91.44%, 72.72% dan 63.09%. Dengan pengurangan tersebut, sistem ini berjaya mencapai had piawaian A yg ditetapkan oleh JAS. Melalui proses rawatan ini, unsur surih dapat dikurangkan sekali gus dapat memberikan rumput Napier pertumbuhan serta hasil yang bagus dari rumput Napier yang hidup didalam system ini. Unsur surih seperti silika, cesium, rubidium, strontium, magnesium, mangan dan kuprum dapat dikurang kepada 80.51%, 71.17, 66.07%, 35.56%, 56.81%, 20.81% dan 59.27%. Melalui sistem ini juga, rumput Napier mampu mengurangkan nutrisi yang terdapat didalam air efluen kilang sawit. Antara nutrisi yang dikesan ialah nitrogen, fosforus, kalium dan natrium dan melalui sistem ini, nutrisi tersebut dapat diturunkan sebanyak 54.6%, 91.8%, 75% dan 58.46%. Melalui analisis mikrob yang dijalankan, *Anaerolineaceae* uncultured, *Cyanobacteria* norank, *Acidobacteria* norank dan *Nitrosomonadaceae* uncultured dikesan didalam sampel pelepasan akhir efluen kilang sawit dan sampel pelepasan akhir efluen kilang sawit terawat. *Anaerolineaceae* meningkat dari 0.67% kepada 13.21%. *Cyanobacteria* juga menunjukkan penigkatan didalam system ini apabila meningkat sebanyak 93.9%. Pada permulaan ekperimen ini, *Acidobacteria* hanya 0.06% dapat di kesan didalam sistem ini tetapi selepas 102 menjalankan uji kaji ini, populasi *Acidobacteria* didalam sistem ini meningkat kepada 2.44% yang memberi peningkatan sebanyak 97.54%. Terakhir sekali ialah *Nitrosomonadaceae*.Genus ini meningkat dari 0.07% kepada 1.1% dan peningkatan ini menunjukan bukti yang kukuh terdapat proses nitrifikasi berlaku didalam sistem ini yang membawa kepada pengurangan ammonia nitrogen dan nitrogen total didalam pelepasan akhir ini. Kesimpulanya, sistem tanah becah ini boleh digunakan sepagai salah satu cara untuk merawat pelepasan akhir efluent kepala sawit kerasa sistem ini mampu mengurankan kekotoran didalam pelepasan akhir ini kepada had piawaian A yg ditetapkan oleh JAS. Selain itu, kajian ini juga menjumpai bakteria dari *Nitrosomonadaceae* genus yang mungkin membantu proses fotoremidiasi.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Ahmad Muhaimin Roslan, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Mohd Ali Hassan, PhD
Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Member)

Juferi Idris, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Member)

Mohd Izuan Effendi Halmi, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: Dr. Ahmad Muhaimin Roslan

Signature: _____
Name of Member of Supervisory Committee: Prof. Dato' Dr. Mohd Ali Hassan

Signature: _____
Name of Member of Supervisory Committee: Dr. Juferi Idris

Signature: _____
Name of Member of Supervisory Committee: Dr. Mohd Izuan Effendi Halmi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NH_3N	Ammonia nitrogen
NH_4-N	Ammonium nitrogen
AN	Ammoniacal nitrogen
et al.,	And friends
APHA	American Public Health Association
BOD	Biological oxygen demand
BTC	Biomass Technology Centre
COD	Chemical oxygen demand
CWs	Constructed wetland system
DOE	Department of Environment
DO	Dissolved oxygen
EFB	Empty fruit brunch
EPA	Environmental Protection Agency
FWS	Free water surface
HF	Horizontal flow
HRT	Hydraulic retention time
O&G	Oil and grease
OPB	Oil palm biomass
OPF	Oil palm frond
OPKS	Oil palm kernel shell
OPT	Oil palm trunk
MPOC	Malaysia Palm Oil Council
N	Nitrogen
N2	Nitrogen gas
NO_2-N	Nitrite-nitrogen

NO	Nitric oxide
N2O	Nitrous oxide
PK	Palm kernel
POME	Palm oil mill effluent
POME FD	Palm oil mill effluent final discharge
P	Phosphorus
SS	Suspended solids
SSF	Subsurface flow
TS	Total solids
TDS	Total dissolved solids
TN	Total nitrogen
TSS	Total suspended solids
VF	Vertical flow

CHAPTER 1

INTRODUCTION

The two major industries in Malaysia can be divided into resource-based industries and non-resource based industries (Singh et al., 2010). The resource based industries include products from rubber, palm oil, wood, and petrochemicals. On the other hand, the non-resource based industries include electronic and electrical products, machinery and engineering products, and textiles. A key contributing factor of Malaysia's leading resource-based industry is due to the country's abundant natural resources. This allows for major commercial cultivation of crops such as rubber and palm oil. Thus, Malaysia has become the world second largest producer of palm oil, the third largest for rubber and fourth largest for cocoa exporters (Singh et al., 2010).

In Malaysia, palm oil industry is the second largest resource-based industry (Gan and Li, 2014). The industry takes up more than 3.79 million hectares of land; occupying more than one-third of the total cultivated areas in the country (Yusoff and Hansen, 2007). According to Faizal (2014), 11% of Malaysian land accounted for oil palm plantation area. Consequently, Malaysia is able to mass produce palm oil every year, resulting into production of more than 13 million tons of crude palm oil yearly (Abdullah and Sulaim, 2013). The rapid development of palm oil industry in Malaysia contributed to the substantial growth of economy, however, it comes with a concerning drawback towards the environment. This is because the abundance of wastes produced from the palm oil processing are the major problem since the oil palm production produces a lot of wastes. The by-product of the production of crude palm oil (CPO) are empty fruit bunch(EFB), oil palm fronds (OPF), oil palm trunks (OPT), oil palm mesocarp fibers (OPMF), palm kernel shells, palm kernel cake, and liquid discharge which are palm oil mill effluent (POME) (Singh et al., 2010). However, amongst the waste mentioned above, the liquid discharge is the most costly and a crucial waste to manage since it is make up in huge volume (in tons at a time) (Madaki and Lau, 2013). In addition, POME is considered the most harmful waste produced if release untreated (Rupani et al.,2010; Singh et al., 2010).

Discharge of the wastewater and other byproducts may cause environmental problem if they were not treated properly before being discharged to the environment (Rupani et al., 2010). Palm oil mills used to burn the EFB to produce oil palm ash, but the practice is considered illegal by the government since it caused huge pollution hazard (Abdullah and Sulaim, 2013). Presently, palm oil mills in this country burn the waste biomass in a boiler to generate energy for the operation of the mills itself (Ali, et al., 2015). POME on the other hand, was treated using a ponding system since it's less

costly and is capable to reduce the pollutants generated. The treated POME (final discharge) will be released to a neighbouring land or river since it is a simple and low-cost method of disposal (Madaki and Lau, 2013).

The treated POME from most of the mill in Malaysia still does not comply to the standard discharge limit set by the government (Department of Environment, 2010). It still consists of great chemical oxygen demand (COD) and suspended solids (SS) content compared to the river water (Ibrahim et al., 2017). The high concentration of COD and the visible colour of palm oil mill effluent final discharge (POMEFD) will raise the risk of eutrophication and lower down the quality of river water. The best way to solve the POME FD problem is to treat the liquid waste from the mill by reducing the quantity of contaminants in the wastewater, thus, decreasing the adverse effects towards the environment. The optimal goal is to treat the wastewater to standard A discharge limit and then, having the treated wastewater reuse back to the mill as fuel water. This was the concept recommended by Othman et al., (2014), where the water from POMEFD that accomplish river water quality was reused as recycled water in zero emission system. From previous studies, it was found that the POME FD can be successfully treated using commercial activated carbon from oil palm biomass. However this process is expensive since the cost for commercial activated carbon was high. In addition, the activated carbon produce from palm oil biomass using carbonization and activation reactor using the boiler is also quite expensive. Not only that, the process also requires more energy to generate the reactor (Ibrahim et al., 2017). Therefore, the treatment of POME FD needs a cheaper alternative in order to make the palm oil production more viable while preserving the quality of the environment.

A more environmentally conscious way to treat POME is through phytoremediation. According to Greipsson, (2015), phytoremediation basically is the operation of plants, associated with the soil microbes in decreasing the concentrations or the toxic effects of contaminants in their environment. The study also suggested that the technology has been widely accepted as it is cost competent. Phytoremediation can be used to remove contaminants because the plants has the ability to take up contaminants from environment and accomplish the detoxification of the compounds using various mechanisms (Ali et al., 2013). Other ways to apply phytoremediation is through a wetland system to treat POME FD. This is because a wetland system is an energy saving and green way to solve the pollution issue as compared to the previous method discussed before. A wetland system is a biological approach that can give less side effects to the environment compared to the chemical approach and it is more cost efficient (Lone et al., 2008).

Constructed wetlands are widely used in wastewater treatment throughout the world. Not only that, the vegetation from these systems can also be used

for raw material production (Maddison et al., 2009). Plant from constructed wetlands has the ability to accelerate the development of microbial communities and promote living environments around roots like aerobic and anaerobic alternant environments. It was also assumed that the plants play a central role in sludge treatment wetlands (STWs) by preventing clogging, favoring dewatering and improving sludge mineralization (Vymazal, 2013). 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 (Vymazal, 2010). Thus, choosing the most suitable plants for the wetland system is the key in improving the effectiveness of the treatment.

Plants that were chosen 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 rapidly in a range of different conditions of the polluted water (Darajeh et al., 2014). One of the suitable plants to be used as a phytoremediator is *Pennisetum purpureum* (Napier grass). Napier grass is perennial grass species that can be found in the tropical and subtropical areas around the world. This plant contains high morphological variation within the species and is known as the fastest growing plant. A study has been conducted by (Tayade et al., 2005) where they have planted Napier Grass (*Pennisetum purpureum*) together with broadleaf cattail (*Typha latifolia*) in a horizontal subsurface flow system for the primary-treated municipal wastewater treatment and the result from the study showed a great removal of chemical oxygen demand (COD) in primary-treated municipal wastewater. Therefore, Napier Grass is a choice phytoremediator to be applied in a treatment wetland system.

However, various designs of constructed wetland (CW) systems with various types of waste water have been studied, but no study using POME FD as feed for the constructed wetland system has been conducted. As such, this research is expected to be able to produce the constructed wetland system using Napier grass to efficiently reduce residual pollutants from the final discharge to standard A discharge limit by DOE. The constructed wetland system is also expected to be stable and able to grow the Napier grass robustly. Therefore, the overall objective of this study is to reduce the residual pollutants from biologically treated POME final discharge using the Napier grass constructed wetland to standard A discharge limit effectively.

The other component of wetlands is microorganisms and it has been proven to be the one that help on the removal of pollutants in CW such as nitrogen, organic matter, industrial organic pollutants and emerging organic contaminants (Zhang et al., 2015; Lin et al., 2012; Fernandes et al., 2015). Nowadays, investigation of microorganism in CWs for the treatment of wastewater was increased to get a fully understanding of the removal of the pollutant and its mechanisms (Lv et al., 2017). The microbial communities

REFERENCES

Abas, R., Kamarudin, M.F., Nordin, A., Simeh, M.A., 2011. A Study on the Malaysian Oil Palm Biomass Sector – Supply and Perception of Palm Oil Millers. Oil Palm Ind. Econ. J. 11, 28–41. https://doi.org/10.1146/annurev-marine-121211-172337

Abdirahman Elmi, H.S., 2015. Colour and COD Removal from Palm Oil Mill Effluent (POME) Using *Pseudomonas aeruginosa* Strain NCIM 5223 in Microbial Fuel Cell. Int. J. Waste Resour. 05, 3–5. https://doi.org/10.4172/2252-5211.1000181

Abdullah, N., Sulaim, F., 2013. The Oil Palm Wastes in Malaysia. Biomass Now - Sustain. Growth Use. https://doi.org/10.5772/55302

Ahmad, A.L., Ismail, S., Bhatia, S., 2003. Water recycling from palm oil mill effluent (POME) using membrane technology. Desalination 157, 87–95. https://doi.org/10.1016/S0011-9164(03)00387-4

Ali, A.A.M., Othman, M.R., Shirai, Y., Hassan, M.A., 2015. Sustainable and integrated palm oil biorefinery concept with value-addition of biomass and zero emission system. J. Clean. Prod. 91, 96–99. https://doi.org/10.1016/j.jclepro.2014.12.030

Ali, H., Khan, E., Sajad, M.A., 2013. Phytoremediation of heavy metals-Concepts and applications. Chemosphere. https://doi.org/10.1016/j.chemosphere.2013.01.075

APHA/AWWA/WEF, 2012. Standard Methods for the Examination of Water and Wastewater. Stand. Methods 541. https://doi.org/ISBN 9780875532356

Arias, C.A., Becares, E., Garrido, L., Mas, J., 2014. ScienceDirect Microbial communities from different types of natural wastewater treatment systems : Vertical and horizontal flow constructed wetlands and biofilters. https://doi.org/10.1016/j.watres.2014.02.011

Arroyo, P., Sáenz de Miera, L.E., Ansola, G., 2015. Influence of environmental variables on the structure and composition of soil bacterial communities in natural and constructed wetlands. Sci. Total Environ. 506–507, 380–390. https://doi.org/10.1016/j.scitotenv.2014.11.039

Azmi, N.S., Md Yunos, K.F., Baharuddin, A.S., Dom, Z.M., 2013. The effect of operating parameters on ultrafiltration and reverse osmosis of palm oil mill effluent for reclamation and reuse of water. BioResources 8, 76–87. https://doi.org/10.15376/biores.8.1.76-87

Baharuddin, A.S., Hock, L.S., Yusof, M.Z., Abdul, N.A., Shah, U., Hassan, M.A., Wakisaka, M., Sakai, K., Shirai, Y., 2010. The effect of palm oil mill effluent (POME) anaerobic sludge from 500 m 3 of closed anaerobic methane digested tank on pressed-shredded empty fruit bunch (EFB) composting process. African J. Biotechnol. 9, 2427–2436. https://doi.org/10.5897/AJB10.1418

Bala, J.D., Lalung, J., Ismail, N., 2014. Palm Oil Mill Effluent (POME) Treatment "'Microbial Communities in an Anaerobic Digester'": A Review. Int. J. Sci. Res. Publ. 4, 1–24.

Butterbach-Bahl, K., Baggs, E.M., Dannenmann, M., Kiese, R., Zechmeister-Boltenstern, S., 2013. Nitrous oxide emissions from soils: how well do we understand the processes and their controls? Philos. Trans. R. Soc. B Biol. Sci. 368, 20130122–20130122. https://doi.org/10.1098/rstb.2013.0122

Calheiros, C.S.C., Rangel, A.O.S.S., Castro, P.M.L., 2008. The effects of tannery wastewater on the development of different plant species and chromium accumulation in Phragmites australis. Arch. Environ. Contam. Toxicol. 55, 404–414. https://doi.org/10.1007/s00244-007-9087-0

Canfield, D.E., Glazer, A.N., Falkowski, P.G., 2010. WEEK 2_REVIEW The Evolution and Future of Earth ' s Nitrogen Cycle 2–6.

Currie, H.A., Perry, C.C., 2007. Silica in plants: Biological, biochemical and chemical studies. Ann. Bot. 100, 1383–1389. https://doi.org/10.1093/aob/mcm247

Darajeh, N., Idris, A., Truong, P., Abdul Aziz, A., Abu Bakar, R., Che Man, H., 2014. Phytoremediation potential of Vetiver system technology for improving the quality of palm oil mill effluent. Adv. Mater. Sci. Eng. 2014. 1-10 https://doi.org/10.1155/2014/683579

Davis, L., 2005. A handbook of constructed wetlands. Washigt. DC USDA - NRCS EPA 1, 53.

Department of Environment, 2010. Environmental Requirements: A Guide For Investors. Minist. Nat. Resour. Environ. 1–78.

Dhulap, V.P., Patil, S.S., 2014. Removal of Pollutants from Sewage through Constructed Wetland using *Pennisetum purpureium* Introduction : The constructed wetlands are basically manmade or human septic tanks or ponds systems with inefficient treatment . Siedel 2005. In 1970 ' s and 1980 II, 543–558.

Dickinson, N., 2016. Phytoremediation. Encycl. Appl. Plant Sci. 3, 327–331. https://doi.org/10.1016/B978-0-12-394807-6.00016-2

Din, A.K., 2017. Malaysian Oil Palm Industry Performance 2016 and Prospects for 2017.

DNesay PowerMax Soil kit handbook, 2017. 1–14.

Eapen, S., Singh, S., D'Souza, S.F., 2007. Advances in development of transgenic plants for remediation of xenobiotic pollutants. Biotechnol. Adv. 25, 442–451. https://doi.org/10.1016/j.biotechadv.2007.05.001

Faulwetter, J.L., Gagnon, V., Sundberg, C., Chazarenc, F., Burr, M.D., Brisson, J., Camper, A.K., Stein, O.R., 2009. Microbial processes influencing performance of treatment wetlands: A review. Ecol. Eng. 35, 987–1004. https://doi.org/10.1016/j.ecoleng.2008.12.030

Feng, Z., Sun, T., 2015. A novel selective hybrid cation exchanger for low-concentration ammonia nitrogen removal from natural water and secondary wastewater. Chem. Eng. J. 281, 295–302. https://doi.org/10.1016/j.cej.2015.06.052

Gan, P.Y., Li, Z.D., 2014. Econometric study on Malaysias palm oil position in the world market to 2035. Renewable & Sustainable Energy Reviews. 39 740–747. https://doi.org/10.1016/j.rser.2014.07.059

Ge, Z., Wei, D., Zhang, J., Hu, J., Liu, Z., Li, R., 2019. Natural pyrite to enhance simultaneous long-term nitrogen and phosphorus removal in constructed wetland: Three years of pilot study. Water Res. 148, 153–161. https://doi.org/https://doi.org/10.1016/j.watres.2018.10.037

Ghaly, A.E., Kamal, M.A., Mahmoud, N.S., Cote, R., 2007. Treatment of landfill leachate using limestone/sandstone filters under aerobic batch conditions. Am. J. Environ. Sci. 3, 43–53. https://doi.org/10.3844/ajessp.2007.43.53

Greipsson, S., 2015. Phytoremediation.

Halim, R.A., Shampazuraini, Idris, A.B., 2013. Yield and nutritive quality of nine napier grass varietas in Malaysia. Malaysian Soc. Anim. Prod. 16, 37–44.

Ibekwe, A.M., Ma, J., Murinda, S.E., 2016. Science of the Total Environment Bacterial community composition and structure in an Urban River impacted by different pollutant sources. Sci. Total Environ. 566–567, 1176–1185. https://doi.org/10.1016/j.scitotenv.2016.05.168

Ibrahim, I., Hassan, M.A., Abd-Aziz, S., Shirai, Y., Andou, Y., Othman, M.R., Ali, A.A.M., Zakaria, M.R., 2017. Reduction of residual pollutants from biologically treated palm oil mill effluent final discharge by steam activated bioadsorbent from oil palm biomass. J. Clean. Prod. 141, 122–127. https://doi.org/10.1016/j.jclepro.2016.09.066

Imfeld, G., Braeckevelt, M., Kuschk, P., Richnow, H.H., 2009. Monitoring and assessing processes of organic chemicals removal in constructed wetlands. Chemosphere 74, 349–362. https://doi.org/10.1016/j.chemosphere.2008.09.062

Jadia, C.D., Fulekar, M.H., 2008. Phytotoxicity and remediation of heavy metals by fibrous root grass (sorghum). J. Appl. Biosceiences 10, 491–499.

Jasrotia, S., Kansal, A., Mehra, A., 2017. Performance of aquatic plant species for phytoremediation of arsenic-contaminated water. Appl. Water Sci. 7, 889–896. https://doi.org/10.1007/s13201-015-0300-4

Kaman, S., Tan, I., Lim, L., 2017. Palm oil mill effluent treatment using coconut shell–based activated carbon: Adsorption equilibrium and isotherm. MATEC Web 87, 3009. https://doi.org/10.1051/matecconf/20178703009

Klomjek, P., 2016. Swine wastewater treatment using vertical subsurface flow constructed wetland planted with Napier grass. Sustain. Environ. Res. 26, 217–223. https://doi.org/10.1016/j.serj.2016.03.001

Korndörfer, G.H., Lepsch, I., 2001. Effect of silicon on plant growth and crop yield. Stud. Plant Sci. 8, 133–147. https://doi.org/10.1016/S0928-3420(01)80011-2

Krämer, U., Talke, I.N., Hanikenne, M., 2007. Transition metal transport. FEBS Lett. 581, 2263–2272. https://doi.org/10.1016/j.febslet.2007.04.010

Krzmarzick, M.J., Crary, B.B., Harding, J.J., Oyerinde, O.O., Leri, A.C., Myneni, S.C.B., 2012. Natural Niche for Organohalide-Respiring Chloroflexi. American Society for Microbiology Journal. 393–401. https://doi.org/10.1128/AEM.06510-11

Lam, M.K., Lee, K.T., 2011. Renewable and sustainable bioenergies production from palm oil mill effluent (POME): Win-win strategies toward better environmental protection. Biotechnol. Adv. 29, 124–141. https://doi.org/10.1016/j.biotechadv.2010.10.001

Levy-Booth, D.J., Prescott, C.E., Grayston, S.J., 2014. Microbial functional genes involved in nitrogen fixation, nitrification and denitrification in forest ecosystems. Soil Biol. Biochem. 75, 11–25. https://doi.org/10.1016/j.soilbio.2014.03.021

Liew, W.L., Kassim, M.A., Muda, K., Loh, S.K., Affam, A.C., 2014. Conventional methods and emerging wastewater polishing technologies for palm oil mill effluent treatment: A review. J. Environ. Manage. 149, 222–235. https://doi.org/10.1016/j.jenvman.2014.10.016

Liu, F., Huang, G., Fallowfield, H., Guan, H., Zhu, L., Hu, H., 2014. Study on Heterotrophic-Autotrophic Denitrification Permeable Reactive Barriers (HAD PRBs) for In Situ Groundwater Remediation. SpringerBriefs in Water Science and Technology. https://doi.org/10.1007/978-3-642-38154-6

Liu, X., Zhang, Y., Li, X., Fu, C., Shi, T., Yan, P., 2018. Effects of influent nitrogen loads on nitrogen and COD removal in horizontal subsurface flow constructed wetlands during different growth periods of Phragmites australis. Sci. Total Environ. 635, 1360–1366. https://doi.org/10.1016/j.scitotenv.2018.03.260

Loh, S.K., Ngatiman, M., Lim, W.S., Choo, Y.M., 2014. A Zero Discharge Treatment System Of Palm Oil Mill Effluent. Malaysian Palm Oil Board Inf. Ser. 657, 6–9.

Lone, M.I., He, Z., Stoffella, P.J., Yang, X., 2008. Phytoremediation of heavy metal polluted soils and water: Progresses and perspectives. J. Zhejiang Univ. Sci. B 9, 210–220. https://doi.org/10.1631/jzus.B0710633

Lv, T., Carvalho, P.N., Zhang, L., Zhang, Y., Button, M., Arias, C.A., Weber, K.P., Brix, H., 2017. Functionality of microbial communities in constructed wetlands used for pesticide remediation: Influence of system design and sampling strategy. Water Res. 110, 241–251. https://doi.org/10.1016/j.watres.2016.12.021

Ma, C., Ming, H., Lin, C., Naidu, R., Bolan, N., 2016. Phytoextraction of heavy metal from tailing waste using Napier grass. Catena 136, 74–83. https://doi.org/10.1016/j.catena.2015.08.001

Madaki, Y.S., Lau, S., 2013. Palm oil Effluent (POME) from Malaysia Palm Oil Mills: Waste or Resource. Int. J. Sci. Environ. Technol. 2, 1138–1155.

Maddison, M., Soosaar, K., Mauring, T., Mander, Ü., 2009. The biomass and nutrient and heavy metal content of cattails and reeds in wastewater treatment wetlands for the production of construction material in Estonia. Desalination 246, 120–128. https://doi.org/10.1016/j.desal.2008.02.040

Mander, Ü., Tournebize, J., Kasak, K., Mitsch, W.J., 2014. Climate regulation by free water surface constructed wetlands for wastewater treatment and created riverine wetlands. Ecol. Eng. 72, 103–115. https://doi.org/10.1016/j.ecoleng.2013.05.004

Mba, O.I., Dumont, M.J., Ngadi, M., 2015. Palm oil: Processing, characterization and utilization in the food industry - A review. Food Biosci. 10, 26–41. https://doi.org/10.1016/j.fbio.2015.01.003

Mohammed, R.R., Chong, M.F., 2014. Treatment and decolorization of biologically treated Palm Oil Mill Effluent (POME) using banana peel as novel biosorbent. J. Environ. Manage. 132, 237–249. https://doi.org/10.1016/j.jenvman.2013.11.031

Mohd Udaiyappan, A.F., Abu Hasan, H., Takriff, M.S., Sheikh Abdullah, S.R., 2017. A review of the potentials, challenges and current status of microalgae biomass applications in industrial wastewater treatment. J. Water Process Eng. 20, 8–21. https://doi.org/10.1016/j.jwpe.2017.09.006

MPOC 2012 The Oil Palm Tree, n.d.

Muhrizal, S., Shamshuddin, J., Fauziah, I., Husni, M.A.H., 2006. Changes in iron-poor acid sulfate soil upon submergence. Geoderma 131, 110–122. https://doi.org/10.1016/j.geoderma.2005.03.006

Obarska-Pempkowiak, H., Klimkowska, K., 1999. Distribution of nutrients and heavy metals in a constructed wetland system. Chemosphere 39, 303–312. https://doi.org/10.1016/S0045-6535(99)00111-3

Othman, M.R., Hassan, M.A., Shirai, Y., Baharuddin, A.S., Ali, A.A.M., Idris, J., 2014. Treatment of effluents from palm oil mill process to achieve river water quality for reuse as recycled water in a zero emission system. J. Clean. Prod. 67, 58–61. https://doi.org/10.1016/j.jclepro.2013.12.004

Peralta, R.M., Ahn, C., Gillevet, P.M., 2013. Characterization of soil bacterial community structure and physicochemical properties in created and natural wetlands. Sci. Total Environ. 443, 725–732. https://doi.org/10.1016/j.scitotenv.2012.11.052

Rezania, S., Ponraj, M., Talaiekhozani, A., Mohamad, S.E., Md Din, M.F., Taib, S.M., Sabbagh, F., Sairan, F.M., 2015. Perspectives of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in wastewater. J. Environ. Manage. 163, 125–133. https://doi.org/10.1016/j.jenvman.2015.08.018

Roslan, A.M., Mohd Zahari, M.A.K., Hassan, M.A., Shirai, Y., 2014. Investigation of Oil Palm Frond Properties for Use as Biomaterials and Biofuels. Trop. Agric. Dev. 58, 26–29. https://doi.org/10.11248/jsta.58.26

Rousseau, D.P.L., Lesage, E., Story, A., Vanrolleghem, P.A., Pauw, N. De, 2008. Constructed wetlands for water reclamation. Desalination 218, 181–189. https://doi.org/10.1016/j.desal.2006.09.034

Rupani, P.F., Rajeev, P.S., Irahim, M.H., Esa, N., 2010. Review of Current Palm Oil Mill Effluent (POME) Treatment Methods: Vermicomposting as a Sustainable Practice. World Applied Sciences Journal. 11, 70–

81. https://doi.org/10.5539/jas.v7n4p68

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. J. Environ. Manage. 112, 429–448. https://doi.org/10.1016/j.jenvman.2012.08.011

Sambanthamurthi, R., Sundram, K., Tan, Y.A., 2000. Chemistry and biochemistry of palm oil. Prog. Lipid Res. https://doi.org/10.1016/S0163-7827(00)00015-1

Schachtman, D., Liu, W., 1999. Molecular pieces to the puzzle of the interaction between potassium and sodium uptake in plants. Trends Plant Sci. 4, 281–287. https://doi.org/10.1016/S1360-1385(99)01428-4

Schachtman, D.P., Reid, R.J., Ayling, S.M., 1998. Phosphorus Uptake by Plants: From Soil to Cell. Plant Physiol. 116, 447–453. https://doi.org/10.1104/pp.116.2.447

Singh, R.P., Ibrahim, M.H., Esa, N., Iliyana, M.S., 2010. Composting of waste from palm oil mill: A sustainable waste management practice. Rev. Environ. Sci. Biotechnol. 9, 331–344. https://doi.org/10.1007/s11157-010-9199-2

Sonune, N.A., Garode, A.M., 2015. Bioremediation Potential of Bacterial Isolates for Municipal Wastewater Treatment. Curr. World Environ. 10, 619–625. https://doi.org/10.12944/CWE.10.2.27

Stottmeister, U., Wießner, A., Kuschk, P., Kappelmeyer, U., Kästner, M., Bederski, O., Müller, R.A., Moormann, H., 2003. Effects of plants and microorganisms in constructed wetlands for wastewater treatment. Biotechnol. Adv. 22, 93–117. https://doi.org/10.1016/j.biotechadv.2003.08.010

Susarla, S., Medina, V.F., Mccutcheon, S.C., 2002. <Phytoremediation an ecological solution to organic chemical contamination. 18, 647–658. https://doi.org/10.1016/S0925-8574(02)00026-5

Tan, K.T., Lee, K.T., Mohamed, A.R., Bhatia, S., 2009. Palm oil: Addressing issues and towards sustainable development. Renew. Sustain. Energy Rev. 13, 420–427. https://doi.org/10.1016/j.rser.2007.10.001

Tarmizi, A.H.A., Ismail, R., Kuntom, A., 2016. Effect of frying on the palm oil quality attributes-A review. J. Oil Palm Res. 28, 143–153. https://doi.org/10.21894/jopr.2016.2802.01

Tayade, S.T., Ojha, A.R., Kumar, R., Singh, R.N., 2005. Feasibility study of constructed wetland for treatment of municipal wastewater. Green Pages, Dir. Environ. Technol.

Tilak, A.S., Wani, S.P., Patil, M.D., Datta, A., 2016. Evaluating wastewater treatment efficiency of two field scale subsurface flow constructed wetlands. Curr. Sci. 110, 1764–1772. https://doi.org/10.18520/cs/v110/i9/1764-1772

Truu, J., Truu, M., Espenberg, M., Nõlvak, H., Juhanson, J., 2015. Phytoremediation And Plant-Assisted Bioremediation In Soil And Treatment Wetlands: A Review. Open Biotechnol. J. 9, 85–92. https://doi.org/10.2174/1874070720150430E009

Udom, I.J., Mbajiorgu, C.C., Oboho, E.O., 2018. Development and evaluation of a constructed pilot-scale horizontal subsurface flow wetland treating piggery wastewater. Ain Shams Eng. J. 9, 3179–3185. https://doi.org/10.1016/j.asej.2018.04.002

Vymazal, J., 2013. Plants in constructed, restored and created wetlands. Ecol. Eng. 61, 501–504. https://doi.org/10.1016/j.ecoleng.2013.10.035

Vymazal, J., 2010. Constructed Wetlands for Wastewater Treatment. Water 2, 530–549. https://doi.org/10.3390/w2030530

Vymazal, J., Brix, H., Cooper, P.F., Haberl, R., Perfler, R., Laber, J., 1998. Removal mechanisms and types of constructed wetlands. Constr. Wetl. wastewater Treat. Eur.

Wang, J., Tai, Y., Man, Y., Wang, R., Feng, X., Yang, Yufen, Fan, J., Guo, J.J., Tao, R., Yang, Yang, Chen, Z., Vymazal, J., Cai, N., 2018. Capacity of various single-stage constructed wetlands to treat domestic sewage under optimal temperature in Guangzhou City, South China. Ecol. Eng. 115, 35–44. https://doi.org/10.1016/j.ecoleng.2018.02.008

Weber, K.P., Gagnon, V., 2015. Microbiology in Treatment Wetlands.

Wu, H., Zhang, J., Ngo, H.H., Guo, W., Hu, Z., Liang, S., Fan, J., Liu, H., 2015. A review on the sustainability of constructed wetlands for wastewater treatment: Design and operation. Bioresour. Technol. 175, 594–601. https://doi.org/10.1016/j.biortech.2014.10.068

Wu, T.Y., Mohammad, A.W., Jahim, J.M., Anuar, N., 2010. Pollution control technologies for the treatment of palm oil mill effluent (POME) through end-of-pipe processes. J. Environ. Manage. 91, 1467–1490. https://doi.org/10.1016/j.jenvman.2010.02.008

WWF, 2002. The palm oil industry in Malaysia: From seed to frying pan. Wwf 145.

Xu, D., Liu, S., Chen, Q., Ni, J., 2017. Microbial community compositions in different functional zones of Carrousel oxidation ditch system for domestic wastewater treatment. AMB Express. 7:40 https://doi.org/10.1186/s13568-017-0336-y

Yacob, S., Ali Hassan, M., Shirai, Y., Wakisaka, M., Subash, S., 2006a. Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment. Sci. Total Environ. 366, 187–196. https://doi.org/10.1016/j.scitotenv.2005.07.003

Yacob, S., Shirai, Y., Hassan, M.A., Wakisaka, M., Subash, S., 2006b. Start-up operation of semi-commercial closed anaerobic digester for palm oil mill effluent treatment. Process Biochem. 41, 962–964. https://doi.org/10.1016/j.procbio.2005.10.021

Yalcuk, A., Ugurlu, A., 2009. Bioresource Technology Comparison of horizontal and vertical constructed wetland systems for landfill leachate treatment. Bioresour. Technol. 100, 2521–2526. https://doi.org/10.1016/j.biortech.2008.11.029

Yang, Q., Xiong, P., Ding, P., Chu, L., Wang, J., 2015. Bioresource Technology Treatment of petrochemical wastewater by microaerobic hydrolysis and anoxic / oxic processes and analysis of bacterial diversity. Bioresour. Technol. 196, 169–175. https://doi.org/10.1016/j.biortech.2015.07.087

Yu, C., Wang, Y., Guo, T., Shen, W., Gu, M., 2012. Isolation and Identification of Ammonia Nitrogen Degradation Strains from Industrial Wastewater 2012, 790–793.

Yusoff, S., Hansen, S.B., 2007. Feasibility study of performing an life cycle assessment on crude palm oil production in Malaysia. Int. J. Life Cycle Assess. 12, 50–58. https://doi.org/10.1065/lca2005.08.226

Zahari, M.A.K.M., Abdullah, S.S.S., Roslan, A.M., Ariffin, H., Shirai, Y., Hassan, M.A., 2014. Efficient utilization of oil palm frond for bio-based products and biorefinery. J. Clean. Prod. 65, 252–260. https://doi.org/10.1016/j.jclepro.2013.10.007

Zain, N.M., Yew, O.H., Sahid, I., Seng, C.T., 2013. Potential of Napier grass *(Pennisetum purpureum)* extracts as a natural herbicide. Pakistan J. Bot. 45, 2095–2100.

Zakaria, M.R., Hirata, S., Hassan, M.A., 2015. Hydrothermal pretreatment enhanced enzymatic hydrolysis and glucose production from oil palm biomass. Bioresour. Technol. 176, 142–148. https://doi.org/10.1016/j.biortech.2014.11.027

Zakaria, S., Ahmadzadeh, A., Roslan, R., 2013. Flow properties of novolak-type resin made from liquefaction of oil palm empty fruit bunch (EFB) fibres using sulfuric acid as a catalyst. BioResources 8, 5884–5894. https://doi.org/10.15376/biores.8.4.5884-5894

Zhang Xiaojing Liang, Yuhai Ma, Yongpeng Du, Jingjing Pang, Long Zhang, Hongzhong, X.Z., 2016. Ammonia removal and microbial characteristics of partial nitrification in biofilm and activated sludge treating low strength sewage at low temperature. Ecol. Eng. v. 93, 104-111–2016 v.93. https://doi.org/10.1016/j.ecoleng.2016.05.016

Zhang, B.Y., Zheng, J.S., Sharp, R.G., 2010. Phytoremediation in engineered wetlands: Mechanisms and applications. Procedia Environ. Sci. 2, 1315–1325. https://doi.org/10.1016/j.proenv.2010.10.142

ZHANG, X. bin, LIU, P., YANG, Y. suo, CHEN, W. ren, 2007. Phytoremediation of urban wastewater by model wetlands with ornamental hydrophytes. J. Environ. Sci. 19, 902–909. https://doi.org/10.1016/S1001-0742(07)60150-8

Zhang, C., Simpson, R.J., Kim, C.M., Warthmann, N., Delhaize, E., Dolan, L., Byrne, M.E., Wu, Y., Ryan, P.R., 2018. Do longer root hairs improve phosphorus uptake? Testing the hypothesis with transgenic Brachypodium distachyon lines overexpressing endogenous RSL genes. New Phytol. 217, 1654–1666. https://doi.org/10.1111/nph.14980

Zhang, J., Sun, H., Wang, W., Hu, Z., Yin, X., Ngo, H.H., Guo, W., Fan, J., 2017. Enhancement of surface flow constructed wetlands performance at low temperature through seasonal plant collocation. Bioresour. Technol. 224, 222–228. https://doi.org/10.1016/j.biortech.2016.11.006

Zhang, J.L., Flowers, T.J., Wang, S.M., 2010. Mechanisms of sodium uptake by roots of higher plants. Plant Soil 326, 45–60. https://doi.org/10.1007/s11104-009-0076-0

Zhang, W., Fu, R., Wang, L., Zhu, J., Feng, J., Yan, W., 2019. Science of the Total Environment Rapid removal of ammonia nitrogen in low-concentration from wastewater by amorphous sodium titanate nano-particles. Sci. Total Environ. 668, 815–824. https://doi.org/10.1016/j.scitotenv.2019.03.051

Zhang, X., Hu, Z., Ngo, H.H., Zhang, J., Guo, W., Liang, S., Xie, H., 2018a. Simultaneous improvement of waste gas purification and nitrogen removal using a novel aerated vertical flow constructed wetland. Water Res. 130, 79–87. https://doi.org/10.1016/j.watres.2017.11.061

Zhang, X., Hu, Z., Zhang, J., Fan, J., Ngo, H.H., Guo, W., Zeng, C., Wu, Y., Wang, S., 2018b. A novel aerated surface flow constructed wetland using exhaust gas from biological wastewater treatment: Performance and mechanisms. Bioresour. Technol. 250, 94–101. https://doi.org/10.1016/j.biortech.2017.08.172

Zhou, X., Wang, X., Zhang, H., Wu, H., 2017. Enhanced nitrogen removal of low C/N domestic wastewater using a biochar-amended aerated vertical flow constructed wetland. Bioresour. Technol. 241, 269–275. https://doi.org/10.1016/j.biortech.2017.05.072

BIODATA OF STUDENT

Nor Farhana Aziz Ujang was born on May 30, 1993. She attended her preliminary school at Sekolah Kebangsaan Seri Jelok, Kajang from 2000 to 2003 and finished preliminary school at Sekolah Kebangsaan Bandar Rinching, Semenyih, Selangor at 2005. She continued her secondary education at Sekolah Menengah Kebangsaan Bandar Rinching, Semenyih, Selangor (2006 – 2008) and Sekolah Sains Seri Puteri, Kuala Lumpur (2009 – 2010). Later, in 2011, she went to Kedah Matriculation College, Changlun, Kedah for one-year matriculation program organized by the Malaysia Education Ministry (MOE). After completion of her matriculation program, she was promoted to continue his First Degree in Bachelor of Science (Honour) Biochemistry, a four-year program at Universiti Putra Malaysia, Serdang, Selangor. She attended three-month internship from June to September 2015 at Kilang Sawit Chiku in Gua Musang, Kelantan and being placed in QA and QC Department for three months. During her final semester of Bachelor's Degree, she managed to complete a final year project, entitled "The Freshness of Malaysian Commercial Honey via HMF Detection". She started her Master's Degree in the field of Environmental Biotechnology under supervision of Dr. Ahmad Muuhaimin Roslan. The result of her research is as presented in this thesis.

LIST OF PUBLICATIONS

Paper Publication:

Farhana Aziz Ujang, Nurul Atiqah Osman, Juferi Idris, Mohd Izuan Effendi Halmi, Mohd Ali Hassan and Ahmad Muhaimin Roslan*. Start-up treatment of palm oil mill effluent (POME) final discharge using Napier Grass in wetland system. IOP Conference Series: Materials Science and Engineering. 2018.

Ahmad Farid Mohammed Abdillah, Roslan Ahmad Muhaimin, Hassan Mohd Ali, **Aziz Ujang Farhana**, Mohamad Zarry, Hasan Muhamad Yusuf, Yoshihito Shirai. Convective sludge drying by rotary drum dryer using waste steam for palm oil mill effluent treatment. Journal of Cleaner Production. 2019

Nurul Atiqah Osman, **Farhana Aziz Ujang**, Ahmad Muhaimin Roslan, Mohamad Faizal Ibrahim & Mohd Ali Hassan. The effect of Palm Oil Mill Effluent Final Discharge on the Characteristics of Pennisetum purpureum. Scientific Report. 2020

Abstract In Conference/Symposium:

Farhana Aziz Ujang, Nurul Atiqah Osman, Juferi Idris, Mohd Izuan Effendi Halmi, Mohd Ali Hassan and Ahmad Muhaimin Roslan. In the 5th SAES – International Symposium on Applied Engineering and Sciences (SAES2017) UPM – Kyutech, UPM, Selangor, Malaysia. (Poster presenter)

Farhana Aziz Ujang, Nurul Atiqah Osman, Juferi Idris, Mohd Izuan Effendi Halmi, Mohd Ali Hassan and Ahmad Muhaimin Roslan. In the Wood & Biofibre International Conference (wobic) 2017, Hotel Bangi-Putrajaya, Selangor, Malaysia. (Poster presenter)

Farhana Aziz Ujang, Nurul Atiqah Osman, Juferi Idris, Mohd Izuan Effendi Halmi, Mohd Ali Hassan and Ahmad Muhaimin Roslan. In the 6th SAES – International Symposium on Applied Engineering and Sciences (SAES2018) UPM – Kyutech, Kyutech Tobata Campus, Fukuoka, Japan. (Poster presenter)

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