Advanced Biological Palm Oil Mill Effluent (POME) Treatment Towards Biological Oxygen Demand (BOD) 20 ppm

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ABSTRACT

Biological treatment pond system has been adopted by Malaysian palm oil mills to treat palm oil mill effluent (POME). Conventional treatment pond system is no longer able to comply with the new legislation requirements as implemented and enforced by Department of Environment (DOE) recently. Various tertiary POME treatment technologies have been introduced, they are not without disadvantages such as sludge generation. Revolutionary Organic Onsite Treatment System (ROOTS) is a microbial enzyme system specially formulated for organic based effluent treatment. ROOTS was installed in Johor after the palm oil mill existing anaerobic ponding system with capacity 40 MT hr^{-1}. The mill is having four facultative ponds 1, 2, 3 and 4 respectively. The enzyme dosing system was installed at facultative pond 1. Predetermined numbers of maintenance-free diffusers and biomedia were mounted at facultative ponds 1, 2 and 3. The system configuration is originally applied for food industries waste water. Results from a year observation showed that the final POME discharge complied with DOE Standard A discharge limit (Johor State).

Keywords: biomedia, diffuser, effluent and enzyme.

INTRODUCTION

Malaysian oil palm planted area sees expansion 3%-5% annually. The crops harvested are processed by 452 mills nationwide (Parveez *et al*., 2020). Oil palm fresh fruit bunches processing generates palm oil mill effluent (POME) which has an average biological oxygen demand (BOD) of around 25,000 ppm and needs to be treated before being discharged. Due to operating and capital expenditures (OPEX and CAPEX) factors, 85% palm oil mills in Malaysia have adopted ponding treatment system to treat POME (Ma, 1999). Huge land area (~1776 m^2 for anaerobic pond) and long hydraulic retention time (HRT) (40-200 days) are essential for mills with processing capacity of 54 t fresh fruit bunches (FFB) per hour (Wong, 1980; Wai *et al.,* 2015).

In line with the exponential growth of the oil palm industry, government agency through the Department of Environment (DOE) is implementing and enforcing environmental regulations to ensure environmental sustainability. The Environmental Quality (Prescribed Premises) (Crude Palm Oil) is predominantly discussed and DOE has decided to impose stringent BOD discharge limit of 20 ppm (Wai *et al*., 2015). For legislation compliance, palm oil millers are either encouraged or in some cases required to install a polishing plant or a tertiary treatment system to further treat the POME (Nahrul Hayawin *et al*., 2017).

Technologies that have been extensively used for POME tertiary treatment are membrane bioreactor technology (MBR) (Sulong *et al*., 2007; Moro, 2010), biological-physicochemical treatment processes (Sulong and Noorshamsiana, 2008; Chong, 2010), suspended packing in activated sludge aeration tank with complete mixing (Tin, 2010), physicochemical treatment processes (Barr, 2010) and combinations of ozone and submerged fixed film biological process (Jurgensen, 2010).

These methods have been proven to be able to lower the BOD by more than 90% or less than 20 mg $litre^{-1}$. However, disadvantage such as sludge generation in biological treatment were observed (Jagaba *et al*., 2020).

REVOLUTIONARY ORGANIC ONSITE TREATMENT SYSTEM (ROOTS)

Revolutionary Organic Onsite Treatment System (ROOTS) is a microbial enzyme system specially formulated for the treatment of organic based effluent such as palm oil wastewater, food and beverage, canteens and other organic-based discharge. The system is a Japanese patented technology which is now available locally via a sole appointed dealer (Blue E Tech Sdn. Bhd.). Using this system, Japan has achieved many excellent results in overcoming uphill wastewater treatments. This system is strongly believed to be able to provide effective water and wastewater, especially POME, treatment solution in Malaysia.

Studies have shown that multi-enzyme complexes, consisting of lipase, protease and amylase, are more effective than single enzyme applications for multi-complex substrate treatment due to the polysaccharides requiring synergistic reactions with other enzymes. According to Spagnuolo *et al*. (1997), substrate complexes bound to cellulose, hemicellulose and pectin need multi-enzymes for better degradation. Pectin will slow the cellulose degradation rate inside the complex. Therefore, pectinase should act first to remove pectin, so that the lignocellulose complex is no longer hindered, which will then allow cellulolytic synergetic activities together with pectinolytic. This relationship is known as multi-enzyme complex.

An example of multi-enzyme complex is in pulp degradation hydrolysis. Hydrolysis with combination of cellulase and pectinase multi-enzymes pulp achieved 78% saccharification, while 47.5% saccharification was achieved using only cellulose and 54.8% saccharification was achieved using pectinase alone (Spagnuolo *et al*., 1997). Multi-enzyme complex has also successfully increased hazelnut *Guevina avellana mol* oil extraction through cold extraction process. Compared to cold extraction with 10-12% oil left over, synergy between pectinase and cellulase has improved oil extraction, where 98% oil were extracted with 1.5% remainder (Zúñiga *et al*., 2003).

The eco-friendly biodegradable enzymes used in ROOTS work efficiently not only in water with high levels of fats, oil and grease (FOG), but also in wastewater with high levels of protein and starch (*Figure 1*).

Figure 2 shows a simple layout of ROOTS for wastewater treatment. The main ROOTS components comprised of enzymes, biomedia and air diffuser. All components are packed in a vessel or incubator chamber. Wastewater will flow into vessel 1 for enzymatic breakdown through hydrolysis and will undergo further hydrolysis in vessel 2. Subsequently, microbes in biomedia will digest the organic molecules. Biomedia provides nesting place for bacteria colony. Oxygen is continuously supplied through air diffuser for microbes.

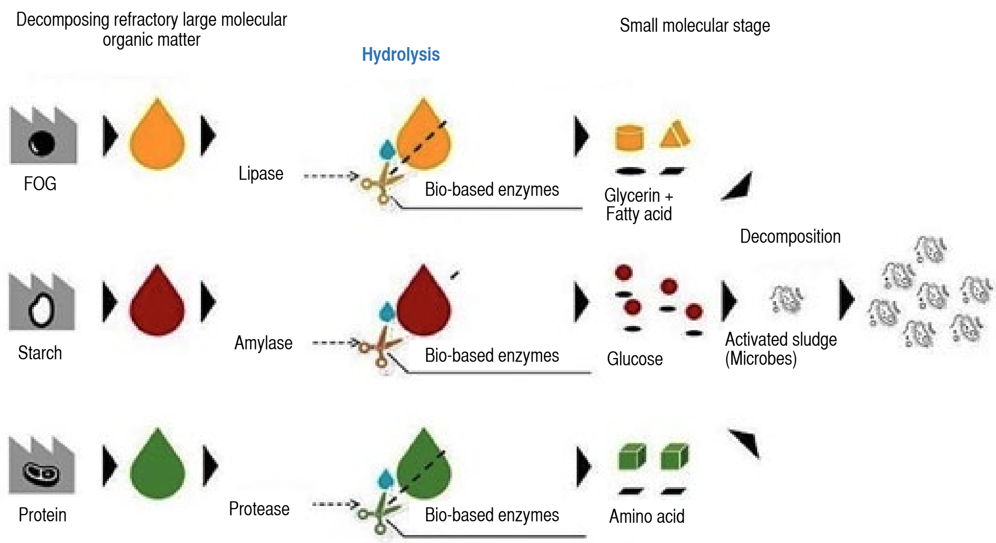

Figure 1. Synergistic effect of multi-enzyme complex in Revolutionary Organic Onsite Treatment System (ROOTS) in breaking down fats, oil and grease (FOG), starch and protein.

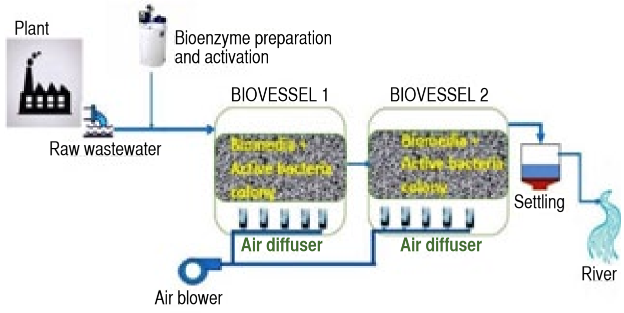

Figure 2. Simple layout of Revolutionary Organic Onsite Treatment System (ROOTS) for wastewater treatment.

PERFORMANCE MONITORING

The ROOTS with 40 MT hr^{-1} was installed at existing effluent ponding system at a palm oil mill in Johor. The system was installed after the anaerobic pond (AP3) to ensure its effectiveness. Food to mass ratio is crucial for active microbes in the biological treatment to hinder sludge bulking in the pond (Vijayaraghavan *et al*., 2003). Enzyme dosing system was then installed at facultative pond 1 (FP1) to accelerate degradation of the remaining oil and fats, carbohydrate or protein that were undigested during the anaerobic stage. In addition, predetermined numbers of maintenance-free diffusers and biomedia were mounted at FP1, FP2 and FP3. The biomedia provided nesting area for the bacteria colony to propagate, while air diffusers supplied air for the bacteria colony. The system layout design is shown in *Figure 3*. Excluding biogas system, the selected mill has nine ponds with 98 days HRT.

The performance of the system was continuously monitored for about one year (2019-2020) for FP1, FP2, FP3 and final discharge. Quality of POME such as BOD, suspended solids (SS), ammoniacal nitrogen (AN) and total nitrogen (TN) were analysed by an accredited laboratory using DOE methods. Prior to ROOTS installation, BOD of FP1 effluent was in the range of 1200-1600 ppm. After installation of enzyme dosing together with air diffusers and biomedia in FP1, the BOD of effluent from FP1 was significantly reduced by up to 96% with BOD values ranging from 41- 226 ppm. Results showed that enzymes were effective in enhancing the degradation of organic constituents in FP1. Similarly, the addition of aeration and biomedia to FP2 and FP3 also greatly reduced the BOD in effluent by up to 95% and 88%, respectively.

The final discharge of POME in this study complied with Johor State's standard A discharge limit (BOD between 7-19 ppm, SS in the range of 23-118 ppm, AN mostly below 5 ppm and TN between 11 to 34 ppm). ROOTS' performances on quality of FP1, FP2, FP3 and final discharge are shown in *Figures 4-7*. Significant colour intensity reduction were observed for POME treated with and without ROOTS (*Figure 8*).

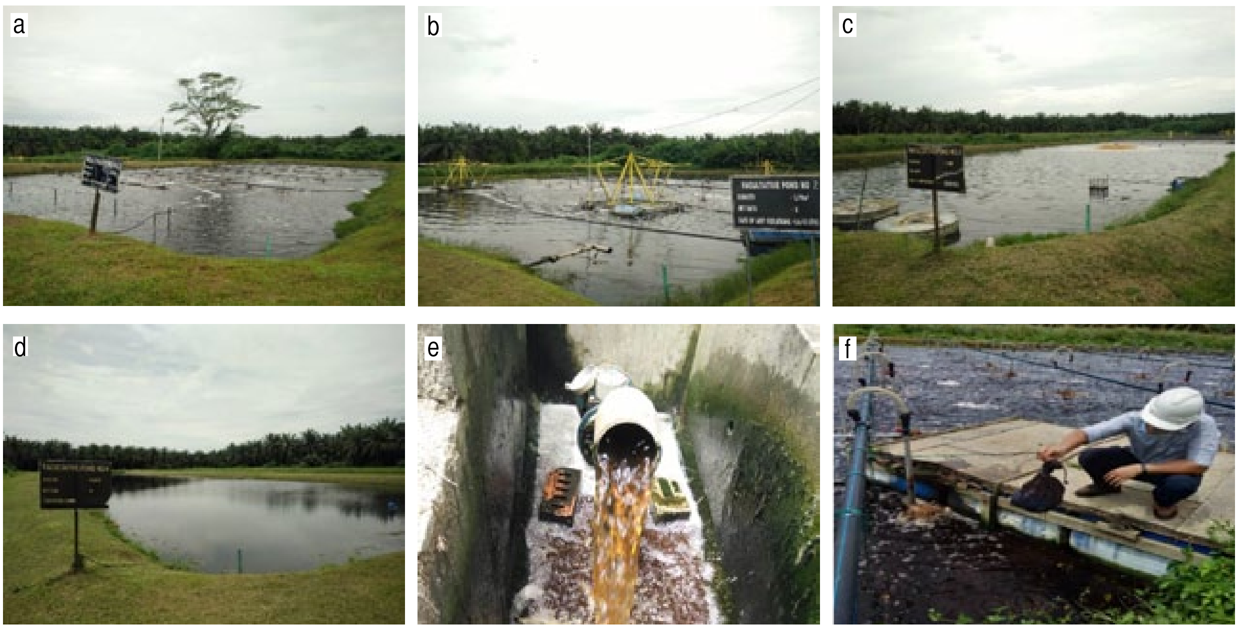

Figure 3. Revolutionary Organic Onsite Treatment System (ROOTS) system installed at one of the palm oil mill effluent (POME) treatment plants; (a) facultative pond 1; (b) facultative pond 2; (c) facultative pond 3; (d) facultative pond 4; (e) final discharge; (f) biomedia.

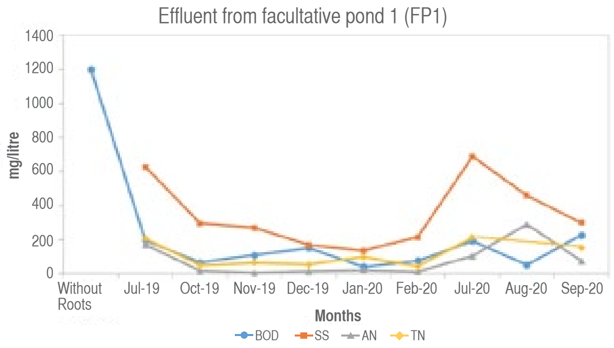

Figure 4. Quality of Palm oil mill effluent (POME) discharge in facultative pond 1; BOD- biological oxygen demand; SS- suspended solids; AN- ammoniacal nitrogen; TN- total nitrogen.

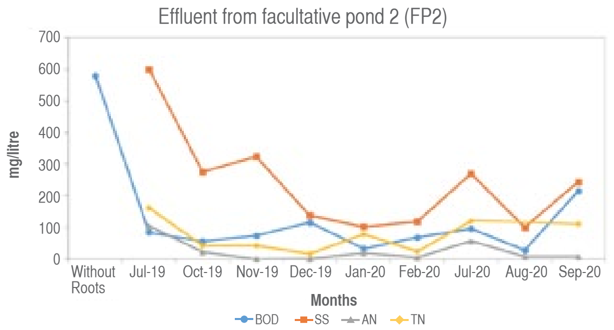

Figure 5. Quality of Palm oil mill effluent (POME) discharge in facultative pond 1; BOD- biological oxygen demand; SS- suspended solids; AN- ammoniacal nitrogen; TN- total nitrogen.

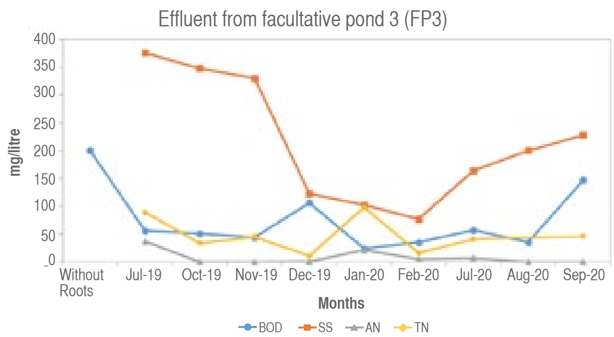

Figure 6. Quality of Palm oil mill effluent (POME) discharge in facultative pond 3; BOD- biological oxygen demand; SS- suspended solids; AN- ammoniacal nitrogen; TN- total nitrogen.

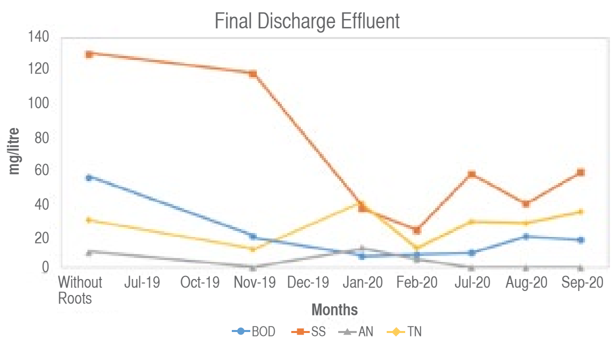

Figure 7. Quality of Revolutionary organic onsite treatment system (ROOTS) final discharge; BOD- biological oxygen demand; SS- suspended solids; AN- ammoniacal nitrogen; TN- total nitrogen.

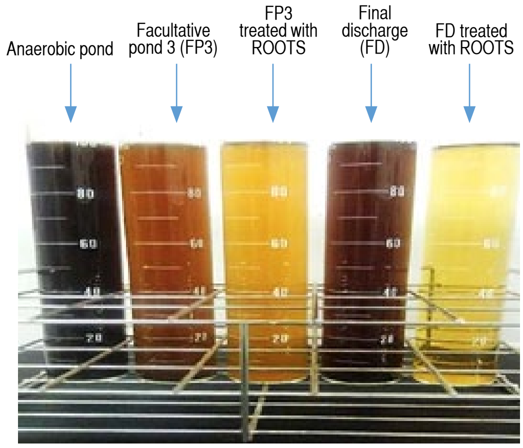

Figure 8. Colours of Palm oil mill effluent (POME) with and without Revolutionary organic onsite treatment system (ROOTS) treatment.

CONCLUSION

ROOTS pilot system installed at effluent ponds in a palm oil mill in Johor is able to produce final discharge of POME that complies with the new DOE discharge limit, especially for BOD (20 ppm) and AN (20 ppm). Compared to conventional ponding system, ROOTS has significantly and consistently improved the quality of POME. Malaysian palm oil mills are highly recommended to install ROOTS.

FUTURE EFFORT

Process operation parameter optimisation such as enzymes dosing, number of diffusers for oxygen transfer, type of bio media for microbe immobilision and power consumption need to be carried out for system economic. Continuous monitoring on system performance will be carried out for both normal and peak season throughout the year.

ACKNOWLEDGEMENT

The authors would like to express their deepest appreciation to Blue E Tech Sdn. Bhd. for funding this project. Special thanks are also due to the participating palm oil mill. Finally, the authors would like to thank the Director-General of Malaysian Palm Oil Board (MPOB) for his permission to publish this article.

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