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# A Review Study on Biological Treatment in Palm Oil Industries and Microbial Activity in Pome Treatment

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**Abstract**: As one of the leading countries in manufacturing palm oil, Malaysia is burdened with the problems of water pollution caused by the palm oil mill effluent (POME) being released into the environment untreated. Various methods have been studied by researchers to overcome the problem arise from the palm oil industries around the globe. The effectiveness of biological treatment in POME namely aerobic and anaerobic processes which includes the study of indigenous microorganisms have been proved to greatly reduce the contamination of the effluent. The microbial activity of the indigenous microorganisms has shown some promising findings that it can be more effective than introduced microorganisms for the treatment method. The findings of this research study has shown that under the optimum condition, these indigenous microorganisms are able degrade much of the organic matter present in the POME effectively. In order to enhance the treatment of POME, the characteristics of these microorganisms should be studied to provide a better understanding of the function of each microorganisms in the biodegradation of POME.

**Keywords**: Palm Oil Mill Effluent (POME), Biotechnology, indigenous microorganisms

## 1. Introduction

Malaysia claimed to be one of the major agro-industries for palm oil industry. Due to this fact, however, results in a large quantities of pollution in wastewater or also known as palm oil mill effluent (POME). Consequently, POME is the largest waste produced from the palm oil production [5]. The presence of high chemical oxygen demand (COD), biochemical oxygen demand (BOD), phenol and

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color concentration in POME will affect the environment where it is very hazardous if these pollutants are released directly into the water bodies. This act can also results in oxygen depletion particularly among the aquatic environments. Since POME pollutants is considered unsafe to the ecosystem and are likely endangers the aquatic life altogether, it is crucial to treat or purify POME prior to discharge into the environment. [9]

High concentration of BOD will somehow affect the aquatic life when it is being discharged in relatively large quantities into watercourses without a proper treatment in advance. According to [7], the biochemical oxygen demand (BOD) concentration of the effluent is very high considering that it is nontoxic (i.e., 25,000 mg/L) while the amount of total solids (40,500 mg/L) is also considered high also contributes to a possible algae bloom as it contains a large amount of nutrients in the wastewater. Generally, the ponding system for the treatment of POME have mainly adopted by the palm oil mills in Malaysia which includes waste stabilization ponds, activated sludge system, closed anaerobic digester and land application system [7].

Palm oil industries have come up with several cost-effective treatment methods that have been developed to treat POME over the past years. Namely anaerobic, aerobic and facultative processes. However, these conventional treatments are not viable in terms of retention time, surface area required, facilities to capture biogas and producing good quality effluent in contrast to the high rate and hybrid bioreactors which are more effective in biodegradation because of shorter hydraulic retention times (HRT) and high production rate of methane. There are many other alternatives to treat POME such as aerobic digestion and membrane separation. These alternatives, however, encounter major drawbacks such as high operational cost and fouling problem. [9]

Therefore, this study will help to review the biological treatment in palm oil industries and the microbial activities in POME treatment. At the end of this study, all findings and arguments will be summarized and tabulated to connect back the closing statement and main aims.

With the exceeding number of palm oil industry over the years in Malaysia, it has become a problem among these industries to overcome the environmental pollution that has been done towards the environment due to the releases of pollutants from the processes of palm oil production. The presence of high chemical oxygen demand (COD), biochemical oxygen demand (BOD), phenol and color concentration in POME will affect the environment where it is very hazardous if these pollutants are released directly into the water bodies. This act can also results in oxygen depletion particularly among the aquatic environments. Since POME pollutants is considered unsafe to the ecosystem and are likely endangers the aquatic life altogether, it is crucial to treat or purify POME prior to discharge into the environment [9].

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Thus, various methods have been proposed to overcome the problems faced by the palm oil industries around the world where biological treatment process are more commonly used in order to treat the POME wastes produced. This study will help to review the biological treatment in palm oil industries and the microbial activities in POME treatment. At the end of this study, all findings and arguments will be summarized and tabulated to connect back the closing statement and main aims.

## 1.2 Literature Review

Malaysia is one of the biggest palm oil exporters in the world. Based on the recent data published by the Malaysian Palm Oil Board (MPOB., 2014), the total amount of crude palm oil production in 2014 was about 19.67 million t in export revenue in the same year. The rapid growth of palm oil industries however, has led to water pollution. Palm Oil Mill Effluent (POME) is one of the major wastes discharged from the mill, which contains rich amount of organic matters and nutrients [2]. It reported that the production of 1 t crude palm oil (COD) generates about 2.5 - 3.5 $m^3$ of POME. Typically, POME consists of 60,000 - 40,000 mg LG1 of total suspended solids, 6000 mg LG1 of oil and grease, 50,000 mg LG1 of chemical oxygen demand (COD) 30,000 - 25,000 mg LG1 of biochemical oxygen demand (BOD), 750 mg LG1 of total nitrogen and 220 - 120 mg LG1 of ammoniacal nitrogen. These water quality characteristics account to the elevated levels of organic substances in POME which necessitate efforts to treat POME. One of the most widely used technology to treat the POME is anaerobic process due to the ease of operation and low cost. However, this technology is rather slow, low in efficiency and demands large piece of land to accommodate different stages of oxidation ponds.

The processing of oil palm to consumable products like edible palm oil is often accompanied with the generation of many unfriendly environmental wastes such as palm oil mill effluent (POME), Oil palm fronds (OPF), Palm shells (PS) and empty fruit bunches (EFBs) that are mostly disposed improperly. During the palm oil extraction, approximately 5.0 - 7.5 tons of water was needed to produce 1.0 ton of crude palm oil. Alarmingly, more than 50.0 % of the water consumed would end up as wastewater, commonly known as palm oil mill effluent (POME). In Malaysia, POME waste is considered as one of the major sources of water due to the inefficiency of widely adopted open ponding treatment system. [10]. According to [3], raw POME is a thick brownish, viscous and voluminous colloidal matters, containing 95.0 –96.0 % of water, 4.0 –5.0 % total solids including 2.0 – 4.0 % suspended solids as well as 0.6–0.7 % of oil and grease which discharged at a temperature of 80 – 90 °C. It is also acidic. POME containing a vigorous amount of amino acids, inorganic nutrients (Na, K, Ca, Mg, Mn, Fe, Zn, Cu, Co and Cd), short fibres nitrogenous compounds, free organic acids and carbohydrates. It contains small pH value, suspended solids (SS), nitrogen content as ammoniacal nitrogen and total nitrogen. It also contains organic matters such as lignin (4700 ppm), phenolics (5800 ppm), pectin (3400 ppm) and carotene (8 ppm).

Palm oil industry generated huge volume of palm oil mill effluent (POME) by the oil extraction process. Enormous amounts of water are required to extract the crude palm oil (CPO). It is calculated that around 1.5 $m^3$ of water are typically used in each tonne of fresh fruit bunches (FFB) processing and almost half of the water discharge as POME. This POME is a combination of wastes, which are produced and discharged from the three principal sources such as clarification wastewater (60.0 %), sterilizer condensate (36.0 %) and hydrocyclone wastewater (4.0 %). Subsequently, around 0.9, 1.5 and 0.1 $m^3$ of POME will be discharged from these sources respectively for the handing out of one tonne of CPO. The production of crude palm oil (CPO) has been intensively increased together with the consumption of the oil has growing massively as the demand of palm oil across the globe increases. In year 2012, around 18.8 million tonnes of CPO were produced. The activities of exportation of palm oil has surged across the globe which somehow had boosted the Malaysian economy as well. Along with the surge in CPO production, it has its downfall where the industry generates large amount of waste in the form of empty fruit brunches (EFB), pressed fibre, palm kernel endocarp, palm kernel pressed cake and POME through its processing. 23.0 % of EFB, 12.0 % of mesocarp fiber, 5.0 % of shell and 60.0 % of POME were produced for every ton of fresh fruit brunches (FFB) processed. In other words, POME is the largest waste produced from palm oil production hence, researchers all around the world have come up with many different ways to counter these problems which causes pollution to the environment.

## 2. Methods

Integrative review methodology is adopted for the review study on biological treatment in palm oil industry and microbial activity in POME treatment. According to [14] integrative review is a qualitative and quantitative research study that summarizes a topic of interest. As suggested by [6] the methodology includes five stages that guide the review design, which are problem identification, literature search, evaluation of data, analysis of data, and the presentation of data collected.

i. Problem identification

The first stage of an integrative review is to identify the problem based on the topic of interest of the research study. The arising number of water pollution around the globe has been a problem for palm oil industries. Hence, the wastewater effluent produced by these industries needed to be properly treated before being released into the environment. Palm Oil Mill Effluent (POME) is considered one of the major wastes discharged from the mill, which contains rich amount of organic matters and nutrients according to [2].

ii. Literature search

The second stage of an integrative review is literature search, which according to [6] contains a comprehensive search strategy relating to the topic of interest. In this study, relevant articles and journals from the internet have been collected for the research. These articles and journals have been reviewed as references and to gather information in order to complete the research.

iii. Data evaluation

The third stage of integrative review is the evaluation of data. According to [6] this stage highlights the authenticity, methodological quality, informational value and the representatives of the available primary researches. The evidences and the information from primary sources are gathered and appraised for this research study. Descriptive, evaluative, and interpretive data were extracted from the sources and coded based on a uniform classification schemes as suggested by [11]

iv. Data analysis

The fourth stage of the methodology is to analyze the gathered information and findings from primary sources. The outcomes of the studies are extracted and integrated for the review study of this research. Analyzing of data consists of documenting the use of a descriptive summary for data synthesis in detail and justify the use of data synthesis method on the grounds of implementing qualitative and quantitative studies for comparisons of themes, relationships, patterns or outliers according to [6]. In this study, the data were evaluated and analyzed more or less using the following strategies: overall quality study, data reduction, and identification of patterns, variations and relationships, data display, data comparison, conclusion drawing and verification as suggested by [6].

v. Presentation

In the last stage of the methodology, the analyzed data from the studies are interpreted and the results are presented. As suggested by [6] this stage consists of the author, participants, study design and findings form the sources being described in tables. However, this may differ as this stage can be documented in various ways such as only highlighting certain criteria instead of presenting a wider range of descriptive quality of data. In this review study, the findings and arguments collected will be summarized and tabulated to connect back the closing statement and main aims.

## 3. Findings

The chapter discussed on the findings that have been collected through the integrative review study based on the research topic according the methods stated in this section.

### 3.1 Biological treatment in palm oil industries

POME is a harmful wastewater that produces high biochemical oxygen demand, high chemical oxygen demand, high concentration of organic nitrogen, phosphorus and other harmful substances to the environment. This means that this wastewater contains the contaminant effects to the water bodies because of its polluting properties and acidic nature. Through recent years, the treatment of POME

using biological processes is most commonly practiced by the industries. With the emerging technologies of POME treatment, it is necessary to keep on focusing at the treatment properly as not to cause any environmental pollution and contribute to human health which is the most important thing. The treatment of POME using the biological process can help solve the problem. The biological process includes waste stabilization ponds, activated sludge system and anaerobic digester. These processes are tabulated in comparison in Table 1.

**Table 1: The comparison of biological treatment systems**

| | Description | Advantage | Disadvantage |
|---|---|---|---|
| **Waste stabilization ponds** | Waste stabilization ponds are ponds designed and built for wastewater treatment to reduce the organic content and remove pathogens from wastewater. | • Relatively low cost<br>• Simplicity of operational and maintenance<br>• High effectiveness<br>• Robust | • Requires larger land area<br>• Possible contamination and high pollution risks such as odor<br>• Effluent from ponds contains algae which requires additional treatment before discharge |
| **Activated sludge system** | The activated sludge process is a type of wastewater treatment process for treating industrial wastewaters using aeration and a biological floc composed of microbes. | • Low installation cost<br>• Simple and easy of handling<br>• Low land requirement | • Requires high energy (aeration)<br>• High operation and maintenance costs |
| **Anaerobic digester** | Anaerobic digestion is a sequence of processes that involve microorganism breakdown of organic matter which does not requires oxygen, which consists of four processes which are hydrolysis, acidogenesis, acetogenesis and methanogenesis | • Low energy requirements (no aeration)<br>• High effectiveness in removing COD [5]<br>• Shorter retention time using high rate anaerobic digester than conventional | • Inefficient anaerobic digester could cause uncontrolled odor<br>• Heavy metals and contaminations in sludge may accumulate<br>• High production of methane gas which could cause safety concerns |

3.2 The effects of biological treatment on the POME parameters

The purpose of treating POME before being released into the water bodies is to keep sustain the environment from polluting. Consequently, the discharge limit of the wastewater set by the Department of Environmental (DOE) standards will be met. This is due to the POME discharge is considered as one of the sources of water pollution as it contains a high palm oil based nutrient content and the presence of other indigenous microbial properties.

In order to meet the discharge limit the parameters of POME have to be analyzed through such as the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammoniacal nitrogen (AN), and oil and grease. These parameters will somehow be affected by the biological treatment introduced which is aimed to reduce the concentrations of the parameters to meet the discharge limit. The treatments which include the ones that have been mentioned in the Literature Review such as waste stabilization ponds which is a type of ponding system, an anaerobic digestion system and activated sludge system. The data study by [12] of the chemical characteristics of raw POME before it is treated are shown in Table 2.

**Table 2: POME chemical characteristics from the study by [12]**

| Parameter | Concentration (mg/L) |
|---|---|
| **Biochemical oxygen demand (BOD)** | 23,400-52,100 |
| **Chemical oxygen demand (COD)** | 80,100-95,000 |
| **Total suspended solid (TSS)** | 9,400-12,500 |
| **Ammonium nitrogen (AN)** | 24-31 |
| **Oil and grease** | 8,500-11,000 |

From the study by [12], the method used to treat POME is using the biological treatment that mainly depends on consortium of microbial activities. The activities of these microorganisms converts the organic substances or nutrients from the POME into supplements and biodegradation of the organic matters into simple by product such as carbon dioxide, methane and water. Ponding system is adapted in the study for the treatment process in order to contain the POME for effective biodegradation. As suggested by [12] the treatment takes a few days for the biodegradation by the native microorganisms to take place. The biodegradation of POME by the biological treatment of using local isolated microorganisms itself shows that the BOD and COD concentrations are mainly decreased which further indicates reduced environmental organical matters to the water streams.

### 3.3 Microbial activity in POME treatment

Many researchers have shown in their studies that the indigenous microorganisms found in POME are far more effective in the biodegradation of organic matters in POME as compared to the introduced foreign microorganisms. In the study by [1] suggests that the ability of microorganisms to adapt, survive and degrade POME which contains a high level of organic matters, oil and greases and high in BOD and COD would be improved significantly by using the indigenous microorganisms for the treatment of POME. According to [12], the effectiveness of biodegradation of POME by indigenous microorganisms that are presently available in the POME itself are higher than the introduced foreign microorganisms.

A study by [13] suggests that the diversed microbial activities in POME that contains hydrocarbons, nitrogenous compounds, lipids and inorganic materials indirectly promotes the natural biodegradation in POME. The microorganisms release hydrolytic enzymes such as xylanase, lipase, and cellulose which functions is to break down the complex polymers in POME. Some of the microorganisms are functioned to remove nitrogen and phosphorus from POME via bioaccumulation while others are functioned for the removal of phenol and the decolorized of POME. In order to enhance the treatment of POME, the characteristics of these microorganisms should be studied to provide a better understanding of the function of each microorganisms in the biodegradation of POME. Some of the common type of microorganisms in POME with its functions in the biodegradation are classified in Table 3.

**Table 3: Microorganisms with its functions in the biodegradation of POME [13]**

| Microorganisms | Functions |
|---|---|
| Pseudomonas species | Produces cellulose and xylanase for hydrolytic purposes |
| Bacillus firmus | Degrade organic matters |
| Micrococcus luteus | Broken down lipids into fatty acids and glycerol |
| Cellulomonas species | Synthesized acid from glucose |
| Stenotrophomonas maltophilia | Broken down lipids into fatty acids and glycerol; degrade oil and cellulose |
| Aspergillus niger | Broken down lipids into fatty acids and glycerol; degrade oil and cellulose |
| Aspergillus fumigatus | Broken down lipids into fatty acids and glycerol; degrade oil and cellulose |
| Pseudomonas putida | Converting nitrate to nitrite to nitrogen gas via reduction |
| Staphylococcus aureus | Converting nitrate to nitrogen via reduction |
| Candida species | Produce biosurfactant for degradation of lipid |
| Mucor species | Degradation of lignocellulosic biomass and lipid |
| Penicillium species | Degradation of lignocellulosic biomass and lipid |
| Fusarium species | Degradation of phenol |

3.4 The optimum condition for microorganism activity in POME treatment process

The types of microorganisms mentioned in Table 3 are mainly fungi and bacteria. These two types microorganism have different optimum conditions for its different ability to function. For instance, in the POME treatment process, fungi such as aspergillus niger and aspergillus fumigatus are identified as the species that produces lipase and cellulose. This species claimed to be a good producer of lipase and cellulose [5]. They are aerobic and can grow under conditions that have low pH and poor nutrient status. As a result, these fungi are most commonly known for its ability in surviving oily wastewater such as POME by the presence of nutrients such as lipid. Hence, the hydrolysis of lipid with the presence of lipase can cause in the conversion into fatty acid and glycerol (alcohol) at 28.0 °C-37.0 °C [5].

Most microorganisms are best functioned at a mesophilic condition. Mesophilic condition where the temperature range for the microbial activity is between 30.0 °C-45.0 °C. According to [4], anaerobic digestion process is done in the mesophilic condition because of its low energy consumption and stable process. The diversity of microbes also decreases when temperature increase in anaerobic pond hence the degradation of organic matters is preferred under mesophilic condition where the temperature is at moderate as high temperature will negatively affect the performance of the treatment process.

The optimum pH for the best growth of microbes is 6.5-7.5. Hence, the optimum condition for microbial activity must be met. This is due to the inactivation of the microbes and conversion of organic matters by the microbes into by products in an anaerobic pond are unable to happen if the pH is below the optimum value. Therefore, pH value must be constantly observed in an anaerobic process treatment in order to sustain the optimum condition for the best performance of the microbial activities. [4]

## 4. Conclusion

This study concludes that biological treatment is effective as improved technology in the treatment of POME as compared to the conventional methods of POME treatment. An integrated review study of different types of biological treatment in POME has shown some findings that indicates the treatment using local isolated microorganisms has impacted in the reduction of biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The role of indigenous microorganisms has been found to be a great help in the reduction of organic matters presence in the wastewater. Furthermore, this will indirectly impact in the reduction of cost in POME treatment as the viability of indigenous microorganisms in the breakdown of organic matters in POME would limit the use in supplementing the process system with normally expensive and synthetic growth media. Consequently, the consumption of energy can be greatly reduced. Therefore, it is advisable to study more further on the indigenous microbial characteristics, nature properties and the impact towards the biological treatment of POME.

Some recommendations that would be an aid in improving further research study regarding the case study involved:

1. Future research of biological treatment should include more studies on understanding the role of indigenous microorganisms for the biodegradation of organic matters in POME as well as the characteristics of each microbe to enhance the removal efficiency of the treatment.
2. The optimum condition of each indigenous microorganism must be thoroughly studied to achieve a more accurate findings and results in the best performance of the microbial activity at degrading POME.
3. Future research on the study of other parameters such as temperature, total soluble carbohydrates, total solids and phenol will be an advantageous to be included in the study of the biodegradation of organic matters by indigenous microorganisms.

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