EFFECTS OF *NYMPHAEA CAERULEA* ON WASTEWATER QUALITY FROM PALM OIL PRODUCTION

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DECLARATION

I declare that this thesis entitled *"Effects of Nymphaea Caerulea on Wastewater Quality from Palm Oil Production"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :………………………

Name : Siti Afifah binti Muda

Date : APRIL 2010

DEDICATION

To my beloved parents, siblings and friends

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First of all, I like to express my gratitude to Allah s.w.t because giving me a good health condition during the period of finishing this project. The opportunities by doing this project have taught me lots of new things.

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Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project.

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ABSTRACT

Palm oil industry is the most important agro-industry in Malaysia, but its by-product–palm oil mill effluent (POME), posed a great threat to water environment. Although the palm oil industry has applied biological treatment for POME, it still faces challenge of balancing the environmental protection, its economic viability and sustainable development. This experiment was carried out to examine the feasibility of POME treatment by using *Nymphaea Caerulea*. The sample was obtained from LCSB Oil Palm Plantation in Lepar Hilir and analysis would be conducted at University Malaysia Pahang in laboratory scale. The aquatic plant was collected from Semuji Agro Resort. The objectives of this experiment are to study the feasibility of aquatic plants in POME treatment for POME at stage 7 and to investigate treatment efficiency by using optimal design condition whereby emphasis is placed on waste water circulation. The presence of circulation in this experiment is to enhance the kinetic process, as compared to control. The sample is tested on day 1, day 3 and day 5. The parameters to be evaluated include BOD, COD, pH, TSS and Oil and Grease. From overall experiment, the highest percentage removal of BOD is 76%, COD is 62%, TSS is 56%, Oil and Grease is 84.7%. The specimen of plant can reduce the pH level. It is shown that in the presence of *Nymphaea Caerulea* that is supplemented with circulation can improve the water quality with five days of retention time compared to control.

ABSTRAK

Industri minyak sawit merupakan agro-industri terpenting di Malaysia, tetapi produk sampingannya iaitu sisa minyak sawit (POME) menjadi ancaman yang besar kepada persekitaran air. Walaupuan industri sawit telah melaksanakan rawatan biological terhadap POME, ianya masih lagi menghadapi cabaran untuk mengimbang penjagaan persekitaran, kelayakan ekonomi dan pembangunan berterusan Ujikaji ini adalah bertujuan untuk memeriksa kebolehlaksanaan *Nymphaea Caerulea* dalam merawat POME. Sampel diperolehi dari LCSB Oil Palm Plantation in Lepar Hilir dan dianalisis di Universiti Malaysia Pahang. Tumbuhan akuatik ini didapati dari Semuji Agro Resort. Objektif ujikaji ini adalah untuk mengetahui kebolehlaksaan Nymphaea Caerulea dalam merawat POME pada tahap 7 dan untuk menyiasat kecekapan rawatan menggunakan keadaan rekabentuk optimum dimana kitaran air sisa ditekankan. Dengan adanya kitaran dalam ujikaji ini adalah bertujuan untuk meningkatkan proses kinatik jika dibandingkan dengan sistem kawalan. Sampel diuji pada hari pertama, ke-3 dan ke-5. Parameter yang dinilai ialah BOD, COD, pH, TSS dan Minyak dan Gris. Daripada keseluruhan ujikaji, peratusan penyikiran tertinggi untuk BOD ialah 76%, COD ialah 62%, TSS ialah 56%, dan Minyak dan Gris ialah 84.7%. Selain itu, specimen tumbuhan boleh menurunkan paras pH. Ini menunjukkan bahawa dengan kehadiran tumbuhan akuatik bersama dengan kitaran boleh meningkatkan lagi kualiti air dalam tempoh 5 hari jika dibandingkan dengan sistem kawalan.

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LIST OF ABBREVIATIONS

BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
CPO	-	Crude Palm Oil
DO	-	Dissolved Oxygen
EFB	-	Empty Fruit Bunch
EPA	-	Environmental Protection Agency
EQA	-	Environmental Quality Act 1974
FFB	-	Fresh Fruit Bunch
H_2SO_4	-	Sulfuric Acid
MPOB	-	Malaysian Palm oil Board
MPOC	-	Malaysian Palm Oil Council
O&G	-	Oil and Grease
POME	-	Palm Oil Mill Effluent
TKN	-	Total Kjeldahl Nitrogen
TSS	-	Total Suspended Solids
SS	-	Suspended Solids

LIST OF SYMBOLS

%	-	percent
°C	-	degree of Celsius
cm	-	centimeter
L	-	Liter
m	-	meter
mg/L	-	milligram per Liter
mL	-	milliliter
mm	-	milimeter

CHAPTER 1

INTRODUCTION

1.1 Introduction of Palm oil

Palm oil has played a positive role in the world oils and fats supply and demand equation largely due to its techno-economic advantages and versatility as well as some of the developments in the world in relation to security of supply, health and environment. Palm oil industry is the most important agro-industry in Malaysia, but its by-product–palm oil mill effluent (POME), posed a great threat to water environment. In the past decades, several treatment and disposal methods have been proposed and investigated to solve this problem (Zhang, 2007).

1.2 Research background

Malaysia currently accounts for 41 % of world palm oil production and 47% of world exports, and therefore also for 11% and 25% of the world's total production and exports of oils and fats. As the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global need for oils and fats in general (MPOC, 2009). In general, the palm oil milling process can be categorized into a dry and a wet (standard) process. The wet process of palm oil milling is the most common and typical way of extracting palm oil, especially in Malaysia (T.Y. Wu et al., 2008).

Palm oil processing is carried out in palm oil mills where oil is extracted from a palm oil fresh fruit bunch (FFB). A Significant quantity of water needed in the palm oil mill extraction. In daily life, palm oil is used mainly in producing cooking oil, margarine, soap, detergent, cosmetics and else. Palm oil mill effluent (POME) is a waste produced from the palm oil processing plants. POME is a thick brownish color and discharged at a temperature between 80ºC - 90ºC. It is fairly acidic with pH ranging from 4-5. POME is an organic wastewater from palm oil industry with high biochemical oxygen demand (BOD) which is about one hundred times more than that of sewage. Besides that, POME also contains high chemical oxygen demand (COD) and suspended solid. This oily waste is produced in large volumes and contributes major problem to the palm oil processing mill's waste stream. Thus it has to be treated efficiently to avoid environmental hazard. If such wastewater is discharged to the environment without a proper treatment, it can pollute the watercourse, river and as well as receiving bodies. Most of the public complaints regarding water pollution were directed at the palm oil industry and the natural rubber processing industry during the last decade (A. R. Khalid, W.A Wan Mustafa, 1992). To minimize the impact of this problem towards the environment, a new method is required in POME treatment with low cost, new enhancement of efficiency and more profitable to palm oil industry. In addition, the role of aquatic plant can reduce the contaminant in POME in order to meet the requirement of Department of the Environment (DOE) discharge limits.

1.3 Problem Statement

Nowadays, water pollution is a major problem in Malaysia. Pollutants such as herbicides, pesticides, fertilizers, and hazardous chemicals can make their way into our water supply. When our water supply is contaminated, it is a threat to human, animal, and plant health unless it goes through a costly purification procedure. Pollutants can contaminate our drinking water sources, reduce oxygen levels which can kill fish and other wildlife, accumulate in the tissue of fish we catch and eat from the lakes, and reduce the beauty of the water.

In Malaysia, there are two main sources of water pollution which are domestic sewage and industrial waste. From the previous research, industrial waste has higher pollutant than domestic sewage. In industrial wastewater treatment, the most common and efficient system applied in industry by the palm industry are ponding system, the open tank digester, close tank digester, thermophilic anaerobic contact process and extanded aeration. Although the palm oil industry has applied biological treatment for POME, it still faces challenge of balancing the environmental protection, its economic viability and sustainable development (Ahmad et al, 2003).

Several studies and research have been done by the government, private sector and also educational institute to find the most effective techniques to treat the POME. Generally, Malaysia rarely used aquatic plants in industrial waste water treatment. In this research, we will introduce a new method for POME treatment by using aquatic plants. This method is required in order to give a better solution in managing this waste which is economic and environmental friendly. Besides that, the aim of this research is also to fulfill the requirements of Department of Environmental (DOE) discharge limits.

1.4 Objectives

- To study the feasibility of plant (Nymphaea Caerulea) in POME treatment for POME at stage 7.
- To investigate treatment efficiency by using optimal design condition whereby emphasis is placed on waste water circulation.

1.5 Scope of the research

- The sample of palm oil mill effluent is obtained from LCSB Oil Palm Plantation in Lepar Hilir and analysis will be conducted at University Malaysia Pahang.

- *Nymphaea Caerulea* will be examined in order to observe its effectiveness on palm oil mill effluent (POME) treatment. This plant is collected from Semuji Agro Resort.
- In order to complete this research, the parameters that must be measured are BOD, COD, pH, total solids, suspended solids, and oil and grease.
- POME at stage 7 will be used in this research because of the concentration for each stage is different. POME at stage 7 has low concentration compared to other stages.

1.6 Rational and significance

POME can be classified as a major problem in water pollution in Malaysia. In this research, POME treatment by using aquatic plant which is *Nymphaea Caerulea* gives us more advantages in order to achieve the requirements of Department of Environmental (DOE) discharge limits. The rational and significance of this research include:

- By using this aquatic plant, it can save our environment by reducing water pollution.
- *Nymphaea Caerulea* growth in the lake and exist in abundance.
- The method using this aquatic plant is low in cost. Thus, it is very economical and effective.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Palm oil is an edible plant oil derived from the fruit and kernels (seeds) of the oil palm *Elaeis guineensis*. Palm oil is naturally reddish because it contains a high amount of beta-carotene (though boiling it destroys the carotenoids and renders the oil colourless). Palm oil is one of the few vegetable oils relatively high in saturated fats (like coconut oil) and thus semi-solid at room temperature. Palm oil production is a basic source of income for many of the world's rural poor in South East Asia, Central and West Africa, and Central America. In 2003, Malaysia produced 14 million tons of palm oil from more than 38,000 square kilometers of land, making it the largest exporter of palm oil in the world. Palm oil processing is carried out in palm oil mills where oil is extracted from a palm oil fruit bunch. In daily life, palm oil is used mainly in produce cooking oil, margarine, soap, detergent, cosmetics and else. The extraction process for crude palm oil (CPO) starts from the local palm oil mills throughout Malaysia. The mills processes FFB received from the oil palm plantations into CPO and other by-products. A schematic process flow of palm oil milling for the extraction of crude palm oil and sources of waste generation is shown in Fig. 2.1. Palm oil mills typically generate large quantities of extremely oily organic contented liquid (Industrial Processes and The Environment, 1999).

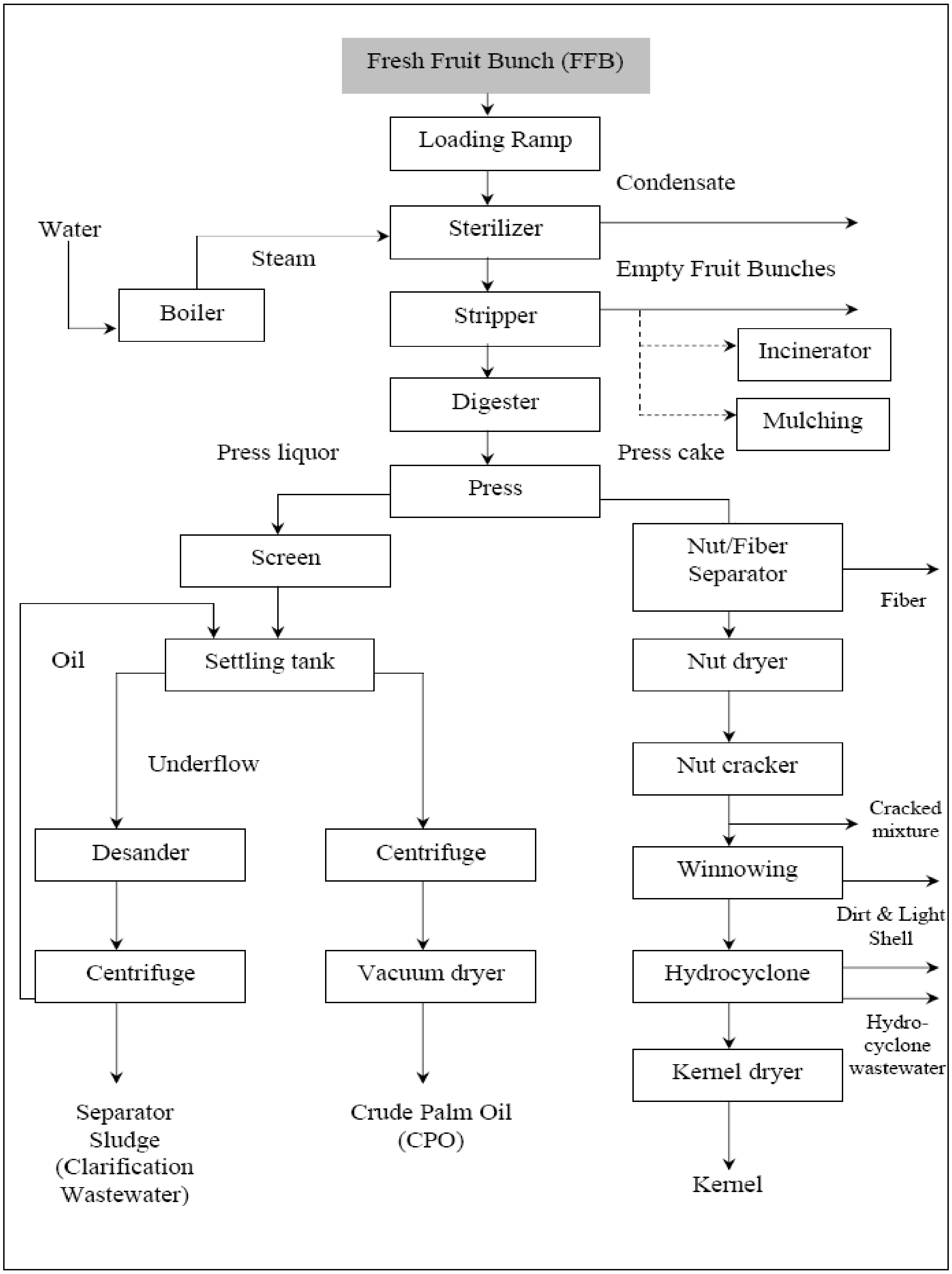


Figure 2.1 A schematic process flow of palm oil milling for the extraction of crude palm oil and sources of waste generation

2.2 PALM OIL MILL EFFLUENT (POME)

Palm oil mill effluent is a waste produced from the palm oil processing plants. This oily waste is produced in large volumes and contributes major problem to the palm oil processing mill's waste stream. Thus it has to be treated efficiently to avoid environmental hazard. Besides, the process to extract the oil requires significantly large quantities of water for steam sterilizing the palm bunches and clarifying the extracted oil. It is estimated that for 1 tonne of crude palm oil produced 5-7.5 tonnes of water are required, and more than 50% of the water will end up as palm oil mill effluent (POME) (Ahmad et al.,2003). Thus, while enjoying a most profitable commodity, the adverse environmental impact from the palm oil industry cannot be ignored.

Raw POME is a colloidal suspension which is 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids originating in the mixing of sterilizer condensate, separator sludge and hydrocyclone wastewater (Ahmad et al., 2003; Borja and Bark, 1996; Khalid and Wan Mustafa, 1992; Hameed Bassim, 2003). If the untreated effluent is discharged into watersources, it is certain to cause considerable environmental problems due to its high biochemical oxygen demand, BOD (25,000 mg/l), chemical oxygen demand, COD (50,000 mg/l), total solids (40,500mg/l), suspended solid (18,000mg/l) and 4,000 mg/l of oil and grease.

Table 2.1 Characteristics of POME and its respective standard discharged limit by the Malaysian Department of the Environment.

Parameter	Concentration, mg/L	Standard limit, mg/L
pH	4.7	5-9
Oil and grease	4,000	50
BOD	25,000	100
COD	50,000	--
Total solids	40,500	--
Suspended solids	18,000	400
Total nitrogen	750	150

However it contains appreciable amounts of N, P, K, Mg and Ca which are the vital nutrient elements for plant growth (Industrial Processes & The Environment, 1999).

Table 2.2 Characteristics of combined palm oil mill effluent (POME) (Industrial Processes& The Environment, 1990)

Parameters	Mean	Range	Metals & Other Constituents	Mean
pH	4.2	3.4-5.2	Phosphorus	180
Oil & Grease	6,000	150-18,000	Potassium	2,270
BOD; 3-day, 30°C	25,000	10,000-44,000	Magnesium	615
COD	50,000	16, 000-100,000	Boron	7.6
Suspended Solid	40,500	11,500-79,000	Iron	47
Dissolved Solids	18,000	5,000-54,000	Manganese	2.0
Ammonical Nitrogen	35	4-80	Copper	0.9
Total Nitrogen	750	80-1,400	Zinc	2.3
			Calcium	440

*All units are in mg/l except for pH

Table 2.3 Environment Quality Act 1974

THIRD SCHEDULE

ENVIRONMENTAL QUALITY ACT 1974

ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS) REGULATIONS 1979

(REGULATIONS 8(1), 8(2), 8(3)

PARAMETER LIMITS OF EFFLUENTS OF STANDARDS A AND B

Parameter		Unit	Standard	
			A	B
(i)	Temperature	°C	40	40
(ii)	pH value	-	6.0 - 9.0	5.5 - 9.0
(iii)	BOD at 20°C	mg/ l	20	50
(iv)	COD	mg/ l	50	100
(v)	Suspended Solids	mg/ l	50	100
(vi)	Mercury	mg/ l	0.005	0.05
(vii)	Cadmium	mg/ l	0.01	0.02
(viii)	Chromium, Hexavalent	mg/ l	0.05	0.05
(ix)	Arsenic	mg/ l	0.05	0.10
(x)	Cyanide	mg/ l	0.05	0.10
(xi)	Lead	mg/ l	0.10	0.5
(xii)	Chromium Trivalent	mg/ l	0.20	1.0
(xiii)	Copper	mg/ l	0.20	1.0
(xiv)	Manganese	mg/ l	0.20	1.0
(xv)	Nickel	mg/ l	0.20	1.0
(xvi)	Tin	mg/ l	0.20	1.0
(xvii)	Zinc	mg/ l	2.0	2.0
(xviii)	Boron	mg/ l	1.0	4.0
(xix)	Iron (Fe)	mg/ l	1.0	5.0
(xx)	Phenol	mg/ l	0.001	1.0
(xxi)	Free Chlorine	mg/ l	1.0	2.0
(xxii)	Sulphide	mg/ l	0.50	0.50
(xxiii)	Oil and Grease	mg/ l	Not Detectable	10.0

According to POME characteristic and standard discharge limit in EQA 1974, the palm oil industry faces the challenge of balancing the environmental protection, its economic viability and sustainable development.

In terms of biochemical oxygen demand (BOD) which amounts to 25000 mg/l, it is highly polluting. It is 100 times more polluting than the domestic sewage. Besides that, the suspended solid in the POME are mainly cellulosic material from the fruit. When the biodegradable organics are discharged to stream containing dissolved oxygen, microorganisms begin the metabolic processes that convert the organics along with the dissolve oxygen into new cells and oxidized waste products. The quantity of oxygen required for this conversion is the biochemical oxygen demand.

Because of the pressing problems of the disposal of palm oil mill wastes, the environmental quality regulation for CPO mills was formulated. The regulation was cited as the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulation, 1977. The mills were required to reduce the effluent components, using BOD as a critical parameter, from 20,000 m~ L -1 to 5,000 mg L -1 in 1978, and to 500 mg L -1 by 1981. These BOD limits were further reduced to 250 m~z L -1 in 1982, 100 mg L -1 in 1983 and 50 mg L -'T in 1986 (Khalid and Wan Mustafa, 2003). The effluents have been discharged into water courses causing serious pollution, killing fish, prawns and crabs on which some fishermen depend. They leave unsightly sludge and stench on river banks and ditches. There is an urgent need to find a way to preserve the environment while keeping the economy growth.

2.3 Treatments of POME

Khalid and Wan Mustafa (2003) said that, since 1974, a considerable amount of research has been carried out to establish reasonably acceptable methods for treatment and disposal of palm oil mill effluents. Various treatment technologies have been developed with local expertise and a number of mills have installed treatment plants since that time. The three most common and efficient treatment systems adopted by the palm oil industry are the ponding system, the open tank digester and extended aeration system, and the closed anaerobic digester and land application system. The choice of which system is used depends very much on the individual mills, company policy, location and availability of suitable land.

Membrane separation technology has been widely used in water and wastewater treatment and has been applied in various types of industry (Zhang et al., 2008). Besides that, a POME treatment system based on membrane technology shows high potential for eliminating the environmental problem, and this alternatives treatment system offers water recycling (Ahmad et al., 2003)

Anaerobic digestion is usually the basic biological treatment process for high organic strength wastewaters, since it results in limited production of stabilized sludge compared to the conventional aerobic treatment. Anaerobic digestion of organic material under methanogenic conditions, is a complex process (Aggelis et al., 2001). Besides that, the disadvantage of anaerobic digesters is that additional treatment is necessary to polish and lower the pollution load (Alvares et al., 2008)

Biological treatment of green olive debittering wastewater was investigated using aerobic and anaerobic systems based on combined and separate reactors. The results showed that aerobic treatment was found to be more efficient than the anaerobic, whereas combined anaerobic–aerobic treatment yielded less aerobic sludge (Aggelis et al., 2001).

2.4 Parameters

2.4.1 Chemical oxygen demand (COD)

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes The dichromate reflux method is preferred over procedures using other oxidants (e.g. potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is 95-100% of the theoretical value.

2.4.2 Biochemical oxygen demand (BOD)

Biochemical oxygen demand (BOD) test measures the ability of naturally occurring microorganisms to digest organic matter, usually in 5 days incubation at 20°C by analyzing the depletion of oxygen. BOD is the most commonly used parameter for determining the oxygen demand on the receiving water of a municipal or industrial discharge. BOD can also be used to evaluate the efficiency of treatment processes, and is an indirect measure of biodegradable organic compounds in water.

2.4.3 pH

pH is the measure of acidity or alkalinity of water. Measured on a scale of 0-14, solutions with a pH of less than 7.0 are acids while solutions with a pH of greater than 7.0 are bases. In very simple terms bases are used to neutralize acids, while acids are used to neutralize caustics The pH scale commonly in use ranges from 0 to 14. In the process of waste water, the pH is very important to determine the proper chemical processing and corrosion control.

2.4.5 Total suspended solid (TSS)

Total suspended solid is the quantity of solid particles contained in wastewater. Suspended solids, where such material is likely to be organic and/or biological in nature, are an important parameter of wastewater. The suspended solids parameter is used to measure the quality of wastewater influent, to monitor several treatment processes, and to measure the quality of the effluent. Environmental Protection Agency (EPA) has set a maximum suspended solids standard of 30 mg/L for most treated wastewater discharges. Other suspended material may result from human use of the water. Domestic wastewater usually contains large quantities of suspended solids that are mostly organic in nature. Industrial wastewater may result in a wide variety of suspended impurities of either organic or inorganic nature. Immiscible liquids such as oils and greases are often constituents of wastewater.

2.4.6 Oil and grease

Oil and grease content of domestic and certain industrial wastes and of sludges is an important consideration in the handling and treatment of the material for ultimate disposal. Oil and grease are singled out for special attention because of their poor solubility in water and their tendency to separate from the aqueous phase. Although this characteristic is advantageous in facilitating the separation of oil and grease by use of floatation devices, it does complicate the transportation of wastes through pipelines, their destruction in the biological treatment unit, and their disposal into receiving waters (Abid Baig et al., 2003)

2.5 Aquatic plants

The aquatic plants within a lake are often grouped by managers into three plant communities, or assemblages of species, according to their growth form and depth range within a lake. In practice, there are no hard divisions between plant communities. Some plants are adapted to growing in a wide variety of conditions and may be found associated with more than one plant community, while other plants are very specific to a Aquatic plants — also called hydrophytic plants or hydrophytes — are plants that have adapted to living in or on aquatic environments. Because living on or under water surface requires numerous special adaptations, aquatic plants can only grow in water or permanently saturated soil narrow range of environmental conditions and occur in only one plant community.T he three plant communities—emergent, floating-leaf and submergent—are named according to the predominant plant form found in the community. They typically form concentric rings within our lakes. However, under certain conditions one or more plant communities may be absent from a portion of a lake.

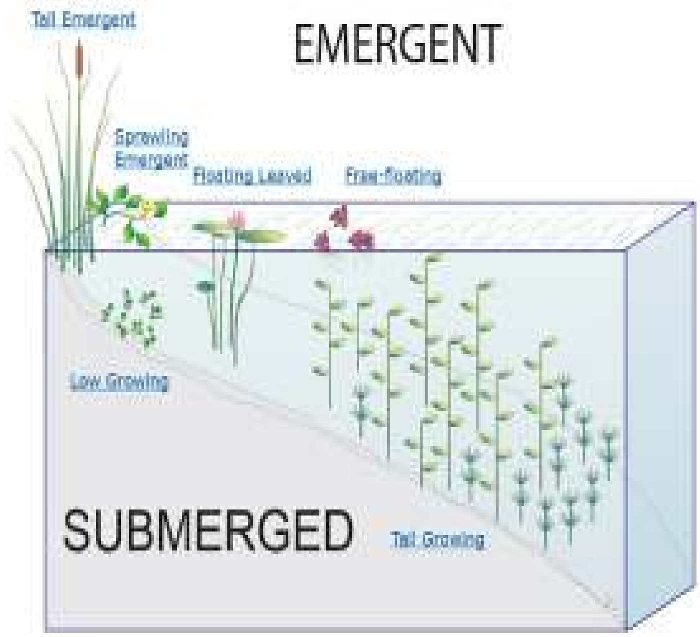


Figure 2.2 Aquatic plants communities

2.5.1 The Emergent Plant

The emergent plant community extends from the water's edge to a depth of 2–4 feet. This area typically receives high nutrient inputs from runoff from the land. It supports predominantly emergent plants that have leaves and flowers extending above the water surface and a dense network of roots. These roots anchor plants (and soil) in the area right along the shoreline that typically is most exposed to the erosive power of waves and ice action. Emersed (aerial) leaves are essentially like typical leaves of herbaceous angiosperms that inhabit full-sun environments. Such leaves are emergent from the water and, consequently, have a waxy cuticle on both surfaces. Many are also amphistomatic (stomates on both surfaces and in nearly equal densities) and have well-developed leaf mesophyll, to take advantage of the abundant light.

2.5.2 The Floating leaf Plant

The floating-leaf plant community extends from a water depth of about 2 feet out to 6–8 feet. It supports predominantly floating-leaf plant forms, but frequently includes emergent and submergent plant forms. This community is found on smaller lakes, in protected bays of larger lakes, or in backwaters of rivers with little wave action or current. Floating leaves tend to be much broader, without major lobing, and remain flat on the water, taking advantage of full sun. Stomates are present for gas exchange, especially on the upper (adaxial) leaf surface. The upper leaf surface tends to have a very prominent cuticle, thereby permitting water to roll off, and not interfering with photosynthesis or promoting growth of epiphytic algae. Epidermis may be rich in chloroplasts, and a bifacial mesophyll (palisade and spongy layers) is formed. Floating leaves often have well-developed air chambers **(**lacunae**),** which provide buoyancy, and they may also have hard cells, sclereids**,** within the mesophyll that provide some toughness for the leaf and prevent the layers from becoming collapsed.

2.5.3 The Submergent Plant

The submergent plant community extends from a water depth of about 6 feet out to 20 feet or more, depending upon water clarity. Leaves of submergent plants are often finely dissected and offer little resistance to water movement. Some are able to photosynthesize at very low light levels—as low as 5% of the light reaching plants above the water surface. Plants of this community also use a wide variety of reproductive and overwintering strategies to insure their survival—seeds, tubers, rhizomes, turions (compact stem structures having dormant buds), and evergreen vegetation. Submersed leaves receive low levels of sunlight (PFD) because light energy diminishes rapidly while passing through a water column. Light penetration is especially poor in turbid water with dense surface populations of algae. Such underwater leaves are often so highly dissected that the segments may appear superficially to be macroscopic green algae (e.g., *Chara* and *Nitella*). This is a strategy to maximize surface-to-volume (S/V), permitting rapid diffusion of carbon dioxide into the chloroplasts of the cells by having proportionately greater surface area. Certain aquatic species have very high ratios of surface to volume (S/V) by having one- or two-cell layer construction. These leaves have a very thin cuticle (wax), but the wax is porous enough to permit easy diffusion of gases through the surface. On these leaves, stomates are generally absent, and would be useless for submerged plants, where water, not air, continually surrounds the photosynthetic organ. Such leaves have very poor development of xylem tissue (water transport), appropriate inasmuch as shoots are bathed in water. Intercellular air spaces are not well developed, thereby enabling this plant to remain submersed by having greater specific gravity. The highly dissected underwater shoot can be tugged at and pulled by water currents without damaging the segments (i.e., little mechanical resistance to current). In swiftly running streams, these shoots and leaves wave and dance wildly.

2.5.4 The free floating plant

Free floating plants, though not absolutely necessary, add the finishing touch to a natural appearing water garden. These plants move with the breeze and produce an ever changing appearance for the pond. Functionally, they add to the oxygenators and produce varying casts of shadow that the pond owner and the fish will appreciate. Though in colder climates species such as Giant Duck Weed (*Spirodela oligorhiza*), Water Hyacinth (*Eichhornia crassipes*), and Water Lettuce (*Pistia stratiotes*).

2.6 Nymphaea Caerulea

Figure 2.3 Nymphaea Caerulea

Nymphaea Caerulea is also known as ‘blue water lily’ or ‘blue lotus’. It is a kind of aquatic plant that is easy to recognize. It has leaves float and beautiful flower. It was classified as floating leaf plant. It is found on smaller lakes, in protected bays of larger lakes, or in backwaters of rivers with little wave action or current. Lotus leaves that have grown on the water surface while the root growth in depth.

The leaves are broadly rounded, 25-40 cm across, with a notch at the leaf stem. The flowers are 10-15 cm diameter, open in the morning, rising to the surface of the water, then close and sink at dusk. It has blue petals, smoothly changing to a pale yellow in the centre of the flower (http://www.flowersofindia).

As well as being attractive when in flower and offering a range of pleasing colours, water lilies have other positive effects on ponds:

- They spread roots which can be encouraged to attract waste material from the pond, thus improving water quality and so being beneficial to fish health.
- The leaves of water lilies spread over the surface of the pond, creating shaded areas in the pond which fish will utilise but more importantly limiting the growth of green algae which thrives in water open to sunlight. In this respect, again the lilies are helping maintain the quality of the water.

As for disadvantages, the wrong size of water lily for a pond will not look particularly attractive if too large. Conversely, too small a water lily will look understated, depending on the required effect. Many types of water lily spread quite rapidly and overwhelm both the pond and its owner with the amount of maintenance work required.

2.7 Phytoremediation

Phytoremediation, the use of plants to remove pollutants from the environment, is a growing field of research in environmental studies because of the advantages of its environmental friendliness, cost effectiveness and the possibility of harvesting the plants for the extraction of absorbed contaminants such as metals that cannot be easily biodegraded for recycling among others. Phytoremediation takes advantage of the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and contaminant storage/degradation abilities of the entire plant body (Hinchman R). There are many types of phytoremediation such as phytovolatilization, phytodegradation, rhizofiltration and rhizodegradation.

2.7.1 Phytovolatilization

Phytovolatilization refers to the uptake and transpiration of contaminants, primarily organic compounds, by plants. The contaminant, present in the water taken up by the plant, passes through the plant or is modified by the plant, and is released to the atmosphere (evaporates or vaporizes). There are varying degrees of success with plants asphytovolatilizers.

2.7.2 Phytodegradation

Phytodegradation is the degradation or breakdown of organic contaminants by internal and external metabolic processes driven by the plant. *Ex planta* metabolic processes hydrolyse organic compounds into smaller units that can be absorbed by the plant. Some contaminants can be absorbed by the plant and are then broken down by plant enzymes. These smaller pollutant molecules may then be used as metabolites by the plant as it grows, thus becoming incorporated into the plant tissues. Plant enzymes have been identified that breakdown ammunition wastes, chlorinated solvents such as TCE (Trichloroethane), and others which degrade organic herbicides.

2.7.3 Rhizofiltration

This method applies specifically to surface and ground water remediation. In this process, contaminants are extracted either directly by absorption through the roots, or indirectly through root adsorption, meaning that contaminants are attracted to and held by the roots. Plants that have been grown in clean water are transplanted to the contaminated water site. When the roots become saturated with the contaminants, they are harvested and new ones are planted. The use of constructed wetlands to treat wastewater and landfill leachate are examples of rhizofiltration.

2.7.4. Rhizodegradation

Rhizodegradation is the breakdown of an organic contaminant within the soil through microbial activity that is enhanced by the presence of the root zone of a plant. Rhizodegradation is utilised in a process known as "plant-assisted bioremediation", "plant-aided *in situ* biodegradation" or "enhanced rhizosphere biodegradation"

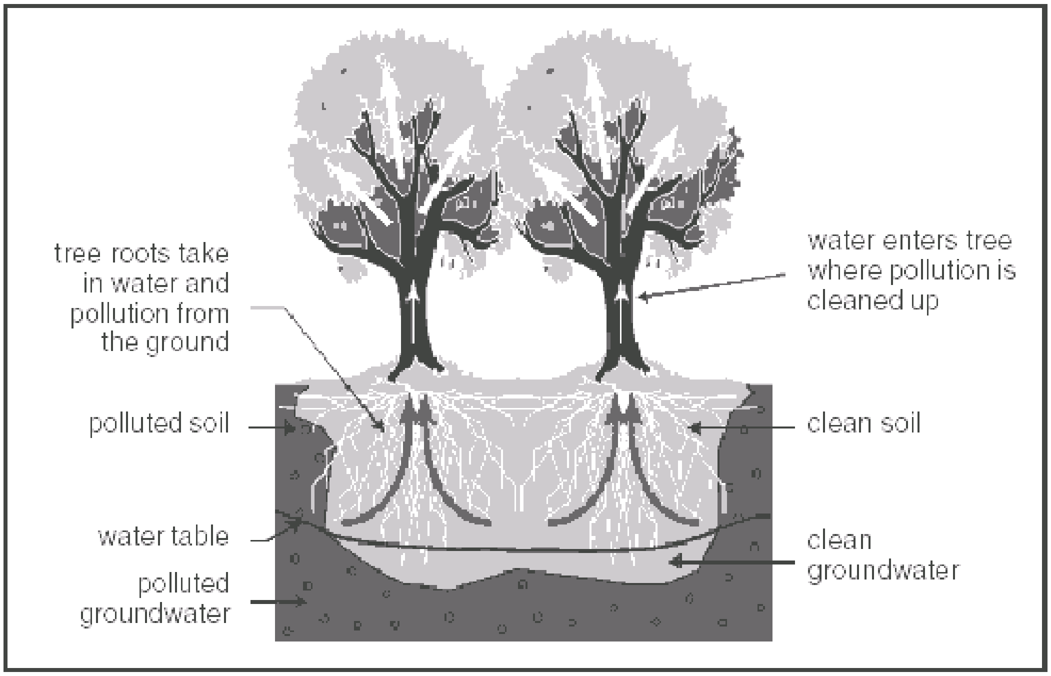


Figure 2.4 Phytoremediation

2.8 Circulation

Natural aquatic systems have created substantial interest with regards to their potential use for wastewater treatment and resource recovery, using green environments. These systems, which require low capital and offer competitive operating cost, are easy to operate and maintain (Y.Zimmels et al., 2009). Relatively few studies have been reported on the use of floating plants for wastewater treatment with circulation and aeration (C.E. 1998).

Plants growing in water produce oxygen by photosynthesis, and during day light hours plants in aquaculture ponds often produce oxygen so fast that dissolved oxygen (DO) concentration in water rises above saturation. Water containing more DO than saturation for the existing temperature and pressure is said to be supersaturated with DO. When water is supersaturated with DO, the pressure of oxygen in water is greater than the pressure of oxygen in the atmosphere. Water circulation devices also enhance DO supplies in ponds by mixing DO supersaturated surface waters with deeper waters of lower DO concentration. This reduces the loss of oxygen from ponds by diffusion. Also, when surface waters are not saturated with DO, water circulation causes surface disturbance and enhances oxygen absorption by the water (C.E. 1998).

Circulation and aeration of the pre-settled sewage enhanced the kinetics of the process, as compared to the control systems. However prolonged application of circulation or aeration may have a different effect. It is shown that in the presence of *Eichhornia* and *Pistia* plants, that are supplemented with circulation or aeration, the local standards of biochemical oxygen demand (BOD) −20mgL−1 and chemical oxygen demand (COD) −70mg/L were reached after 2 and 4.5 days of treatment, while 7–8 days were required to this end without circulation or aeration (Y.Zimmels et al., 2006;2009).

CHAPTER 3

METHODOLOGY

3.1 Introduction

Research methodology is a set procedures or methods used to conduct research. Methods for this research include sample preparation, pretesting, experimental and laboratory testing. This chapter also consist the research process, cross section and schematic diagram. This research was conducted at University Malaysia Pahang.

3.2 Sample preparation

3.2.1 Palm oil mill effluent (POME)

POME was obtained from LCSB Oil Palm Plantation in Lepar Hilir. POME at stage 7 has been used in this research. The temperature and pH of the samples must be recorded once the sample arrived to the lab. POME may vary day to day depending on the discharge limit of the factory, climate and condition of the palm oil processing.

3.2.2 Aquatic plants (*Nymphaea Caerulea*)

Nymphaea Caerulea was collected from Semuji Agro Resort. These aquatic plants were cleaned with water before it moved into the former experiment to remove soil, dust and dirt. But attention must be given so as not to damage the fragile structure. This former must be put at a proper place to get the sunlight for photosynthesis process.

3.2.3 Equipments

In order to finish this experiment, there were a lot of equipments should be used. The main equipments included:

i) Cylinder shape former (0.5m high, 0.3m diameter).
ii) Media (gravel). The media that has high specific area and has more potential for the growth of bacteria (T.Y. Chen et al., 2006).
iii) A motor and pipes to set up the water circulation.

3.3 Research process

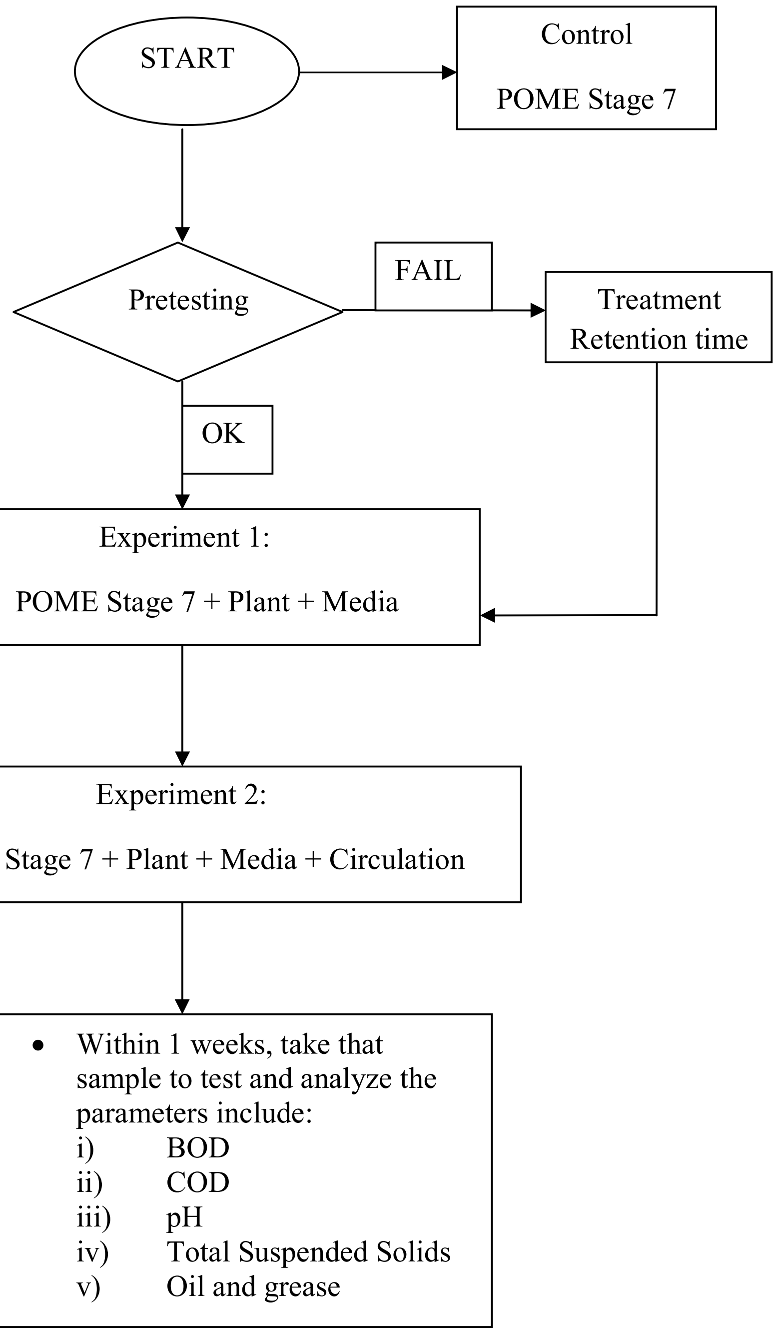


Figure 3.1 Flow chart for research process

3.4 Experimental

3.4.1 Pretesting

Before the experiment is started, pretest on the aquatic plant is done. The purpose of pretesting is to know how long the aquatic plants can life-endure in POME which means retention time. The aquatic plants are allowed to live under POME within one week and their retention time is observed every day. If they failed to survive, the experiment is preceded according to the number of days they can survive. In spite of this, the experiment is carry on according to plan.

3.4.2 Experiment

Based on the research process, after the pretest is done, the experiment is continued with experiment 1 and 2. Before that, the circulation is set up. The aquatic plants are put in all formers about ¾ of POME surface. Here, POME level is set to be equal in every formers. One former only contained POME is used as a control while the remaining two are measured with different conditions. In experiment 1, the former only contained plant and media. For the experiment 2, the circulation is setup alone with the former contained plant and media. All the experiments are run at the same time. The readings of the experiments are obtained on day 1, day 3, and day 5. All the readings/ samples parameters are analysed in the lab.

3.4.3 Cross sectional area

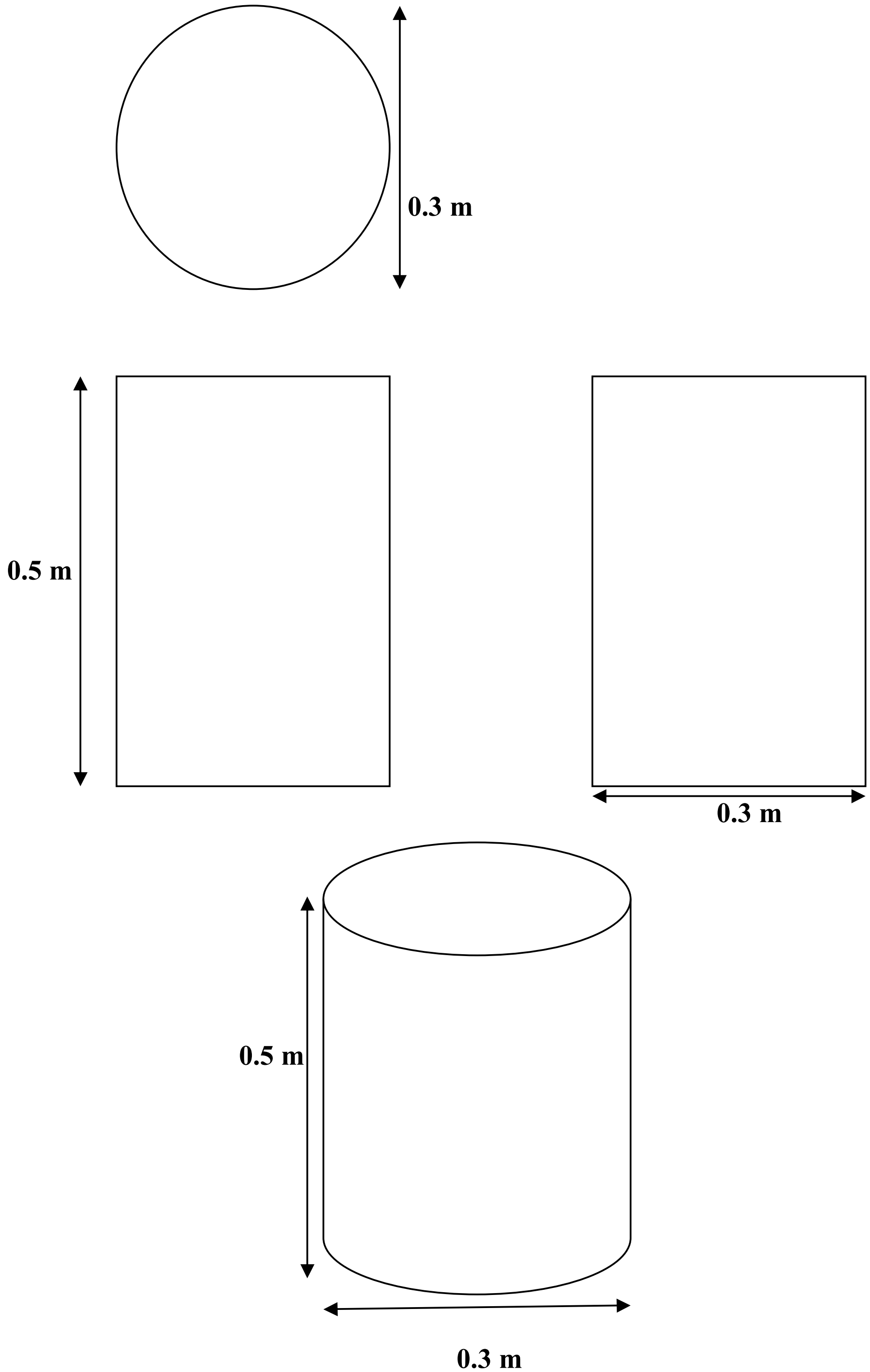
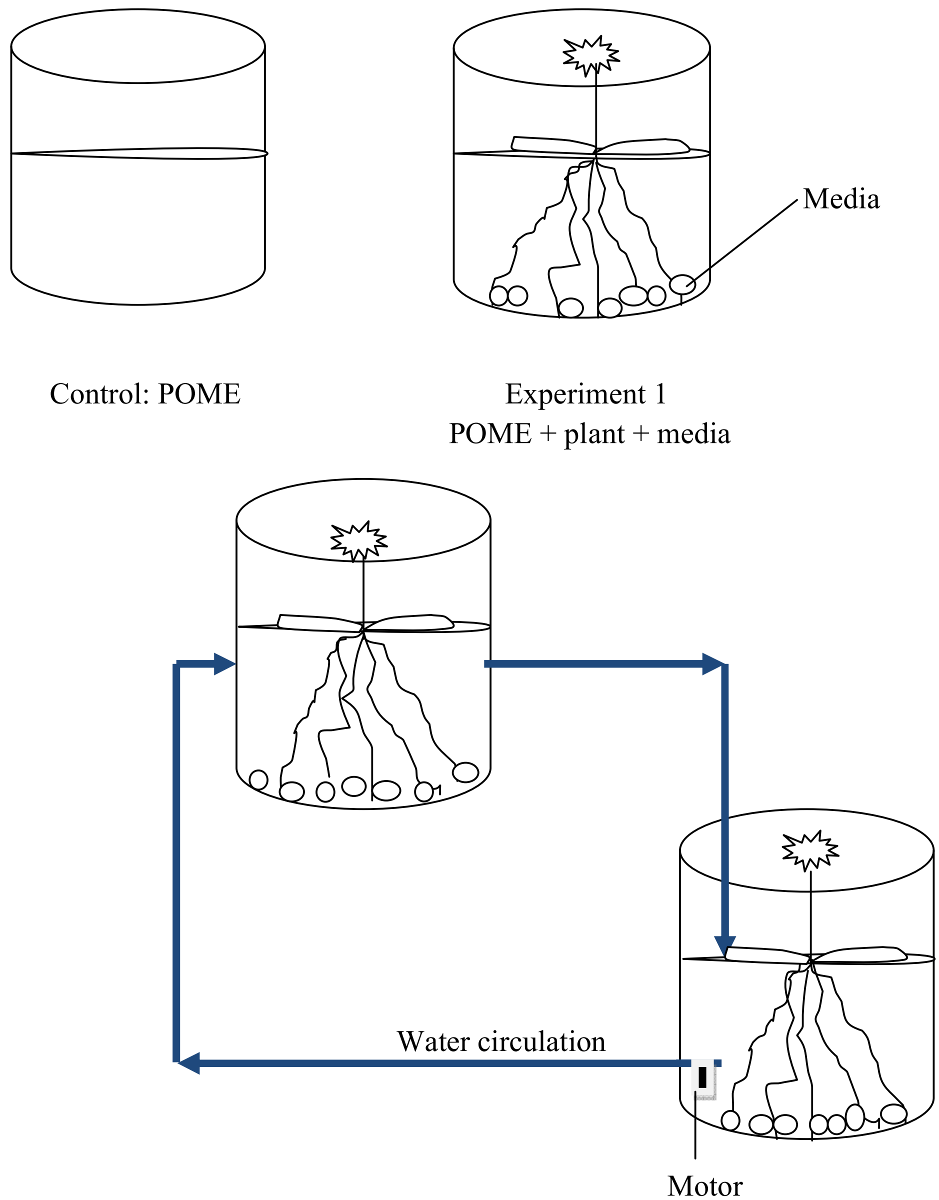


Figure 3.2 Cylinder shape former cross sectional area

3.4.4 Research schematic diagram



Experiment 2

POME + Plant + Media + Circulation

Figure 3.3 Schematic diagrams for the research.

3.5 Laboratory test

The parameters for testing include COD, BOD, pH, total suspended solids, and oil and grease. The procedures for each parameter as follow:

3.5.1 COD

1. Homogenize 100 mL of sample for 30 seconds in a blender.
   *For samples containing large amounts of solids, increase the homogenization time.

2. For the 200-15,000 mg/L range or to improve accuracy and reproducibility of the other ranges, pour the homogenized sample into a 250-mL beaker and gently stir with a magnetic stir plate.

   *If the sample does not contain suspended solids, omit step 1 and step 2.

3. Turn on the COD Reactor. Preheat to 150°C. Place the safety shield in front of the reactor

4. Remove the caps from two COD Digestion Reagent Vials.

   *Be sure to use vials for the appropriate range.

5. Hold one vial at a 45-degree angle. Use a clean volumetric pipet to add 2.00 mL of sample to the vial. This is the prepared sample.

6. Hold a second vial at a 45-degree angle. Use a clean volumetric pipet to add 2.00 mL deionized water to the vial. This is the blank.

7. Cap the vials tightly. Rinse them with de-ionized water and wipe with a clean paper towel.

8. Hold the vials by the cap over a sink. Invert gently several times to mix. Place the vials in the preheated COD Reactor.

   *The sample vials will become very hot during mixing.

9. Heat the vials for two hours.

10. Turn the reactor off. Wait about 20 minutes for the vials to cool to 120°C or less.

11. Invert each vial several times while still warm. Place the vials into a rack and cool to room temperature.

12. Proceed with Colorimetric Determination Method 8000.

13. Touch **Hach Programs**. Select program **430 COD LR** (Low Range) or **435 COD HR** (High Range/High Range Plus). Touch **Start**.

14. Clean the outside of the vials with a damp towel followed by a dry one to remove fingerprints or other marks.

15. Install the 16-mm adapter. Place the blank into the adapter.

16. Touch **Zero**. The display will show: **0 mg/L COD**.

17. When the timer beeps, place the sample vial into the adapter. Touch **Read**. Results will appear in mg/L COD.

3.5.2 BOD

1. *Preparation of dilution water*: Add 1mL each of phosphate buffer, magnesium sulfate, calcium chloride, ferric chloride solution into 1L volumetric flask. Add distilled water to 1L.
2. Add 1mL wastewater sample into a 500mL beaker.
3. Add dilution water up to 300mL into the same beaker.
4. Adjust pH value to 6.5 to 7.5 by adding acid/alkali.
5. Prepare 300mL dilution water as control.
6. Put all prepared samples and control in 300mL-incubation bottle.
7. Measure DO for each sample by using Dissolved Oxygen Meter.
8. Put all the bottles in BOD Incubator for 5 days. Set the temperature at 20°C.
9. Measure final DO value after 5 days.
10. Calculate BOD_5 according to the formula below;

$$BOD_5\text{, mg/L} = (D_1 - D_2) / P$$

Where;

D_1 = DO value in initial sample

D_2 = DO value in final sample

P = Decimal volumetric fraction of sample used

Or;

$$BOD_5\text{, mg/L} = (D_1 - D_2) \times \text{Dilution factor}$$

Dilution factor = Bottle volume (300mL) / Sample volume

3.5.3 pH

1. Pour 20 ml of POME into a beaker
2. Put pH electrode into the sample to read it's pH
3. Take the reading when the sign on pH meter shows READY.

3.5.4 Total suspended solid

1. Dry the filter disk in the oven at 103°C to 105°C for 1 hour, cool in a desiccator and weigh.
2. Assemble filtering apparatus and filter and begin suction. Wet filter with a small volume of distilled water to seat it.
3. Pipette 50 mL of water sample (mixed to ensure homogeneity) onto centre of filter disk in a buchner flask, using gentle suction (under vacuum).
4. Wash filter with three successive 10 mL volumes of distilled water, allowing complete drainage between washings, and continue suction for about 3 min after filtration is complete.
5. Carefully remove filter from filtration apparatus and transfer to aluminum weighing dish/crucible dish as a support.
6. Dry at least 1 hour at 103°C to 105°C in an oven, cool in a desiccator to balance temperature, and weigh.
7. Repeat the cycle of drying, cooling, desiccating, and weighing until a constant weight is obtained.
8. Duplicate the test for each sample.

3.5.5 Oil and grease

1. Pour 100 ml of clear sample into separating funnel
2. Add 2.5 ml of 50% H_2SO_4, 30 ml N-Hexane. Cover the mouth and shake well for two minutes. Add 3 ml propanol
3. Transfer the bottom layer into second separating funnel. Repeat step 2 two times.
4. Collect all the surface layer, then add 1 scoop sodium sulphate.
5. Transfer into round bottom flask and use the rotary evaporator to get the oil and grease and weight them.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The following chapter shows the entire effectiveness of each parameter that was measured in this research. This chapter gives a detail explanation on the results that get in the research.

4.2 Result and Discussion

4.2.1 Biochemical Oxygen Demand (BOD_5)

Table 4.1 Result of Biochemical Oxygen Demand (BOD_5)

	Day 1	Day 3	Day 5
Control (mg/L)	310	279	216
Experiment 1 (mg/L)	310	267	162
Experiment 2 (mg/L)	310	90	75

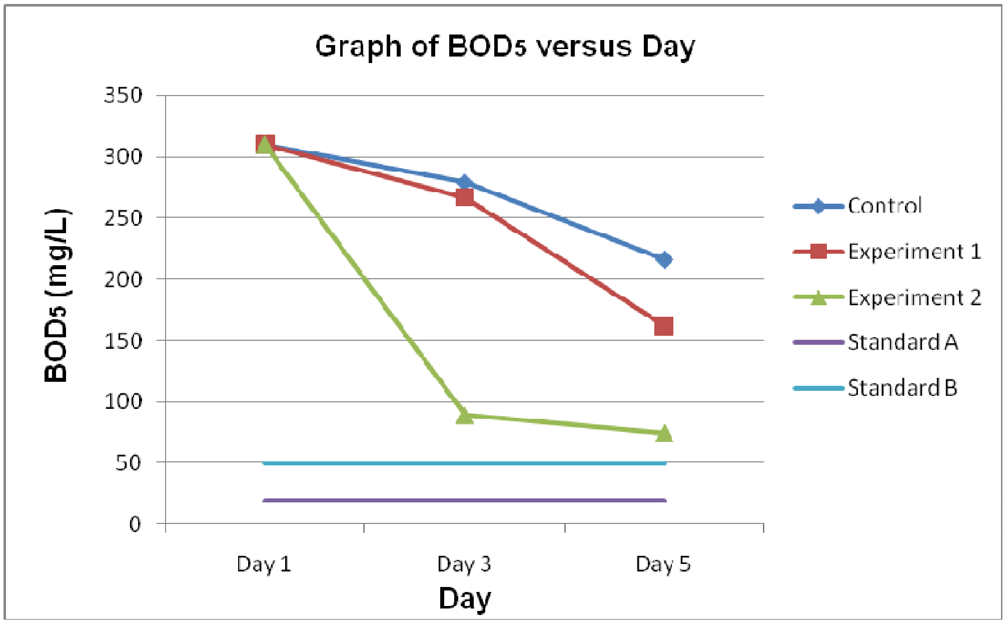


Figure 4.1 Graph of BOD_5 versus Day

Data Analysis

i) For control, BOD_5 decreased from 310 mg/L to 216 mg/L after 5 days. The removal percentage can reach until 30% even though not has aquatic plant and circulation.

ii) For experiment 1, BOD_5 decreased from 310 mg/L to 162 mg/L after 5 days with 47.7% removal. The percentage removal for experiment 1 is higher than control. So that, the presence of *Nymphaea Caerulea* in experiment 1 can reduces the value of BOD_5.

iii) For experiment 2, BOD_5 decreased from 310 mg/L to 75 mg/L after 5 days and reached 76% removal. The presence of *Nymphaea Caerulea*, that is supplemented with circulation can improve the water quality and it is an effective optimal design in this research because this circulation can enhance the kinetic process.

iv) From the graph, we can see that the BOD_5 level is decreased from day to day. However, the value of BOD_5 still does not meet the value of standard in Environment Quality Act 1974 which is 50 mg/L.

Discussion

Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose this waste. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste. The presence of *Nymphaea Caerulea* and circulation can reached up to 76% removal for BOD_5. It is because the stems and leaves of *Nymphaea Caerulea* provide a good habitat for bacteria to attach and grow to assimilate the colloidal/soluble BOD_5 remaining in wastewater (Sooknah, 2000). Besides that, circulation is seen to enhance the kinetics of processes that lower the levels of BOD. Water circulation devices also enhance DO supplies in ponds by mixing DO supersaturated surface waters with deeper waters of lower DO concentration. This reduces the loss of oxygen from ponds by diffusion. Also, when surface waters are not saturated with DO, water circulation causes surface disturbance and enhances oxygen absorption by the water (C.E. 1998).

4.2.2 Chemical Oxygen Demand (COD)

Table 4.2 Result of Chemical Oxygen Demand (COD)

	Day 1	**Day 3**	**Day 5**
Control (mg/L)	985	790	675
Experiment 1 (mg/L)	985	650	475
Experiment 2 (mg/L)	985	505	370

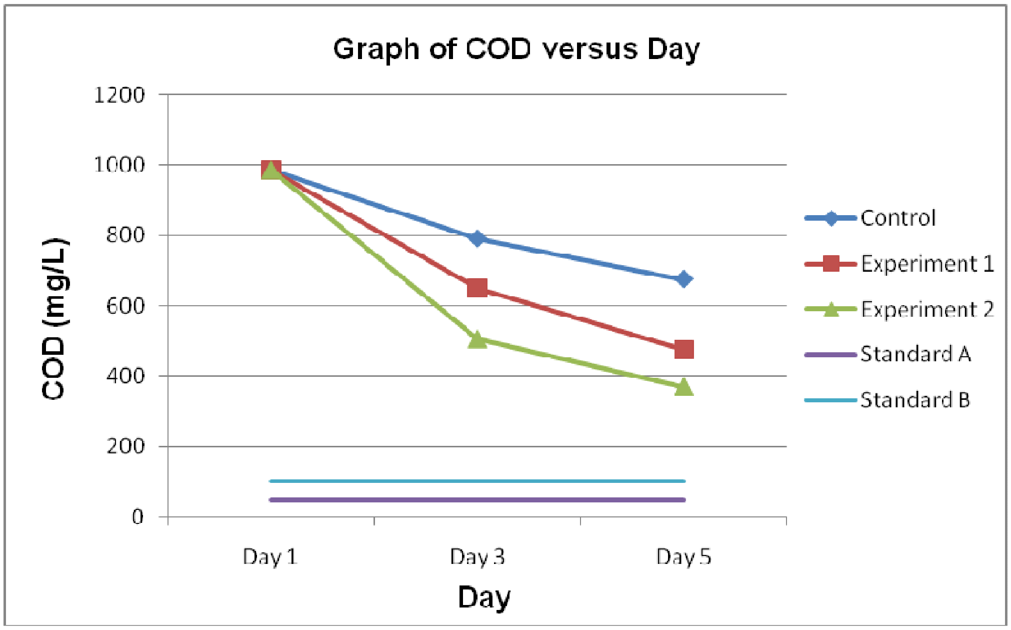


Figure 4.2 Graphs of COD versus Day

Data analysis

i) The graph shows that COD removal displayed an increasing trend over time, while the contribution of plants was the highest at day 5. Removal percentage for control is 32%, experiment 1 is 52%, and experiment 2 is 62%.

ii) *Nymphaea Caerulea*, which supplemented with circulation, played the main role in order to reduce the COD level until reach the highest percentage removal.

iii) Until day 5, the level of COD still does not meet the standard value in Environment Quality Act 1974 which is 100mg/L.

Discussion

COD of wastewater is higher than the BOD because more elements can be oxidized in chemistry than biology from Lignin. Furthermore, dichromate oxidized slightly non-organic materials. Oxygen released by roots will be used by bacteria to decompose organic material and non- organic material in aerobic condition. Besides that, Hydrophytes played an important role in COD removal (Zhang, 2007).

4.2.3 Total Suspended Solids

Table 4.3 Result of Total Suspended Solids

	Day 1	Day 3	Day 5
Control (mg/L)	410	385	357
Experiment 1 (mg/L)	410	342	383
Experiment 2 (mg/L)	410	240	180

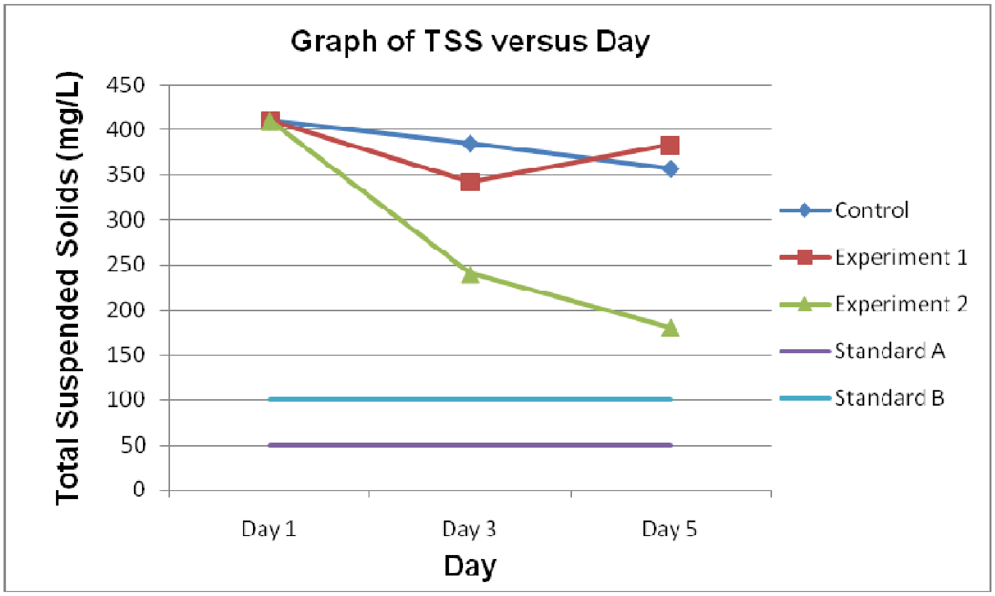


Figure 4.3 Graph of TSS versus Day

Data analysis

i) For control, TSS is slightly decreased from day to day. The reduction occur only 13% removal.

ii) The removal percentage for experiment 1 is not constant. Decrease of the removal percentage is caused by the increase of suspended solids in waste water. The roots and the leaves have died and impurities that enter into the former contributed to the increase suspended solids in the sample.

iii) For experiment 2, TSS decreased constantly within 5 days with 56% removal.

iv) If the shelf life of these aquatic plants can reach until day 7, the potential of removal to achieve the value of standard which is 100 mg/L is inferred.

Discussion

Since most of SS concentrations in aquatic ponds are normally from algae, this situation suggested that the leaves of floating-leaf plants in lotus unit above the water surface can prevent wind action and suppress sunlight. These conditions are unfavorable for growth of suspended algae in the water column and also enhance sedimentation (Jiang and Xinyaun, 1998).

4.2.4 pH

Table 4.4 Result of pH

	Day 1	Day 3	Day 5
Control (mg/L)	8.70	9.10	9.59
Experiment 1 (mg/L)	8.70	8.42	8.21
Experiment 2 (mg/L)	8.70	8.31	8.18

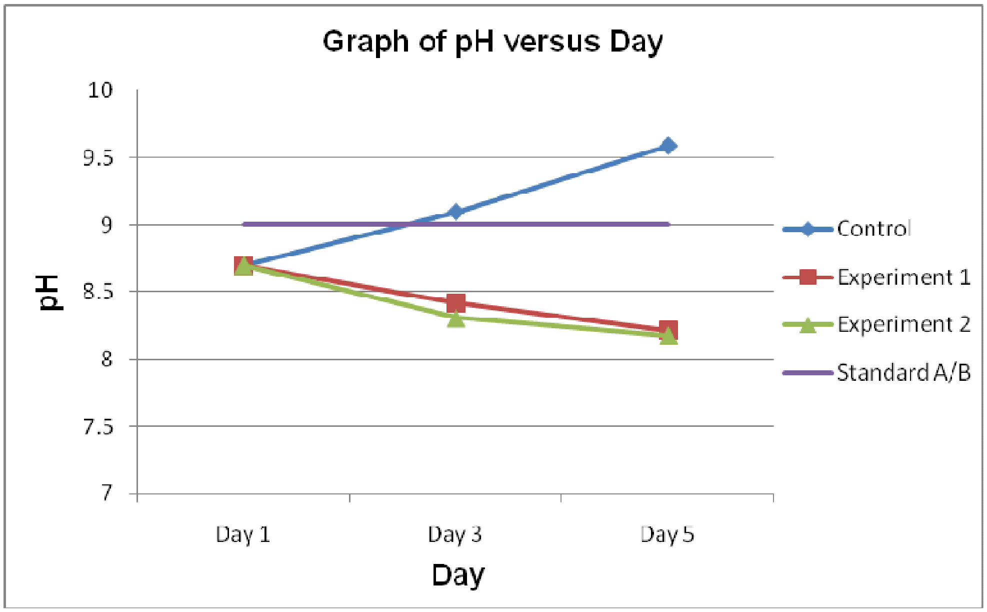


Figure 4.4 Graph of pH versus Day

Data analysis

i) The sample that obtained from LCSB Oil Palm Plantation is in alkaline condition. For Control, the pH level of sample is increase.

ii) For experiment 1 and experiment 2, pH is decreased constantly. The presence of aquatic plants and circulation can decrease pH level. This aquatic plant can encourage metabolism of microorganism to decompose.

iii) From this research, the pH of the sample in experiment 1 and experiment 2 met the value of standard in Environment Quality Act 1974.

Discussion

Process of photosynthesis by algae will reduce the concentration of carbon dioxide in the water and increase pH. When the free carbon dioxide is below its equilibrium with air, an increase in pH will occur (Thongchai and Udomphon, 2004). When the plant spread to the entire sample, the pH level can be reduced effectively.

4.2.5 Oil and Grease

Table 4.5 Result of Oil and Grease

	Day 1	Day 3	Day 5
Control (mg/L)	654	605	560
Experiment 1 (mg/L)	654	595	185
Experiment 2 (mg/L)	654	505	100

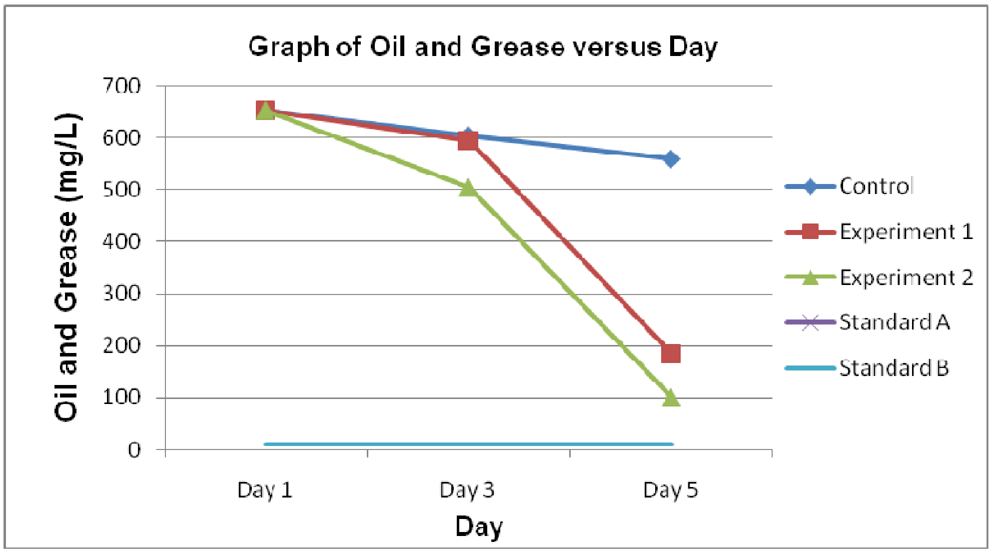


Figure 4.5 Graph of Oil and Grease versus Day

Data analysis

i) The graph shows that Oil and Grease removal displayed an increasing trend over time, while the contribution of plants was the highest at day 5. For the control, the removal percentage reached at 14.37%.

ii) For experiment 1, the removal percentage is increase up to 71.71% and for experiment 2 is 84.7%. The roles of *Nymphaea Caerulea* and circulation influence the increment of removal percentage.

iii) However, the level of oil and grease still do not exceed the value of standard in Environment Quality Act 1974.

Discussion

Generally not all the oil and grease is removed from sewage by primary settling unit. Appreciable amounts remains in a finely divided emulsified form. For this experiment, we can see that, this aquatic plant has efficiency in accumulate oil and grease. The roots of these aquatic plants play the main role in oil and grease removal by absorb oil and grease.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this study, the finding from the experimental runs will be discussed and evaluated to determine the feasibility of aquatic plants to improving water quality. From the result analysis, conclusion can be made to identify the ability of aquatic plants as an alternative method in improving water quality for industrial wastewater. Recommendation is included for future study to improve the performance of treatment industrial effluent by using aquatic plants.

5.2 Conclusion

Objectives of this research are to study the feasibility of aquatic plant (*Nymphaea Caerulea*) in POME treatment for POME at stage 7 and to investigate the efficiency by using optimal design condition whereby emphasis is placed on waste water circulation. The parameter that measured in this research includes BOD, COD, pH, TSS and oil and grease. This research is applied in laboratory scale.

From this research, we can conclude that *Nymphaea caerulea* is able to survive in POME only for 6 days. The parameter is measured on day 1, day 3 and day 5. The pollutants removal percentage increase from day to day. It is shown that in the presence of *Nymphaea Caerulea*, that are supplemented with circulation can reduce the level of each parameter in order to improve water quality.

The highest removal percentage of BOD is 76%, COD is 62%, TSS is 56%, Oil and Grease is 84.7%. Besides that, the specimen of *Nymphaea Caerulea* can reduce the pH level.

5.3.1 Recommendations

The recommendations for this research as follows:

i) Due to 1 week of periods, the POME sample was decrease over day because of the weather. If the concentration of POME sample change, the lab result also affect directly.

ii) Since *Nymphaea Caerulea* has only 6 days in retention time, prefer use other aquatic plant due to the retention time such as water hyacinth in order to get the best result and meet the value of standard in Environment Quality Act 1974. So that, the sample can be discharge into the river safely.

iii) Use the former that suitable with size of leaves and roots of this *Nymphaea Caerulea.* If the size of the former is not sufficient, it may cause the death to part of these aquatic plants that cannot absorb water.

REFERENCES

A.L. Ahmad, M.F. Chong, S. Bhatia, S. Ismail. (2006). Drinking water reclamation from palm oil mill effluent (POME) using membrane technology. *Desalination.* 191, 35-44.

A.L. Ahmad, S. Ismail, S. Bhatia. (2005). Ultrafiltration behavior in the treatment of agro-industry effluent: Pilot scale studies. *Chemical Engineering Science*. 60, 5385 – 5394.

A.R. Khalid and W.A. Wan Mustafa. (1992). External Benefits of Environmental Regulation: Resource Recovery and the Utilisation of Effluents. *The Environmentalist*. 12 (4), 277-285.

Abdul Latif Ahmad, Suzylawati Ismail, Subhash Bhatia. (2003). Water recycling from palm oil mill effluent (POME) using membrane technology. *Desalination*. 157, 87-95.

Bassim H. Hameed, Abdul Latif Ahmad & Ng Ai Hoon. (2003). Removal of residual oil from palm oil mill effluent using solvent extraction method. *Technology*. *38*, 33-42.

Claude E. Boyd. (1998). Pond water aeration systems. *Aquacultural Engineering*. 18, 9-40.

F. Chazarenca, V. Gagnona, Y. Comeaub, J. Brissona. (2009). Effect of plant and artificial aeration on solids accumulation and biological activities in constructed wetlands. *Ecological Engineering*. 35, 1005-1010.

Foluso O. Agunbiade , Bamidele I. Olu-Owolabi , Kayode O. Adebowale. (2009). Phytoremediation potential of Eichornia crassipes in metal-contaminated coastal water. *Bioresource Technology*. 100, 4521–4526.

G. G. Aggelis; H. N. Gavala; G. Lyberatos. (2001). Combined and Separate Aerobic and Anaerobic Biotreatment of Green Olive Debittering Wastewater. *Agricultural of Engineering Research*. 80 (3), 283-292.

J.A. Alvarez , I. Ruız, M. Soto. (2008). Anaerobic digesters as a pretreatment for constructed wetlands. *Ecological Engineering*. 33, 54-67.

J.C. Igwe and C.C. Onyegbado. (2007). A Review of Palm Oil Mill Effluent (Pome) Water Treatment. *Environmental Research*. 1 (2), 54-62.

M. Abid Baig, Mohsin Mir, Zafar I. Bhatti and M A. Baig. (2003). Removal oil and grease from industrial effluents. *Electronic Journal of Environmental, Agricultural and Food Chemistry*. 2 (5), 577-585.

Rafael Borja , Charles J. Banks , Enrique Sinchez. (1996). Anaerobic treatment of palm oil mill effluent in a two-stage up-flow anaerobic sludge blanket (UASB) system. *Biotechnology*. 45, 125-135.

Ray R. Hinchman ,M. Cristina Negri ,Edward G. Gatliff. (n.d.). Phytoremediation: using green plant to clean up contaminated saoil, groundwater, and wastewater.

Sooknah, R. (2000). A review of the mechanisms pollutant removal n water hyacinth systems. *Science and Technology Research Journal , 6*, 49-57.

T.Y. Chen , C.M. Kao , T.Y. Yeh , H.Y. Chien , A.C. Chao. (2006). Application of a constructed wetland for industrial wastewater treatment: A pilot-scale study. Chemosphere. 64, 497–502.

Ta Yeong Wu, Abdul Wahab Mohammad, Jamaliah Md. Jahim, Anuar Nurina. (2009). A holistic approach to managing palm oil mill effluent (POME): Biotechnological advances in the sustainable reuse of POME. *Biotechnology Advances*. 27, 40-52.

Tan, J., Mohd. Ariffin, A. H., Ramlan, A. A., Mohd Rozainee, T. (2006). Chemical precipitation of palm oil mill effluent (POME). *Proceedings of the 1st International Conference on Natural Resources Engineering & Technology 2006*, (pp. 400-407).

Thongchai Kanabkaew and Udomphon Puetpaiboon. (2004). Aquatic plants for domestic wastewater treatment:Lotus (Nelumbo nucifera) and Hydrilla (Hydrilla verticillata) systems. *Journal Science Technology*. 26 (5), 749-756.

Y. Zimmels, F. Kirzhner, A. Malkovskaja. (2006). Application of Eichhornia crassipes and Pistia stratiotes for treatment of urban sewage in Israel. *Environmental Management*. 81, 420-428.

Y. Zimmelsa, F. Kirzhnera, A. Kadmonb. (2009). Effect of circulation and aeration on wastewater treatment by floating aquatic plants. *Separation and Purification Technology*. 66, 570-577.

Zhang Yejian, Yan Li, Qiao Xiangli, Chi Lina, Niu Xiangjun, Mei Zhijian , Zhang Zhenjia ,. (2008). Integration of biological method and membrane technology in treating palm oil mill effluent. *Environmental Sciences*. 20, 558–564.

D. Krantz and Kifferstein., Water pollution and society. Retrieved on 3 August 2009 from http://www.umich.edu/~gs265/society/waterpollution.htm

Aquatic plants. Retrieved on 10 August 2009. http://www.botgard.ucla.edu/html/botanytextbooks/lifeforms/aquaticplants/fulltextonly.html

Malaysian palm oil industry. Retrieved on 15 August 2009 from http://www.mpoc.org.my/malaysian_palm_oil_industry.aspx

http://www.flowersofindia. Retrieved on 20 August 2009.

Chemical oxygen demand. Retrieved on 9 December 2009. http://science –jrank.org/pages/1388/chemical-oxygen-demand.

Oasis: Environment Ltd. Retrieve on 9 December 2009. http://www.oasissenriro.co.uk/Glossary A to B.htm

EPA., A citizen's guide to phytoremediation. Retrieved on 10 December 2009. http://clu-in.org/download/citizens/citphyto.pdf

Biobasics. Retrieved on 10 December 2009. http://www.biobasics.gc.ca/english/View.asp?x=742

What is phytoremediation? Retrieved on 10 December 2009. http://arabidopsis.info/students/dom/mainpage.html

Phytovolatilization. Retrieved on 11 December 2009. http://www.hawaii.edu/abrp/technology/phytovola.html

Environmental engineering lab manual. Faculty of Chemical and Natural Resources Engineering, University Malaysia Pahang.

APPENDIX

EQUIPMENTS

BOD

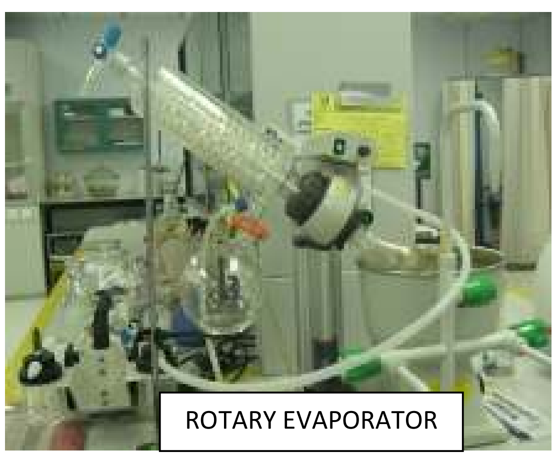

BOD BOTTLE


DISSOLVED OXYGEN METER

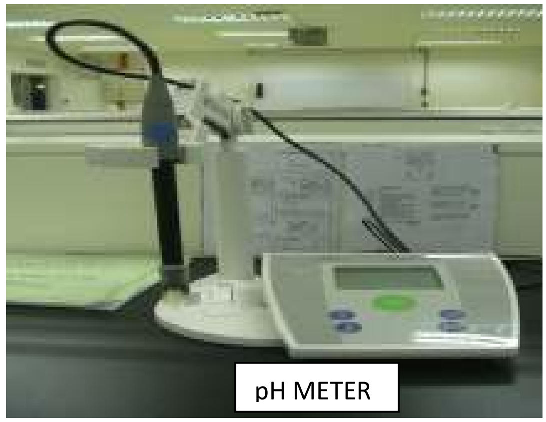

BOD INCUBATOR

COD

OIL AND GREASE

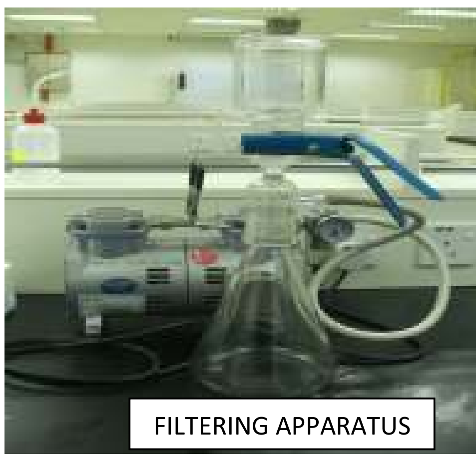


pH

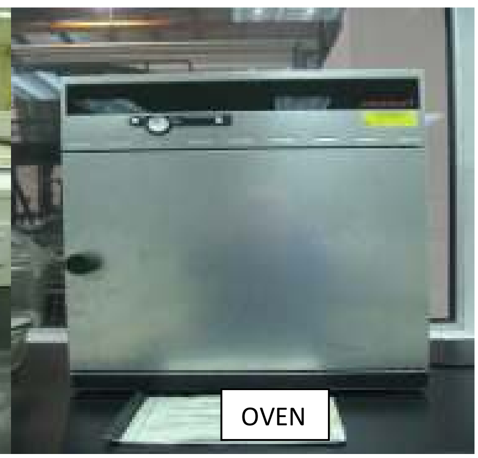


pH METER

TSS



FILTERING APPARATUS



OVEN

ANALYTICAL BALANCE