TREATMENT OF INDUSTRIAL WASTEWATER USING CONSTRUCTED WETLAND: REMOVAL OF CHEMICAL OXYGEN DEMAND (COD) AND TOTAL SUSPENDED SOLID (TSS)

NUR ANIS BT MAT ARIFFIN

A project report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Chemical Engineering (Biotechnology)

Faculty of Chemical and Natural Resources Engineering
Universiti Malaysia Pahang

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I declare that this project report entitled "*Treatment of Industrial Wastewater Using Constructed Wetland: Removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS)*" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	……………………
Name	:	Nur Anis Bt Mat Ariffin
Date	:	30 April 2009

Special dedication to my family members,
my friends and my fellow colleague.

For all your care, support and believe in me.

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ABSTRACT

Wastewaters from industrial places are very complex and lead to water pollution if discharged untreated. Palm oil mill effluent (POME) contain high amount of Chemical Oxygen Demand (COD), Total Suspended Solid (TSS) and nutrients. Therefore, wastewater treatment such as constructed wetland is needed to decrease the effect of contamination. Constructed wetland is a wetland that specifically constructed to control pollution from wastewater. The objective of this research is to study the efficiency of constructed wetland to treat pollutant in POME. Parameters concerns are COD and TSS. In this study, lab scale of constructed wetland had been constructed by using water lettuce (*Pistia stratiotes*) as wetland plant and gravel as filter. This experiment consists of two systems which are without and with cycle. Each system was conducted on four stages; first and third stage used gravel as a filter while second and fourth stage used constructed wetland to remove the pollutant. This experiment was conducted with different concentrations of sample which are 100% concentration and 80% concentration. For the System 1 (without cycle) which is 10 days of treatment, 96.89 % of COD and 96.21% of TSS had been removed from 100% sample concentration while 95.06% of COD and 84.59% of TSS had been removed from 80% of sample concentration. For the System 2 (with cycle) which is 20 days of treatment, the results showed removal of 98.32% of COD and 98.02% of TSS from 100% sample concentration whereas 98.01% of COD and 95.77% of TSS removed from 80% sample concentration. As a conclusion, constructed wetland can be used as industrial waste treatment and also gives high efficiency in removal of contaminant in POME.

ABSTRAK

Sisa buangan dari kawasan industri boleh menyumbang kepada pencemaran air jika tidak diberi rawatan yang betul. Sisa buangan dari kilang pemprosesan kelapa sawit mempunyai kandungan Keperluan Oksigen Kimia (COD) dan Jumlah Pepejal Terampai (TSS) yang tinggi. Oleh itu, rawatan sisa buangan seperti tanah bencah buatan diperlukan untuk mengurangkan pencemaran. Tanah bencah buatan ialah tanah bencah yang dibuat khas untuk mengawal pencemaran dari sisa buangan. Objektif kajian ini adalah untuk mengetahui keberkesanan tanah bencah buatan untuk merawat pencemaran yang terkandung dalam sisa buangan dari kilang pemprosesan kelapa sawit. Parameter yang dikaji ialah COD dan TSS. Dalam kajian ini, tanah bencah berskala makmal dibuat menggunakan pokok kiambang *(pistia stratiotes)* sebagai tumbuhan akuatik dan batu kerikil sebagai penapis. Kajian ini terbahagi kepada dua sistem iaitu dengan Sistem 1 (rawatan tanpa ulangan) dan Sistem 2 (rawatan berulang). Setiap sistem terbahagi kepada empat peringkat; peringkat pertama dan ketiga menggunakan batu kerikil sebagai penapis manakala peringkat kedua dan keempat menggunakan pokok kiambang untuk menyingkirkan pencemaran dalam sisa buangan. Eskperimen ini juga menggunakan sisa buangan berlainan kepekatan iaitu berkepekatan 100% dan 80%. Bagi sistem pertama, 96.89% COD dan 86.21% TSS telah disingkirkan dari sisa buangan berkepekatan 100% manakala 95.06% COD dan 84.59% TSS telah berjaya disingkirkan dari sisa buangan berkepekatan 80%. Bagi sistem kedua, keputusan menunjukkan 98.32% COD dan 98.02% TSS telah disingkirkan dari sisa buangan berkepekatan 100% manakala 98.01% COD dan 95.77% TSS telah disingkirkan dari sisa buangan berkepekatan 80%. Secara keseluruhannya, tanah bencah buatan boleh digunakan untuk merawat sisa buangan dari industri dan juga berkesan untuk menyingkir pencemaran dalam sisa buangan dari kilang kelapa sawit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

BOD	-	Biochemical Oxygen Demand
CH_4	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
Cr^{3+}	-	Chromic ion
Cr^{6+}	-	Chromium
$Cr_2O_7^{2-}$	-	Dichromate ion
CW	-	Constructed wetland
HRT	-	Hydraulic Retention Time
mg/g	-	milligram per gram
mg/L	-	milligram per liter
NH_3	-	Ammonia
POME	-	Palm Oil Mill Effluent
SF	-	Surface flow system
SO_2	-	Sulfur Dioxide
SSF	-	Subsurface flow system
TSS	-	Total Suspended solid

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Saturated wetland is an area of land with soil that is saturated with moisture. Ghaly (2008) defines wetland as aquatic ecosystems that composed of vegetation dominated by hydrophytes and characterized by shallow waters overlying saturated soil. The main function of constructed wetland is to treat a variety of liquid wastes. For examples, wastewater, storm water runoff or sewage treatment. It also acts as biofilters to removing sediments and pollutants such as heavy metal or nutrient. However, Sullivan (2003) describes constructed wetland as engineered marshes that duplicate natural processes to cleanse water. They can be used to process livestock effluent, human wastes, and drainage water.

Water quality refers to the quality of suspended and dissolved solids, dissolved gasses and microorganisms in a given quantity of water. In nature, all these impurities will enter and leave the water through the hydrologic cycles. The constructed wetland can be designed to manage both water quality and quality measure (Nur Asmaliza *et al.*, 2004). The constructed wetland that consists of perfect combination of water, substrate, and plant that needed to improve the water quality successfully. In addition, aquatic plant in this constructed wetland is playing their role to improve water quality by using soluble pollutant and incorporating them into plant tissue.

Wetland plants are important to conduct hydrologic buffering, water purification and also to prevent sediment. This plant is also known as hydrophytic or hydrophytes plant. These kinds of plant have special characteristic due to the abundance of water in its environments. It has smaller roots to make sure water can diffuse directly into leaves and less rigid structure so that water pressure can support them. Water lettuce or its binomial name *Pistia Stratiotes* is one examples of wetland plant.

The water quality can be measured based on the parameters such as Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). These two parameters can be used to determine the quality of the sample. Chemical Oxygen Demand (COD) test is used to measure the maximum amount of oxygen that can be consumed by organic matter that discharge to aquatic environment will normally take up dissolved oxygen during degradation. Thus, the amount of oxygen is reducing in the sample. The difference between COD test with other parameter is the COD test measure nonbiodegradable organic. Total Suspended Solid (TSS) is defined as the portion of retained on a specific size filter after drying at 105^{o}C (Tamimi, 2003).

Malaysia is one of the producers of palm oil in the world. In order to produce product from palm oil such as cooking oil, margarine and soap, palm oil need to extract from fresh fruit bunch. Large amount of water have to use in this process. Malaysia Palm Oil Promotion Council (MPOPC) has state that about 1 to 1.5 tonnes of water is used for processing 1 tonne of fresh fruit bunches and 2.5 tonnes of Palm Oil Mill Effluent (POME) need to discard for every tonne of crude palm oil. POME is a brownish liquid that contain high amount of COD and TSS. Because of that, this effluent needs to treat very well before discharge to environment.

Figure 1.1 Empty fruit bunch and palm oil mill effluent (POME)

1.2 Objective

The objectives of this research are:

i. To determine the percentage of removal of COD and TSS in industrial wastewater by using constructed wetland
ii. To study the efficiency of constructed wetland as industrial wastewater treatment.

1.3 Scope of Study

In each system, Surface Flow System (SF) constructed wetland was set-up for the wastewater treatment. The wastewater was taken from Lepar Hilir Palm Oil Mill, Gambang. The same plant species (*Pistia Stratiotes*) was used as wetland plant and the amount of wastewater for each treatment was 15 liters. The scopes of study include:

i. There were two wetland system being set up which were 100% concentration of sample and 80% concentration of sample. Each of wetland systems had treated without cycle treatment and with cycle treatment.
ii. 15 wetland plants were used for each treatment and 4 containers were used in the experiment. The treatment was carried out for duration of 10 days for without cycle treatment and 20 days for with cycle treatment.
iii. The parameters analyzed were TSS and COD.

1.4 Problems Statement

Since in the middle of twenty century, water pollution have become worse day by day. There are two source of water pollution which are point source and nonpoint source. Point sources of pollution occur when harmful substances are emitted directly into water and nonpoint source delivers pollutants indirectly through environmental changes. It give a lot of harm to all living organism include human, animal and plant due to water intake from the pollutant water and also hydrologic cycle. Hydrologic cycle is describes by continuous movement of water on, above, and below the surface of the earth. Industrial wastewater is also contributed to pollute the environment. Because of that, industrial waste should be treated first before discharge to the river. It is important to decrease the spread of harmful organism. Although industrial wastewater quality varies among industries, it has a fairly consistent intrasystem effluent quality. However, raw material wastewater usually receives some level of pretreatment before discharge to a wetland treatment system.

Measurement of organic is usually by the COD test. These include organic pesticide, some industrial chemicals and hydrocarbon compounds that have combine with chlorine. Some organic are biodegradable because they are toxic to other organism. Therefore, excess of COD is harmful to environment. For example pesticide that is cumulative toxins and cause problems at higher end of the food chain. Excess of TSS also give some effect to our environment. Suspended material may be objectionable in water for several reasons. It is aesthetically displeasing and provides adsorption sites for chemical and biological agents. Suspended organic solids may be degraded biologically, resulting in objectionable by-products. Biologically active suspended solids may include disease-causing organisms as well as organisms such as toxin-producing strains of algae. In addition, high level of TSS also can lead to scaling or corrosion of facilities and equipment.

Reuse of water and nutrients at their source provide the opportunity to use simple and also low cost technology (House, 1998). The combination of treatment environment with constructed wetlands can provide water quality that suitable to reuse in the company. Constructed wetlands have their own advantages compare to other wastewater treatment. They have advantages of low investment, low energy consumption and easy maintenance.

1.5 Rationale and Significance

The rationale of this study is to know the efficiency of this method to treat wastewater. Even at low cost and easy to maintain, constructed wetland can be the best way in treating the industrial wastewater. Wetlands introduce another beneficial aspect of nutrient cycling and ecosystem production in the overall process, through a relationship between plants and the associated microorganism (Okurut, 2000). POME was choosing as sample of this study due to palm oil mill that grow in Malaysia recently. The higher COD and TSS in this solution also can be the best sample to study the removal of COD and TSS in constructed wetland.

The significance of this study is the water quality assessment on this sample can be a reference to construct the wetland for palm oil mill. In addition, this study also proves that the used of natural substances such as wetland plant and gravel as pollutant removal in this constructed wetland is better component to chemical treatment. The wetland plant itself can give the attractive environment to the mill.

CHAPTER 2

LITERATURE REVIEW

2.1 Wetlands

Wetlands is defined as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil condition. In general, wetlands mean those areas of the state that are flooded by surface or ground water with a enough characteristic to support significant vegetation or aquatic life which are depend on saturated soil conditions for growth and reproduction. Wetland has been used for treating municipal, industrial, and mining wastewater for decades. Some of wetland systems are called micro-wetlands or rock filters because they have a media filter such as a plants. It is grow to enhance treatment and create a pleasant landscape. These systems also provide safe treatment of wastewater with low maintenance. Kadlec and Knight (1996) found wetlands either natural or constructed to be effective in treating biochemical oxygen demand (BOD), suspended solids, nitrogen and phosphorus, and also for reducing concentrations of metals, organics and pathogens.

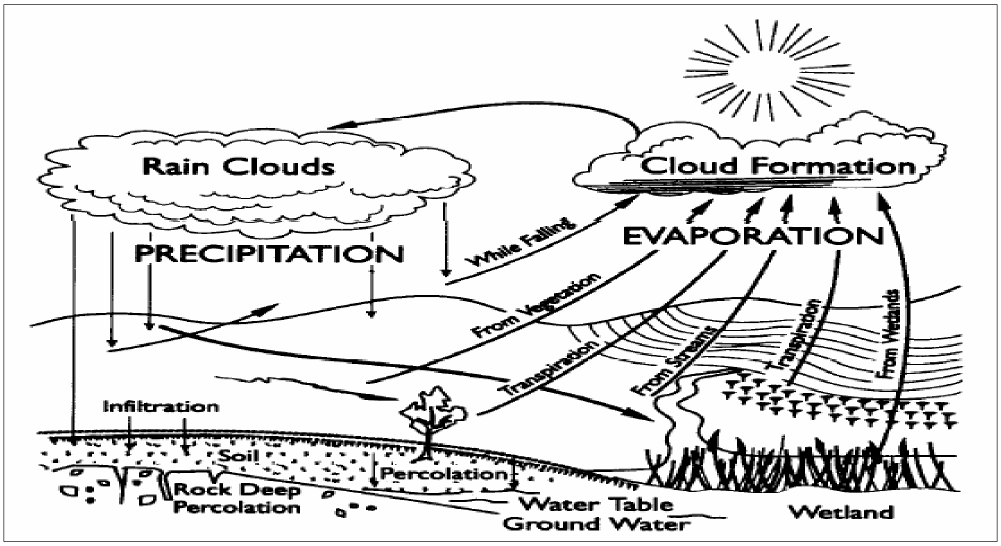

Figure 2.1 Wetland hydrogical cycle

2.2 Natural wetland

Natural wetlands are important for maintaining aquatic ecosystem biodiversity and should be considered as part of an effective ecosystem management strategy. Natural wetlands appear to perform all of the biochemical transformations of wastewater constituents that take place in conventional wastewater treatments plants, septic tanks, drain fields and other form of land treatment. Submerged and emerged plants, associated microorganisms and wetland soils are responsible for the majority of the treatment effected by the wetland (Hammer, 1989). Generally, natural wetland treatment system is used to providing further treatment of secondary effluent to meet downstream water quality standard. Natural wetland is more suitable to treat non point sources of pollution, such as urban stormwater and other diffuse sources of runoff.

Wetlands can function as nutrient sinks, temporary water storage areas, groundwater recharge areas, and critical wildlife habitat. Natural and human activities within a watershed influence the functions of natural wetlands. When these activities remain relatively constant, the functions of natural wetlands tend to exist in dynamic equilibrium with the surrounding conditions. It does purify water by acting like a sponge, soaking up rainwater that runs off the land before it enters rivers and streams. These natural cleaning processes of wetlands help keep our rivers, streams and oceans clean. Natural wetland is removing the pollutant in wastewater in four ways. There are removal of particles of sediment and metal by water flows through wetland vegetation and soils and removal of nutrients and pesticides as water percolated through wetland soils. In addition, natural wetland also serves as essential habitats for hundreds of plant and animal species, including endangered specie and decreases the impacts of flooding and helps prevent soil and shoreline erosion.

United Nations Environment Programme (UNEP) divided natural wetland into four major groups based on where this natural wetland occurs. There are fringe wetlands, riverine wetlands, depressional wetlands and peatlands. Fringe wetlands is include salt marshes and lakeside marshes in which water typically flows in two opposite directions, influenced by lunar and/or storm tides, riverine wetlands, which occupy floodplains, are usually characterized by water flowing in one direction, depressional wetlands, such as prairie potholes, which usually receive much of their water from runoff and/or groundwater seepage rather than from surface water bodies, so that water residence times are longer and peatlands that have long water residence times, but the accumulated peat creates a unique hydrologic regime that differs from the previous three types of wetlands. The disadvantage of natural wetland is the treatment capacity is unpredictable due to wetland performance that changes overtime as a consequence of changes in species composition and accumulation of pollutants in wetland.

2.3 Constructed Wetland

Constructed wetlands have diverse application across the country and around the world. They can be designed to accomplish a variety of treatment objectives. Constructed wetlands for wastewater treatment takes advantage of the same principles as a natural wetland system, but within a more controlled environment. It is because, constructed wetlands can be design with a much greater degree of control, thus following the establishment of experimental treatment facilities with a well-defined composition of substrate, type of vegetation, and flow pattern. In addition, constructed wetlands have several additional advantages compared to natural wetlands. It is include site selection, flexibility in sizing and most importantly, control over the hydraulic and retention time (Moshiri, 1993). United States Environmental Protection Agency (2000) simplify constructed wetland as wastewater treatment systems composed of one or more treatment cells in a built and partially controlled environment designed and constructed to provide wastewater treatment. This constructed wetland has been used to treat many types of wastewater at various levels of treatment.

2.3.1 Options in Constructed Wetland

References from Vaccari *et al*. (2006) said that the constructed wetland designs can be subdivided into two major options. It is include those rely on emergent plants and those that use submerge plants either alone or in combination with other emergent plants. There are Surface Flow system (SF) with shallow water depth and Subsurface Flow systems (SSF) with water flowing laterally through the sand or gravel.

2.3.1.1 Surface Flow System (SF)

The SF system is design with a shallow layer of surface water. This water will flow over mineral such as sand or organic soils. Vegetation for these types of wetland is more to floating and submerged aquatic plants as well as wetland shrubs and trees and often consists of marsh plants, such as cattails and reeds (DeBusk, 1999). Kadlec and Knight (1996) states that wetland plant in SF constructed wetlands are providing mineral cycling and attachment area for microbial populations that are important for water quality improvement. It usually has a natural or constructed clay layer to prevent seepage. Above the layer is the soil or other suitable medium to support the growth of emerged plant. Compared to SSF wetlands, SF systems is more like natural wetlands to treatment the water. It is closely resemble natural wetlands in appearance and function, with combination of open-water area, emergent vegetation, varying water depths, and other typical wetland features (United States Environmental Protection Agency, 2000).

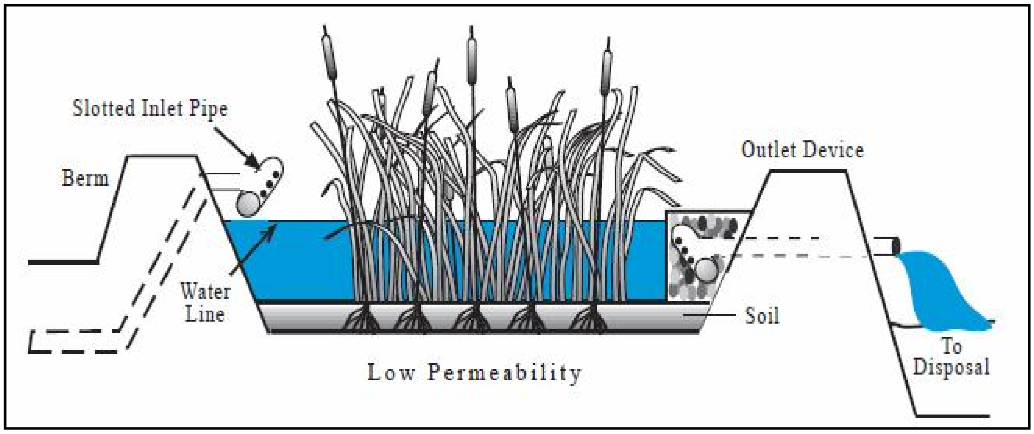

Figure 2.2 Surface Flow System

2.3.1.2 Subsurface Flow Systems (SSF)

In a SSF wetland, the basin is filled with other coarse substrate such as gravel and the water level is maintained below-ground. Microbial attachment sites are located on the surface of the media and on the roots of the wetland plant (Kadlec And Knight, 1996). Water flows horizontally or vertically depends on design of wetland go through the gravel and the root mat of the wetland vegetation (DeBusk, 1999). To operate correctly, a SSF system must initiate and maintain all or most flow, subsurface and horizontally through permeable media. Plant selection is quite similar for SF and SSF constructed wetlands. The same small group of emerged wetland plants grows best in both systems. SSF wetland is most effective compared to SF wetland if the sample contains high TSS. This system is more effective than SF system at removing pollutants at high application rates. However, overloading, surface flooding and media clogging of the media of sub surface system can result in a reduced efficiency. All these disadvantages are because of filter media that place in wetland. In addition, economic factor was need to consider in selection for treatment media such as gravel shape and size, and selection of vegetation as an optional feature that effect wetland aesthetics more than performance (United States Environmental Protection Agency, 2000).

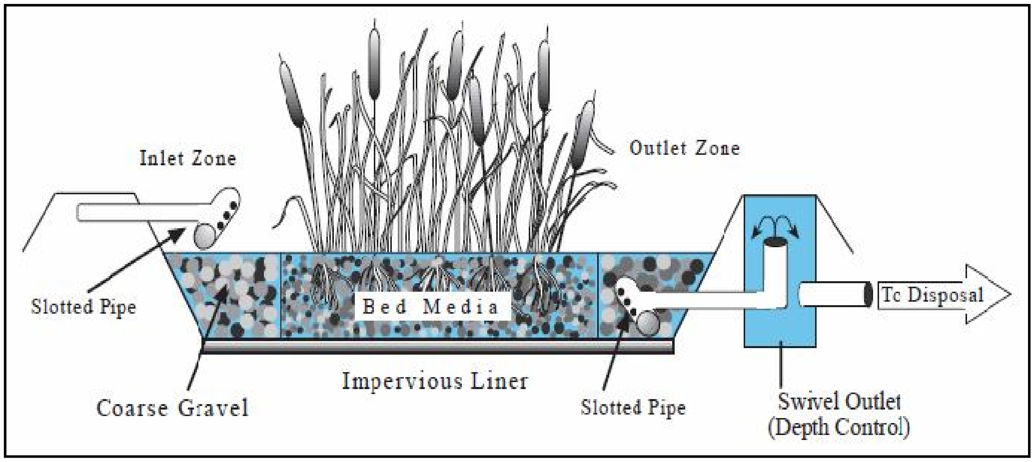

Figure 2.3 Subsurface Flow System

2.4 Pollutant Removal in Constructed Wetland

Constructed wetlands offer all the treatment capabilities of natural wetlands but without constraints related with discharging to a natural ecosystem. Like natural wetlands, constructed wetlands accomplish water quality improvement through a variety of physical, chemical, and biological processes. Constructed wetlands are well-known with special vegetation including cattails, bulrushes, reeds, sedges, and certain mosses and algae. They may also contain a variety of submerged plants. This is known as wetland plant. The especially about wetland plant is this vegetation obstructs the flow and reduces the velocity of the wastewater. Moreover, constructed wetland is efficient in removal of suspended and dissolved material in the wastewater. It is occur when wastewater is slowed. The vegetation also provides surfaces for the attachment of bacteria films, aids in filtration and adsorption of wastewater constituents, transfers oxygen into the water column, and controls the growth of most algae by restricting penetration of sunlight Hairston (2001).