INDUSTRIAL WASTEWATER TREATMENT USING CONSTRUCTED
WETLAND, VEGETATED WITH *PISTIA STRATIOTES*
(REMOVAL OF COD & NITRATES-NITROGEN)

ZAHARATUN NADWA SHA'RANI

A Project report submitted in partial fulfilment of the requirements for the award of
the degree of Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
University of Malaysia

MAY 20008

I hereby declare that this thesis entitled "*Industrial Wastewater Treatment Using Constructed Wetland, Vegetated with Pistia stratiotes (Removal of COD and Nitrates-nitrogen)*" 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   : ZAHARATUN NADWA BT SHA'RANI
Date   :

To my beloved mother and father

ACKNOWLEDGEMENT

Alhamdulillah. First and foremost, grateful to Allah s.w.t., enables me to complete my undergraduate project.

I would like to acknowledge special thanks to my supervisor, Mrs Noor Ida Amalina Ahamad Nordin as for her support and guidance throughout the completion of my project and report. The publication of this study would not be possible without her encouragements and advices. As for all the lessons, guidance and unparalleled knowledge shared will not be forgotten.

I am grateful to extend my special gratitude to all Jps of FKKSA of UMP as for their guidance and willingness to assist me during my lab works. A special thanks also to Mr. Anuar, assistant manager of Lepar Hilir Palm Industries Gambang, Pahang for his willingness to spend time and shares knowledges in industrial wastewater. It was an experience that I will not forget.

My sincere appreciation also goes to my colleagues for all their support and guidance during my report completion. Thanks to Sanisah Arsat, Anabil Ubil, Mohd Shahrel Baharudin and Abdul Zul Afif Abd Manaf.

Last but not least, thanks to my beloved family.

ABSTRACT

River pollution has been an environmental problem since the 1980 in which the major source came from the industrial area build near the waterways. While the country is heading well towards achieving Vision 2020 as an industrialized nation, the industries are facing with the loads of waste that needs treatment before it can be discharge into main waterways. The high cost of some conventional treatment processes has produced economic pressures. Thus, these have caused the search for alternatives which are cost-effective and environmental-friendly. This lab-scale study was investigating the efficiency of Surface-Flow Constructed Wetland (SFCW) to treat industrial pollutant. The treatment system was vegetated with *Pistia stratiotes* (water lettuce). There were two designs of experiments conducted to determine the highest percentage removal of pollutants in 15 days of treatment; varying number of *Pistia stratiotes* and varying dilution factor of wastewater. The parameters studied were Nitrates-Nitrogen and Chemical Oxygen Demand (COD) which are analyzed by using the Hach method. Results from both designated treatment system indicate that the optimal pollutant removal efficiency were the 15 *Pistias* and dilution factor of 15. System vegetated with 15 *Pistia stratiotes* shows COD removal of 92.5% and Nitrate-Nitrogen removal of 91.9%, while system using dilution factor of 15 shows COD removal of 84.9% and Nitrate-Nitrogen removal of 97.7%. Besides, the water quality of treated wastewater in this study complies with the standards of industrial effluents discharge. Thus, the study was a success in treating the industrial wastewater by using the SFCW system vegetated with *Pistia stratiotes.*

ABSTRAK

Pencemaran air sungai telah lama mencemar alam sekitar sejak tahun 1980, di mana sumber utama merupakan sisa buangan industri yang selalunya dibina di kawasan perairan. Semasa negara menuju ke arah kemajuan, mengejar Visi 2020 sebagai negara perindustrian, industri-industri ini terpaksa berhadapan dengan masalah merawat sisa buangan dalam jumlah yang besar. Kos proses rawatan sistem konvensional yang tinggi menyebabkan tekanan ekonomi. Keadaan ini membawa kepada perubahan mencari alternatif yang lebih efekif dari segi kos dan kualiti rawatan itu sendiri. Kajian makmal ini dijalankan untuk mengkaji keberkesanan Surface-Flow Constructed Wetland (SFCW) untuk merawat sisa industri. Kajian selama 15 hari ini menggunakan *Pistia stratiotes* sebagai tumbuhan yang berfungsi di dalam sistem rawatan SFCW ini. Terdapat dua keadaan dalam mengkaji keberkesanan sistem SFCW ini iaitu, bilangan tumbuhan yang digunakan dan faktor pencairan sisa industri. Parameter yang dikaji adalah Nitrat-nitrogen dan COD yang dianalisis menggunakan Teknik Hach. Keputusan kajian mendapati sistem rawatan yang mempunyai peratus penyingkiran bahan pencemar paling optimal adalah sistem 15 Pistia dan faktor pencairan 15. Keputusan hasil kajian sistem 15 Pistia menunjukkan penyingkiran COD, 92.5% dan penyingkiran Nitrat, 91.9% manakala sistem dengan faktor pencairan 15, penyingkiran COD, 84.9% dan penyingkiran Nitrat, 97.7%. Keputusan kajian ini juga mematuhi had piawai pembuangan sisa buangan industri yang telah ditetapkan. Kesimpulannya, SFCW berkesan untuk merawat sisa buangan industri secara efisyen.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

COD	-	Chemical oxygen demand
DF	-	Dilution factor
SF	-	Surface flow
SFCW	-	Surface-flow constructed wetland
SSF	-	Subsurface flow
SSFCW	-	Subsurface-flow constructed wetland

LIST OF SYMBOLS

C	-	Carbon
CH_4	-	Methane
CO_2	-	Carbon dioxide
COD	-	Chemical oxygen demand
Cu^{+2}	-	Copper
Fe	-	Ferum
mg/L	-	Miligram per liter
Ml	-	Mililiter
N_2	-	Nitrogen gas
N_2O	-	Nitrous oxide
NH^{+4}	-	Ammonium
NO^-_3	-	Nitrate-nitrogen

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Constructed wetlands are engineered to duplicate the processes occurring in natural wetlands, where the main purpose of the structure is to remove the contaminant or pollutant from the wastewater (Hammer *et. al.,* 1994). The constructed wetland is an integrated system consists of water, plants, microorganisms and the environment, in which can be manipulated to improve water quality. The constructed wetland is a new green technology, which has been recognized and accepted as a creative, cost-effective and enviromental friendly system when compared to the expensive conventional treatment systems (Jing *et al.*, 2001).

Recently, the multiple values and functions of the constructed wetlands, has been widely used for treating a variety of wastewaters of many sectors (Green *et al.,* 1997). Thus, an extensive research and practical application is being gained in order to operate the system effectively. In the last few decades, the constructed wetlands are widely applied for the purification of stormwater, agricultural, domestic and also industrial wastewater treatment (Panswad *et al.*,1997). The use of constructed wetland on industrial pollutants is increasingly utilized and these represent a promising alternative method to treat the various types of industrial wastewater using the new technology of constructed wetlands (Kadlec, 1996).

Macrophytes are the main biological component in wetland system. The presence of the macrophytes in the constructed wetland system is to reduce the

concentration of pollutant nutrients from wastewater and also to alter the physico-chemical environment of the water (Reddy, 1984). However, it is important in determining the appropriate macrophyte species that can survive the industrial wastewater environment (Hadad *et al.,* 2006).

The study aims to investigate the efficiency of using free-floating species for constructed wetland system, the water lettuce. The abundance of these water lettuces favors the supplies of macrophytes for the purpose of the study. The long feathery roots of the water lettuce can immediately sump all the excess nutrient out of the water column. These root hairs are much more efficient in nutrient uptake than submersed leaves. In recent research suggested that only a suitable macrophyte can treat a high concentration of pollutants in industrial wastewater. The knowledge on characteristics of plant uptake in nutrient removal is essential in achieving an effective removal of nutrient in constructed wetland system (Hadad *et al.,* 2006). Several studies have documented that free-floating macrophytes especially water hyacinth (*Eichornia crassipes*) and water lettuce (*Pistia stratiotes)* have a high capacity to remove a large amount of pollutants (Sooknah *et. al.,* 2004). Thus, it is an appealing option to use water lettuce *(Pistia stratiotes)* as to investigate its potential in constructed wetland treatment.

1.2 PROBLEM STATEMENT

As a developed country, Malaysia is heading well towards achieving Vision 2020 as an industrialised nation. Inevitably, the industrial sector is rapidly emerging as the major threat to the biological diversity in the country. The early industrialisation phase of developing the resource-based industries in the 1970s, primarily palm oil and rubber processing, resulted in the discharge of large amounts of organic effluents into the waterways. As industrialisation progressed and diversified, the major sources of industrial water pollution also increase. The Department of Environment identified the chemical, food and beverage, textile, metal finishing, animal husbandry, and the rubber and palm oil processing industries

as the biggest water polluters in 1995. It is reported that all highly polluted rivers are located in a highly urbanised or industrialised area. Thus, the industries have become a threat to the aquatic living and the ecosystem.

Many industrial facilities provide pretreatment before its discharge into the environment. The conventional industrial wastewater treatment uses chemicals. Hence, still contribute to pollution when react with certain subtances. As for industries which involve complex processes, require a complex treatment process which needs higher costs. The inefficient and ineffective of the wastewater management system of industries has produced economic pressures and caused engineers to search for creative, cost-effective and environmentally ways to control water pollution.

In this research study, an alternative method is suggested by using the constructed wetland system for treating industrial waste. The constructed wetland system provides various advantages, which widens their appeal among different interests from the wastewater treatment facilities. The system are creative in terms of substrates, vegetation and flow pattern, cost-effective as the treatment plant do not rely on concrete and steels and need only periodic on-site labor, also environment friendly as an attraction to varied wildlife. The scheme has the potential to be developed into an environmentally and economically acceptable industrial wastewater treatment technology (Chen *et al.,* 2006). Yet, many studies and lab-scale experiments has been developed and documented in order to improve water quality and achieve the limit parameters of industrial effluents discharge standards.

1.3 SCOPE OF RESEARCH WORK

The treatment system is vegetated with *Pistia stratiotes* plant with different experimental conditions. Parameters that are considered in the experiments are Chemical Oxygen Demand (COD) and Nitrate-Nitrogen.

Below are the scopes in this study;

i. Investigate the removal efficiency of COD and Nitrate in treatment system by using different concentration of industrial wastewater

ii. Investigate the removal efficiency of COD and Nitrate in treatment system by using different number of *Pistia stratiotes*

iii. Duration of treatment process is in 15 days, sampling of wastewater is recorded once in 2 to 3 days.

1.4 OBJECTIVE OF STUDY

The objective of the study is to investigate the removal efficiency of Chemical Oxygen Demand (COD) and Nitrate-Nitrogen in industrial wastewater using constructed wetland treatment system, vegetated with *Pistia stratiotes.*

CHAPTER 2

LITERATURE REVIEW

2.1 WETLANDS

Wetland are defined by the Convention of wetland of International Importance (the Ramsar Convention 1971) as; "Land inundated with temporary or permanent water that is usually slow moving or stationary, shallow, fresh, brackish or saline, where the inundation determines the type and productivity of soils and the plant and animal communities". Hence, wetlands can be further defined into natural wetlands and constructed wetlands.

2.1.1 NATURAL WETLANDS

Natural wetlands is a naturally occuring wetlands which include swamps, marshes, ponds, peatlands and bogs. The plant types, water and geographic conditions vary, creating defferent kinds of wetlands.

2.1.2 CONSTRUCTED WETLANDS

Constructed wetlands, in contrast to natural wetlands, are man-made systems or engineered wetlands that are designed, built and operated to emulate functions of natural wetlands for human desires and needs. It is created from a non-wetland ecosystem or a former terrestrial environment, mainly for the purpose of contaminant or pollutant removal from wastewater (Hammer *et. al.,* 1994).

2.1.2.1 CONSTRUCTED WETLANDS TREATMENT SYSTEM

Constructed wetlands can be built with a much greater degree of control, thus allowing the establishment of experimental treatment facilities with a well-defined composition of substrate, type of vegetation and flow pattern. In addition, constructed wetlands offer several advantages compared to natural wetlands, including site selection, flexibility in sizing and control over the hydraulic pathways and retention time.

Recently, there has been a growing appreciation of the multiple values and functions of constructed wetlands, which are increasingly used for treating a variety of wastewaters (Green *et al.*, 1997). The use of constructed wetlands is widely use in treating municipal effluent, industrial effluent, agriculture runoff, stormwater runoff, animal wastes and landfill leachates.

Although a primary purpose of constructed wetlands is to treat various kinds of wastewater, the facilities also serve other purposes as well. A wetland can serve as a wildlife site, to attract some types of wildlife and provide habitat for these flora and fauna. It is Thus, gives characteristics for tourism facilities. There are also beneficial for publics to exlplore the environmental and educational possibilities of wetland ecosystem.
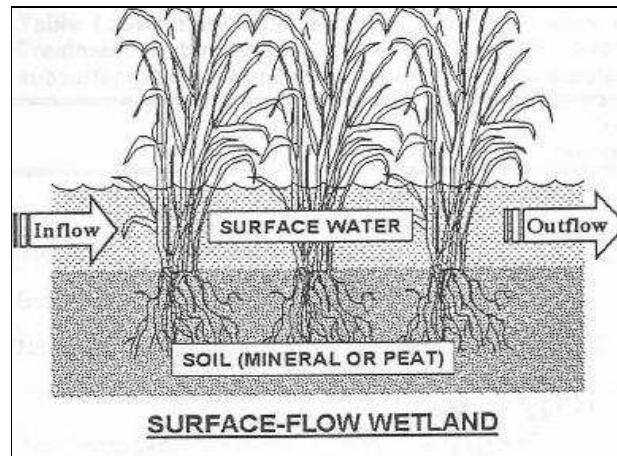
2.1.2.2 BASIC TYPES OF CONSTRUCTED WETLAND

Figure 2.1 Conceptual diagram of Surface-Flow Constructed Wetland (SFCW)
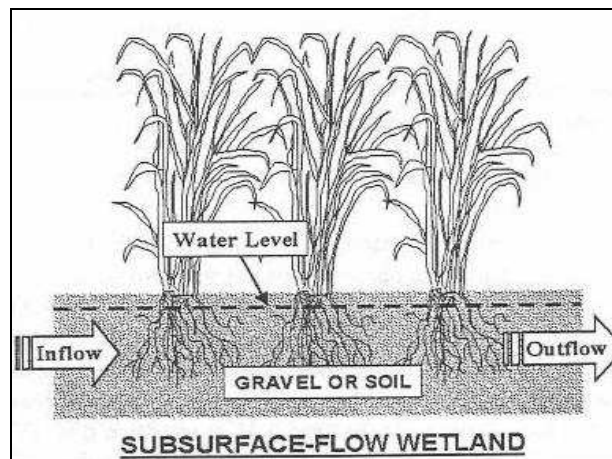
(DeBusk, 1999)

Figure 2.2 Conceptual diagram of Subsurface-Flow Constructed Wetland (SSFCW)

(DeBusk, 1999)

Generally, there are two designs of constructed wetland; Surface-Flow Constructed Wetlands (as shown in Figure 2.1) and Subsurface-Flow Constructed Wetlands (as shown in Figure 2.2)

The Surface-Flow (SF) design typically incorporates a shallow layer of surface water, flowing over mineral (sandy) or organic (peat) soils. Vegetation often

consists of floating and submerged aquatic vegetation, as well as wetland shrubs and trees. Natural wetlands have also been effectively utilized as SF treatment wetlands (DeBusk, 1999). The efficiency of using Surface-Flow system has been documented, where it mimic natural systems as the water flows over the bed surface and is filtered through a dense stand of macrophytes (Li *et al.*,1995).

In a Subsurface-Flow (SSF) wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation. Water level is below ground, water flow is through sand or gravel penetrates to the bottom of the bed (DeBusk, 1999). Subsurface-Flow system is known consisting of an excavated but usually lined shallow basin containing gravel media and emergent macrophytes (Mashauri *et al.*, 2000).

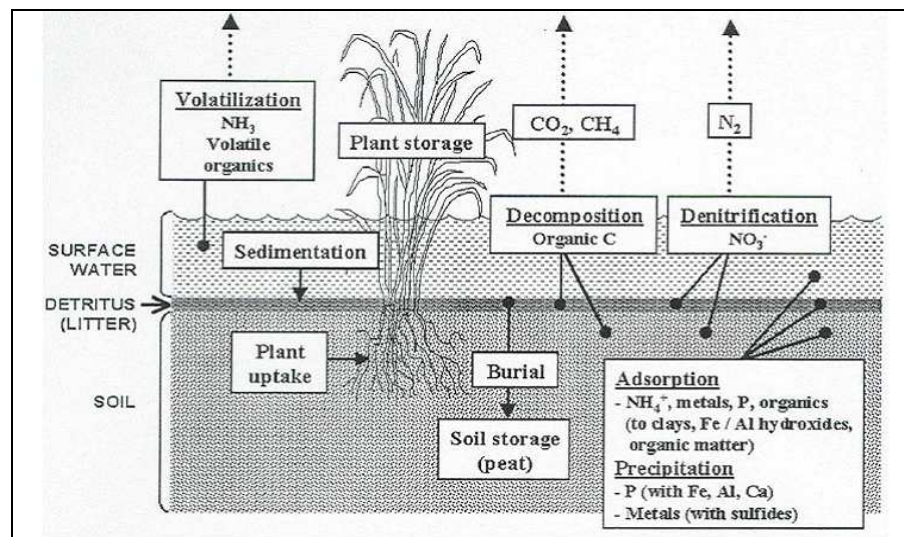## 2.1.3 CONTAMINANT REMOVAL MECHANISM

Figure 2.3 Summary of the major physical, chemical and biological processes
involve in wetlands (DeBusk, 1999).

A number of physical, chemical and biological processes operate concurrently in constructed and natural wetlands to provide contaminant removal. Knowledge of the basic concepts of these processes is helpful in assessing the potential applications, benefits and limitations of wetland treatment system. Figure 2.3 summaries the physical, chemical and biological processes involve in wetlands.

2.1.3.1 Physical Removal Processes

Surface water typically moves very slowly through wetlands due to the characteristic broad sheet flow and the resistance provided by rooted and floating plants. Sedimentation of suspended solids is promoted by the low flow velocity and by the fact that the flow is often laminar (not turbulent) in wetlands. The primary role of floating macrophytes in suspended solids removal is to limit resuspension of settled particulate matter. Resuspension may occur during the export of suspended solids, results from high flow velocity in wetland cause by bioturbation (disturbance by animals and humans), wind-driven turbulence and gas lift (DeBusk, 1999).

2.1.3.2 Biological Removal Processes

The most widely recognized biological process for contaminant removal in wetlands is plant uptake. Contaminants that are also forms of essential plant nutrients, such as nitrate, ammonium and phosphate, are readily taken up by wetland plants. However, many wetland plant species are also capable of uptake and even significant accumulation of, certain toxic metals such as cadmium and lead. The removal percentage of plant uptake is dependent on the plant growth rate and concentration of contaminant in plant tissue.

Bacteria and other microorganisms in the soil also provide uptake and short-term storage of nutrients, and some other contaminants. Although microorganisms

may provide a measurable amount of contaminant uptake and storage, it is their metabolic processes that play the most significant role in removal of organic compounds. This provides an important biological mechanism for removal of a wide variety of organic compounds. The efficiency and rate of organic C degradation by microorganisms is highly variable for different types of organic compounds.

Microbial metabolism also affords removal of inorganic nitrogen, i.e., nitrate and ammonium, in wetlands. Specialized bacteria (*Pseudomonas* spp.) metabolically transform nitrate into nitrogen gas (N_2), a process known as denitrification. Removal of ammonium in wetlands can occur as a result of the sequential processes of nitrification and denitrification. Nitrification, the microbial (*Nitrosomonas* and *Nitrobacter* spp.) transformation of ammonium to nitrate, takes place in aerobic (oxygen-rich) regions of the soil and surface water. The newly-formed nitrate can then undergo denitrification when it diffuses into the deeper, anaerobic regions of the soil. The coupled processes of nitrification and denitrification are universally important in the cycling and bioavailability of nitrogen in wetland and upland soils (DeBusk, 1999).

2.1.3.3 Chemical Removal Processes

In addition to physical and biological processes, a wide range of chemical processes are involved in the removal of contaminants in wetlands. The most important chemical removal process in wetland soils is sorption, which results in short-term retention or long-term immobilization of several classes of contaminants. Sorption is a broadly defined term for the transfer of ions (molecules with positive or negative charges) from the solution phase (water) to the solid phase (soil). Sorption actually describes a group of processes, which includes adsorption and precipitation reactions.

Adsorption refers to the attachment of ions to soil particles, by either cation exchange or chemisorption. Cation exchange involves the physical attachment of