COD AND NITROGEN REMOVAL FROM FERTILIZER WASTEWATER EFFLUENT BY USING AN ENGINEERED WETLAND

by

Mohd Hafiz Bin Mohamad Hazli

Submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

(ASSOC. PROF. DR. NASIMAN SAPARI)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD HAFIZ BIN MOHAMAD HAZLI

ABSTRACT

This project presents the analysis of the effectiveness of engineered wetland to treat the effluent from the Wastewater Treatment Plant (WWTP) of Fertilizer Plant. The Chemical Oxygen Demand (COD) level of the fertilizer wastewater effluent is high, ranging from 89 to 200 mg/L with the average of 140 mg/L. This is higher than the specified discharge standard of 100 mg/L.

The objective of using this wetland system is to remove nutrients as well as other contaminants. The constructed wetland was planted with *Eichhornia crassipes* (floating type of plant). The model was found to be able to remove COD to 45 mg/L after 27 days of treatment (meet the discharge standard A).

The methodology of this project involves the analysis of Chemical Oxygen Demand (COD), ammonia, nitrate, nitrite and phosphorus. The flow rate for the treatment system is set at 8L/day, and the detention time is about 10 days. The result from this project shows that the wetland system with floating plant (*Eichhornia crassipes*) is able to remove 47% COD, 78% ammonia, 83% nitrate, 80% nitrite and 81% phosphorus after 27 days of treatment.

ACKNOWLEDGEMENT

Alhamdulillah, grateful to Allah s.w.t. for giving me the opportunity to complete this final year project report.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

This project is based on the topic- organic matter and nutrient removal of fertilizer wastewater by using an engineered wetland. Treatment cost, less maintenance and environmental friendly are some of the main target in choosing the treatment system for the wastewater. Constructed wetland (e.g. by using the floating plants) emerged as one of the potential treatment to remove pollutants from the wastewater. The use of wetlands to treat fertilizer wastewater is a relatively new compared to the conventional treatment systems. This wetland will create an additional natural aquatic system which could be part of the local environment.

The constructed wetland systems may be described as "engineered" if the system involved:

a) design modifications,
b) process additions or modifications, and
c) vegetation modifications.

1.2 Problem Statement

Water is the second most important element after the oxygen gas in human life. Water has become a global issue nowadays, since the natural sources of the clean water are reducing day by day, around the world. For most develop countries, this matter is definitely being taken into consideration, in line with the rapid economic activities which cause the direct or indirectly point of pollutants. In Malaysia, the major sources of the pollutants are from the industrial waste, residential and pollution from sediment (e.g. such as land development, agricultural and logging). Higher amount of pollutants (e.g. Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and the Nitrogen) discharge in waterways can result in many circumstances which are also violating the laws.(see Parameter Limits of Effluent of Standard A and B in Malaysia from Appendix-A).

One of the sources of pollution is the fertilizer wastewater from the fertilizer plant. The conventional treatment systems are not effective in treating the effluent from the fertilizer plant. Moreover, the system requires high operating costs and highly skilled labor. The constructed wetland then comes in view as an alternative to treat the fertilizer wastewater since the system provides the lower cost of construction and maintenance.

1.2.1 Problem Identification

Basically the problem is that, the organic matter removal in treatment of fertilizer wastewater using engineered wetland is relatively new. Limited research pertaining to this subject has been conducted. It is hope that by the end of this project, the findings can be applied in providing sufficient and meaningful solution related to the topic. And thus, fast forward the use of engineered wetland as the main treatment for various type of wastewater in the future.

There are several parameters that need to be examined when dealing with the fertilizer wastewater. Some of the parameters which have been focused on this project are the Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and the Nitrogen.

1.2.2 Significance of Project

The significance of this project is that in the future, those researchers who want to implement or use an engineered wetland in their project would be able to refer to this project as a beneficial benchmark; and be able to design their own wetland with the data that is found in this project. Different parties including any companies as well as universities would be able to use this research to update the uncertainties when dealing with wetland efficiency and be able to come up with any required design on their own.

Lack of information to predict the efficiencies of the wetland will cause us a lot of uncertainties on the wetland design and yet underestimate its ability for the wastewater treatment. This project will focus on the study of the wetland design by choosing one type of wetland which can be tested in a bench scale model. Therefore it is important to learn how exactly did the wetland behave and next, what can be improved in the future.

1.3 Objectives of the Study

The objectives of this project are:

i) To determine the removal efficiency of Chemical Oxygen Demand (COD), Ammonia (NH_3-N), Nitrate (NO_3^--N) and Nitrite (NO_2^--N) by using the constructed wetland system.

ii) To study the nutrient uptake by wetland plant, *Eichhornia crassipes*.

iii) To study the effect of fertilizer wastewater effluent in the growth of *Eichhornia crassipes*.

1.4. Scope of the Study

The scope of this study includes setting-up of bench-scaled wetland for the treatment of fertilizer wastewater effluent. Experiments were conducted separately in constructed wetland: wetland system with fertilizer only as the control, while another set of wetlands were planted with the *Eichhornia crassipes*. The efficiency of the treatment were evaluated using the water quality parameters (e.g. COD, NH_3-N, NO_3^--N and NO_2^--N). All results were obtained from samples were taken at the outlet of the system on specific days which determine the best hydraulic residence time, HRT and hydraulic loading rate, HLR for this system.

The effect of the fertilizer wastewater on plant growth was determined in terms of the physical appearances of the plant throughout the experiment (e.g. leaf diameter and the length of the roots). The experiment was conducted at the Environmental Engineering Laboratory, Department of Civil Engineering, University of Technology Petronas (UTP). The fertilizer wastewater effluent was collected from the Petronas Fertilizer Kedah (PFK).

1.4.1 Relevancy of Project

This project focuses on the removal of organic matter and nutrient from the fertilizer wastewater effluent as well as to study the wetland operation. The project is also relevant to recent studies where the uses of wetland are becoming more essential in reducing cost of a project in a way to improve the water quality in the environment.

The research provides essential information for the organic matter removal by *Eichhornia crassipes*. This may become an additional system to the conventional method using primary and secondary treatment to remove the organic matter. Secondary and tertiary processes require high input of technology, energy and chemicals (Tchnobanoglous, 1999). In addition to that, the costs needed to establish and maintain them with skilled labor will be very high. This caused the method to be uneconomical and non-attractive for wastewater treatment usage. The solution here is to use the plant which can provide less cost and environmental friendly treatment to remove the organic matter from the wastewater.

CHAPTER 2

LITERATURE REVIEW/THEORY

2.0 LITERATURE REVIEW/ THEORY

2.1 Literature Review

2.1.1. Wetland

Wetlands are defined as a land which the water table is above or at the ground surface level for a sufficient length of time to maintain saturated soil conditions and the growth of micro-organisms and related vegetations (Eng,1998). Wetland is also defined as area where frequent and prolonged presence of water at or near the soil surface drives the natural system; meaning the kind of soil that forms, the plants that grow and the fish or wildlife communities that use the habitat (USEPA, 2000).

The most accepted American definition of wetlands is adopted by the US Fish and Wildlife Service 1979 . The wetland is defined as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water and must have one or more of the following three attributes:

i) at least periodically, the land supports predominant hydrophytes;
ii) the substrate is predominantly undrained hydric soil;
iii) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year. (Cowardin *et al.*, 1979)

Wetlands waters interact strongly with other biotic and non biotic components of the ecosystems. Every water quality parameter is altered by passage through a wetland ecosystem.

2.1.2. Natural Wetland

Natural wetland includes swamps, marshes, fens, and bogs. Natural wetlands are transitional areas located between terrestrial ecosystems and a more permanent water body such as lake. Marsh is wetland that is frequently or continually inundated with standing or inflowing water (Moore, 1993).

The marsh plants are usually dominated by non-woody, emergent aquatic macrophytes with extensive root and rhizome systems that are morphologically adapted to saturated soil conditions (Galbrand, 2003)

Properly managed wetlands can intercept runoff and transform and store (non-point source) NPS pollutants like sediment, nutrients and certain heavy metals without being degraded (Ayob and Supiah, 2005). Apart from that, wetlands vegetation can keep stream channels intact by slowing runoff and by evenly distributing the energy in runoff (Cameron *et al.*, 20303).

2.1.3. Constructed Wetland

Natural wetland should be preserved for nature's purposes rather than being overburdened deliberately as wastewater treatment system (Paquiz, 2004). Constructed wetlands represent an emerging ecotechnological treatment system, which are designed to overcome the disadvantages of natural wetlands (Eng, 2002).

The advantages of a properly constructed wetland are as mention below :

i) can be relatively inexpensive to construct – each constructed wetland's design is site specific, taking into consideration such variables as topography, water supply, soil types, type of livestock operation, etc.

Selection of a site with accommodating specifications keeps establishment costs low (Rew and Mulamoottil, 1999; Higgins and Brown, 1999);

ii) provides a high level of treatment- properly designed, constructed, maintained and managed wetlands can provide very efficient treatment of wastewater (Chen et al., 2006);

iii) can be simply pleasing – depending upon design, location, and type of vegetation, constructed wetlands can enhance the landscape with color, texture, and variety in plant materials;

Hydraulic Residence Time (HRT) is the time it takes the water to leave the wetland system. The water levels must remain relatively constant to provide adequate vegetation for the system to facilitate the removal of contaminants. If the water levels drop rapidly, plant life will diminish and the system does not function correctly. The pollutants removal in constructed wetland is enhanced through aeration. In a research done by Matthys et al., (2004); Kinsley and Crolla (2003); Jamieson et al.,(2000), aerated constructed wetland outperformed the constructed wetland that is not aerated in terms of organic and ammonia nitrogen removal. Due to its high rate of the biological activities, the wetland can transform common pollutants into harmless byproducts and essential nutrients (Kadlec and Knight, 1996).

The constructed wetlands systems can have different flow type, media and types of emergent vegetation. There are two types of constructed wetland which are Free Water Surface (FWS) wetland and Subsurface Flow (SSF) wetland.

a) Free Water Surface Systems (FWS)

Also known as surface flow wetland, this system imitates the marshlands in the natural wetland system (refer figure 1). It consists of several basins or cells with the water surface being 0.15-2 meters above the substrate (Tousignant et al., 1999). It has a natural or constructed clay layer or impervious liner made of geotechnical material at the bottom to prevent seepage.

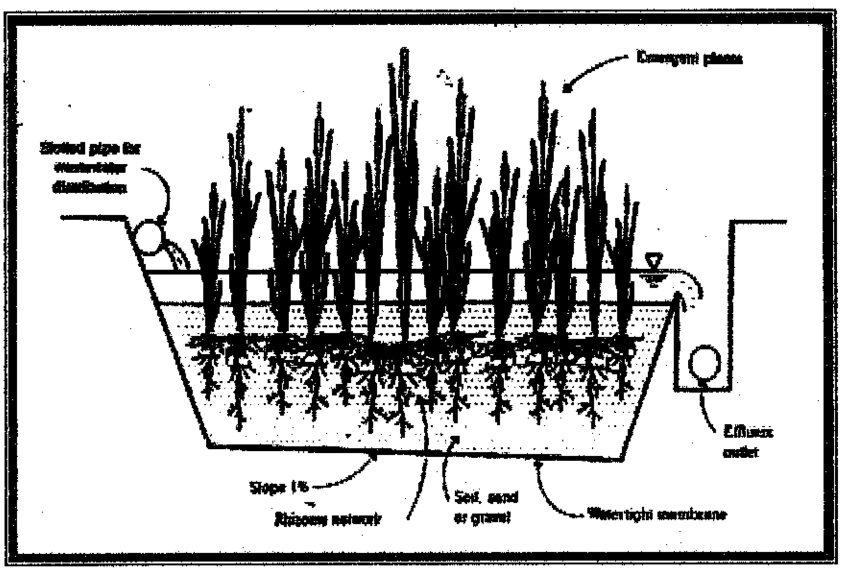


Figure 1: Free water surface wetland system (Eng,1998)

Free water surface wetland can also be further sub-classified according to the dominant type of vegetation which is free-floating macrophyte, emergent , macrophyte and submerged macrophyte (Galbrand, 2003). Below are the different types of FWS wetland (Brix, 1993b).

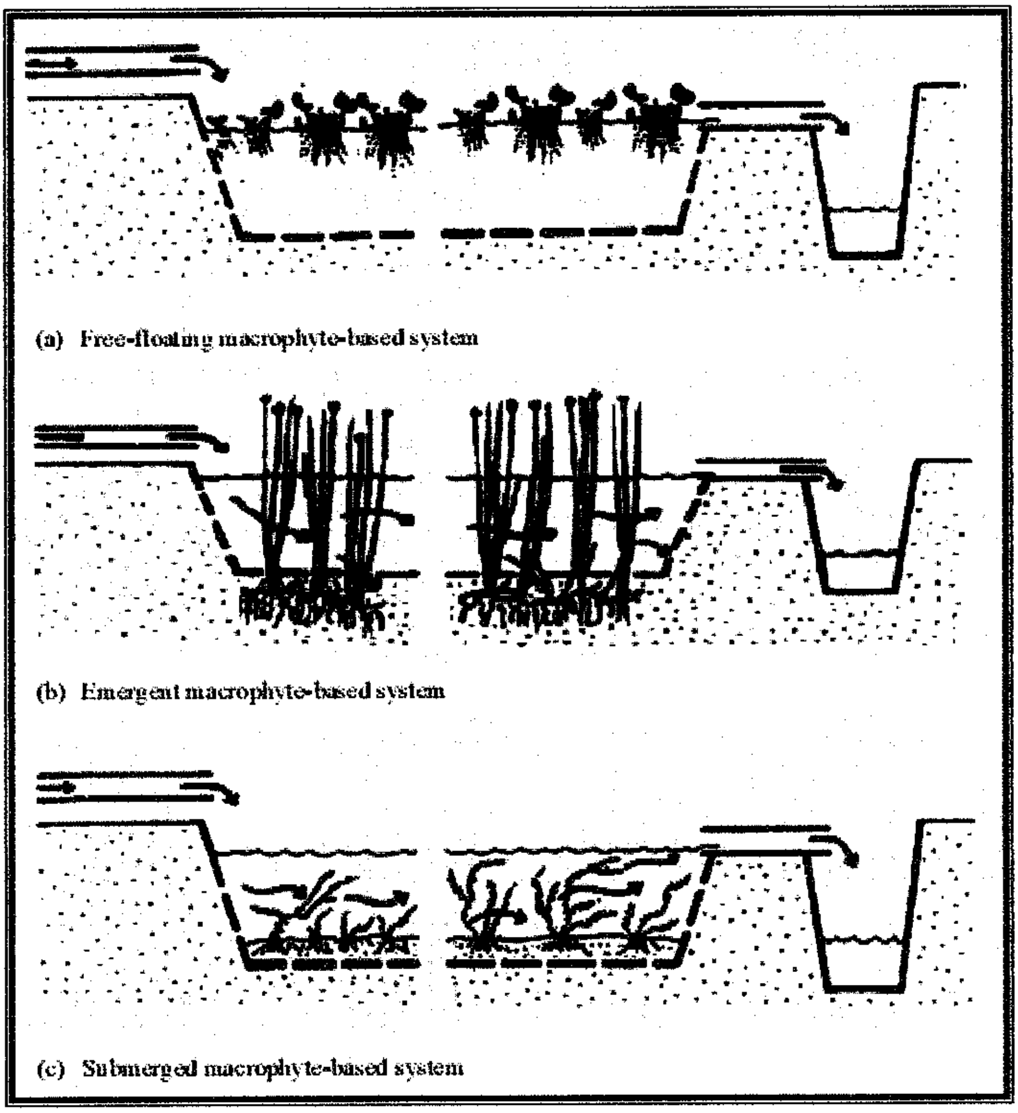


Figure 2 : Types of FWS wetland (a) Free-floating macrophyte-based system, (b) Emergent macrophyte-based system and (c) Submerged macrophyte-based system (Brix,1993b).

b) Subsurface Flow Wetland (SSF)

The system is also known as root zone method wetland or rock-reed filter, consists porous substrate of rock, gravel or coarse sand that allow water to trickle through within the bed from beginning to end, hindering flow across the top surface (Paquiz, 2004). When the wastewater flows through the media, it is being purified through contact with the surface of the media and the root zone of the plants (Lim and Polprasert, 1998). This system is illustrated in Figure 3.

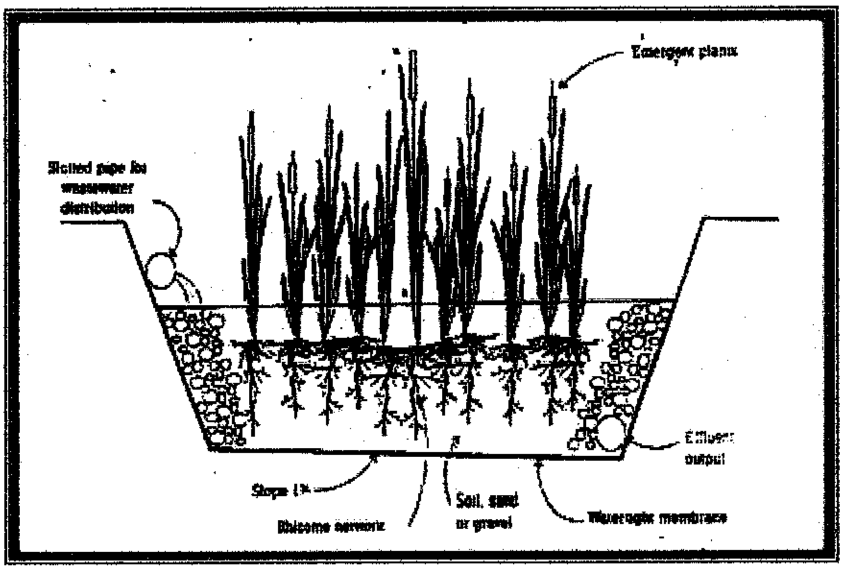


Figure 3 : Subsurface flow wetland system (Eng,1998)

There are two types of SSF system which are horizontal subsurface flow system and vertical subsurface flow system (Liu, 2002). Both systems are as illustrated below:

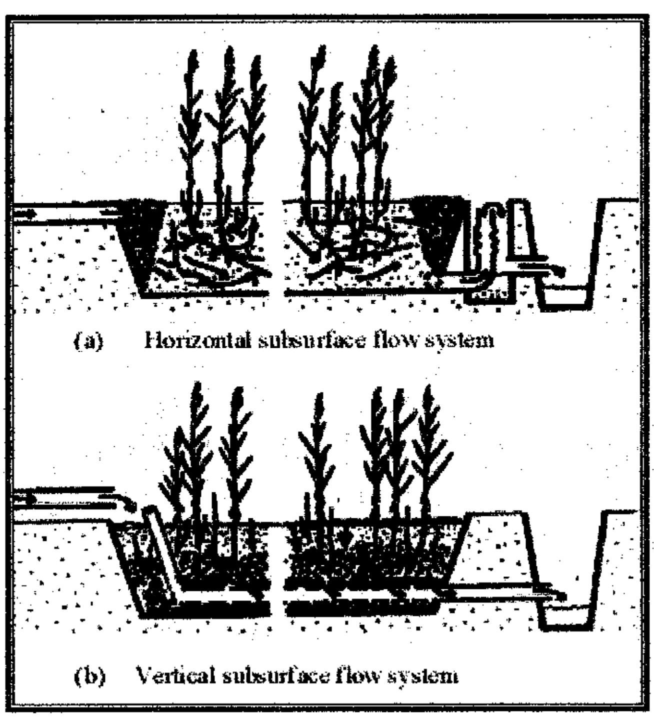


Figure 4 : Types of SSF wetland (a) Horizontal subsurface flow system and (b)Vertical subsurface flow system (Brix,1993b).

2.1.4. Aquatic Plants For Engineered Wetland

Aquatic plants play an important role in human history more than is commonly thought. Common reed (*Phragmites australis*) for example, which naturally grown in vast area of the world is viewed as a pest in parts of the United States, can quickly colonize large areas of wetlands (Craig S. Campbell & Michael Ogden, 1999). It has been widely used in other countries to make fences, thatching roofs and other uses like in Romania it is grown as a commercial crop in the Danute delta. As the technology developed in most country, many scientists tend to do more research on this wetland plants for the benefit of our environmental system.

Nearly about 5,000 plant types may occur in wetlands in North America- plants known as *hydrophytic vegetation*- most aquatic plants fall into three categories, *emergent*, *submergent* and *floating* plants. *Emergent plants* is the plants that are rooted in the soil but send stems and leaves above the water (cattail, bulrush, etc.). *Submergent plants* is the plants which grown completely below the water surface (Elodea, etc.), while *floating plants* is the plants that float on the water surface (duckweed, water hyacinth). Primarily, the researchers are interested in the emergent plants for purposes of water renovation due to their adaptability, deep root structures and local presence.

Water hyacinth (*Eichhornia crassipes*), is one of the floating plant that is found to be able to remove contaminants from water at an impressive rate. It is a plant with extremely dense roots extending down into the water that have the ability to absorb pollutants very effectively. It has been utilized in a large number of experimental pilot-scale wastewater treatment projects, for example by the City of Austin in its Hornsby Bend sludge dewatering facility within a huge greenhouse structure to assist in removing contaminants from the sludge stream.

Another floating plant which has also been employed in wastewater renovation is the duckweed (Lemna, Spriodela, Wolffia, etc.). It is the smallest plant that will drift in windy conditions, so the floating barriers are needed during their installation in the wetland system. The most common species of duckweed employed in wastewater treatment lagoons is *Lemna minor,* due to its extremely vigorous growth. If it has been left undisturbed, a 1-square-inch (645-mm^2) patch of *Lemna minor* would grow to cover well over an acre in fifty-five days.

Emergent plant, such as the bulrushes (*Scirpus* spp.) grow in a diverse range of both inland and coastal waters, and various species can be found throughout most wetlands and in lake or pond shallows. This plant is efficient in removing nitrogen and tolerates a wide pH range. The roots can penetrate to a depth of 2.5 to 3 feet or greater, which make them extremely useful in oxygenating the deepest portion of a gravel subsurface flow bed. Another emergent plant, Common reeds (*Phragmites australis*) has extensive perennial rhizomatous roots that typically penetrate to a depth of 18 inches. The root zone is very effective in transferring oxygen due to a depth of penetration of the roots.

Although the ability of many emergent species to transport oxygen to the root zone provides the basis for predicting high rates of denitrification, some wetland specialists have argued that there is evidence that the oxygenation primarily affects the rooting tissue, not the sediments and that oxygen entering the sediments is usually instantly consumed microbially (Wetzel, 1993).

2.1.5. Treatment Process Mechanisms

The design of the wetland system can be improved by understanding its treatment mechanisms which is essential for better treatment performance. The main mechanisms include the biological processes such as microbial metabolic activity and plant uptake.

Table 1 : Removal mechanisms in macrophyte-based wastewater treatment systems (Cambell and Ogden, 1999).

Wastewater Constituents		Removal Mechanism
Suspended solids	-	Sedimentation and filtration
Biochemical Oxygen Demand	-	Microbial degradation (aerobic and anaerobic)
	-	Sedimentation (accumulation of organic matter/ sludge on the sediment surface)
Nitrogen	-	Ammonification followed by microbial nitrification and denitrification
	-	Plant uptake
	-	Ammonia volatilization
Phosphorus	-	Soil sorption (adsorption-precipitation reactions with aluminums, iron, calcium and clay minerals in the soil).
	-	Plant uptake/ adsorption
Pathogen	-	Sedimentation/ filtration
	-	Natural die-off
	-	UV irradiation (sun)
	-	Excretion of antibiotics from roots of macrophytes.

(a) Biodegradable Organic Matter Removal

Microbial degradation plays an important role in the removal of soluble/ biodegradable organic matter (BOD and COD) in wastewater, while the remaining BOD associated with settleable solids being removed by sedimentation inside the wetland. Wetland vegetation is mainly providing the support medium for microbial degradation to take place and conveying oxygen to the rhizophere for aerobic biodegradation to occur.

(b) Nitrogen Removal

Removal of nitrogen in wetlands is achieved through three main mechanisms, which are nitrification / denitrification, volatization of ammonia and uptake by plants. The figure below shows the process of nitrogen removal in the flooded soil environment.

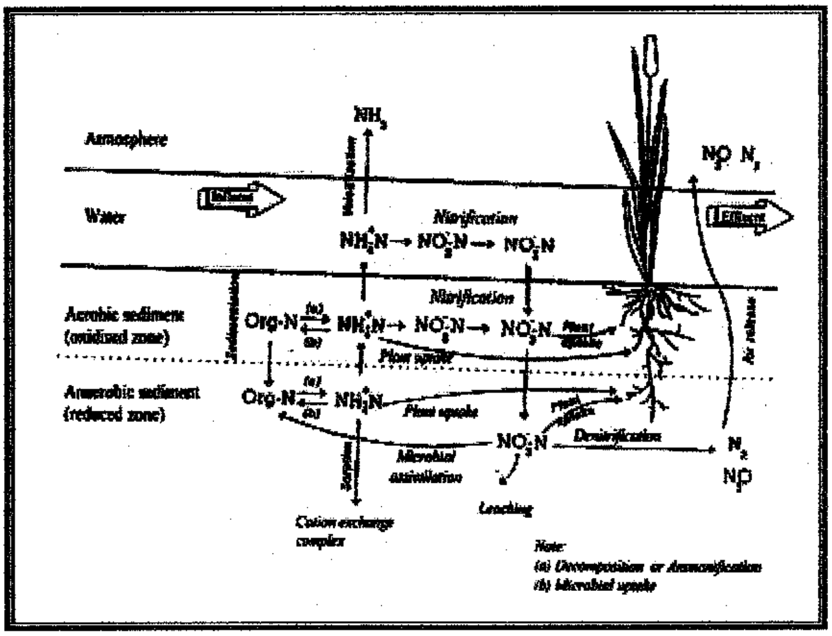


Figure 5 : Nitrogen transformation in wetland system (Lim,1998)

2.1.6. Summary of Treatment Performance in Constructed Wetland

Table 2 below shows the summarization of wastewater pollutants removal in constructed wetland.

Table 2 : Wastewater pollutants removal in constructed wetland.

References	System type	Type of influent	Findings	Remarks
El-Gendy (2003)	FWS with water hyacinth and salvinia	Landfill leachate (100%)	The removal efficiency of pollutants in leachate using water hyacinth was more than 80% in TKN (91%), total ammonia(100%), total reactive phosphorus (97%) and total iron(84%). Salvinia plants died after the first day of the experiments.	Ammonia was removed completely from the system incorporating water hyacinth after 21days of experiment. Water hyacinth therefore outperformed salvinia in leachate treatment.

References	System type	Type of influent	Findings	Remarks
Gersberg et al. (1986)	SSF with bulrush	Primary municipal wastewater	The removal efficiency for the pollutants was high and more 90% for BOD (96%), SS (94%) and TN (94%)	The removal efficiency of BOD was high due to the deep root zone of bulrush which provided more extensive oxidized conditions favoring breakdown of carbonaceous matters.
Lee (2004)	SSF with Typha angustifolia	Treated leachate	The removal efficiency of pollutants in the wetland was BOD (65%), COD (81.8%), NH_3-N (84.4%), PO4 (67.1%) and NO_3^-N *(47.2%). The* plant uptake of Cr and Cd was 91.7% and 81.8% respectively with more than 80% Cd retained in plant leaves. The retention time was three days with 1 hour rainfall every 3 days for a period of 27 days.	T. angustifolia had little contribution in Cr uptake as plant leaves could only retain 1μg/g (dry weight concentration limit). Heavy *metal strongly* bound to the soil, resulting in inability of many plants to uptake Cd. High nitrification process occurred in the wetland with plants supplied more oxygen for nitrifying bacteria. COD removal was also high in wetland as COD was consumed in denitrification process as carbon source.

References	System type	Type of influent	Findings	Remarks
Lin et al. (2005)	Combination of FWS-SF cells with cattail and reed	Intensive shrimp aquaculture wastewater	FWS-SF cells effectively removed TSS (55-66%), BOD_5 (37-54%), total ammonia (64-66%), nitrite (83-94%) with HLR 1.57-1.95 m/day. However, NO_3-N was removed poorly as the nitrate level increased from influent to effluent.	The high HLR applied in this study affected the performance of pollutants removal. High HLR diminished the contact time for nitrate and denitrifying bacteria, thus decreasing the performance of wetland for *denitrification.* Therefore, the constructed wetland did not reach its maximum ability to remove pollutants.
Martin and Moshiri (1994)	*FWS with a* variety of aquatic plants	*Treated leachate*	*The removal* efficiency of nutrients in the system was TKN(58%),AN(98%) and TP(53%) over a 4-month period of experiment.	*Vegetation played* an important role in nutrients removal. The nutrients removal efficiency could be affected by process variables such HLR, HRT and mass loading rate.

CHAPTER 3
METHODOLOGY

3.1 Set- Up Wetland for Fertilizer Treatment

The bench scale model of the engineered wetland system has been prepared in the earlier stage of this project. The water hyacinth was taken from the location near Batu Gajah. (see Figure 6).

Two mini reactors with the volume of water about 46cm (W) x 92cm (L) x 19cm (H) or 80408 cm^3 was used. One of the reactors contained two units of the water hyacinth, and the second reactor was used as the control reactor. The fertilizer wastewater was pumped into both reactor, and continuously flow with low rate which was 8000 mL/day. The samples for the test in the lab were taken from the effluent in the wetland system (see Figure 7 and 8) .

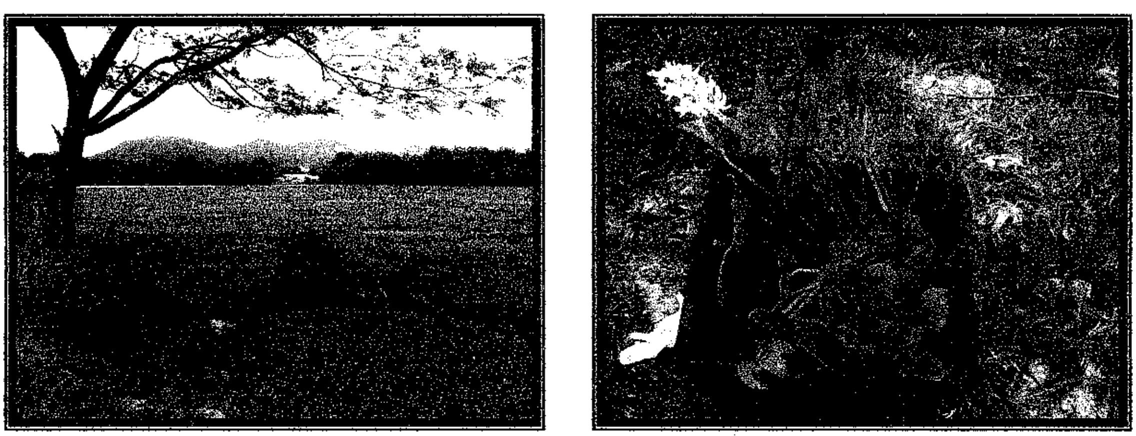


Figure 6 (left) and (right) : the location of the floating plant, (water hyacinth/ *Eichhornia crassipes)* and the sample that has been taken near the Batu Gajah area.

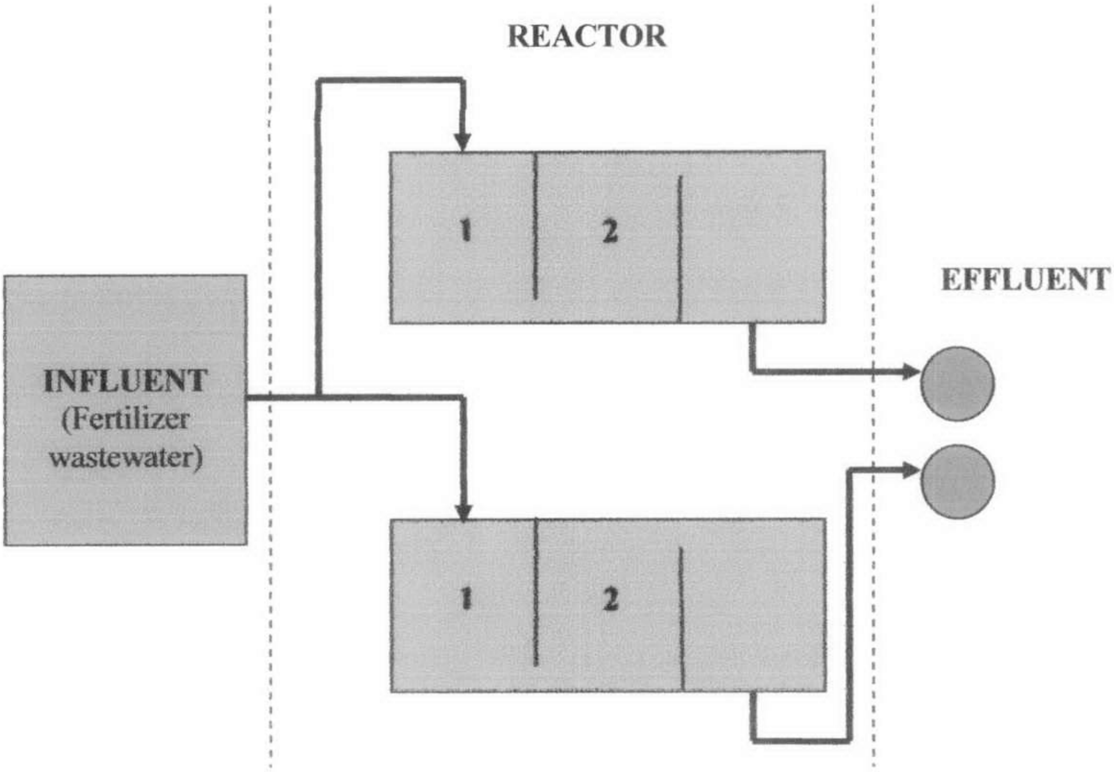


Figure 7: Flow chart of the project system

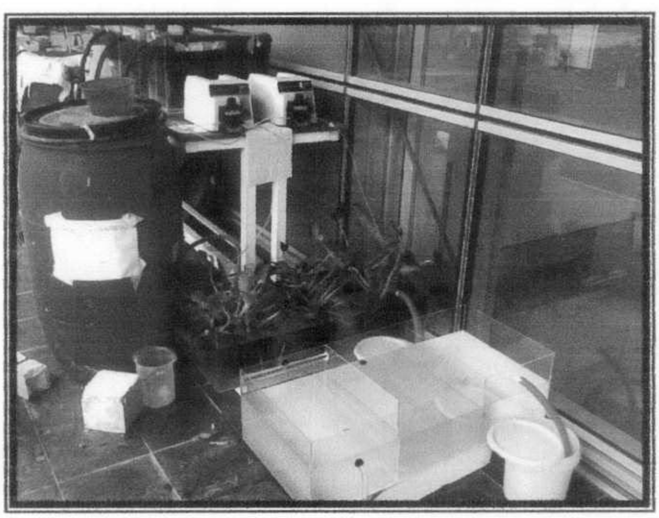


Figure 8 : The wetland system.

The operation of the wetland system is summarized as follows:

- Hydraulic detention time : 10 days
- Loading rate :
  - COD -0.025 kg/m^3/day
  - Ammonia -0.013 kg/m^3/day
  - Nitrate -0.021 kg/m^3/day
  - Nitrite -0.01 kg/m^3/day
  - Phosphorus-0.01 kg/m^3/day
- pH : 6.2-6.5 (Slightly below neutral)

Table 3 shows the common characteristics of *Eichhornia crassipes* (Batcher, 2005).

Table 3 : Common characteristics of *Eichhornia crassipes*

Characteristic	Description
Family	*Pontederiaceae*
Genus	*Eicchornia*
Common name	Water hyacinth
Physical characteristics	Leaves : thick, waxy, rounded, glossy and rise above the water surface on stalks. Flower : six petals, purplish blue or lavender.
Habitat	Lake, river, pond, drain
Reproduction	Vegetative and seed reproduction

3.2. Experimental Analysis

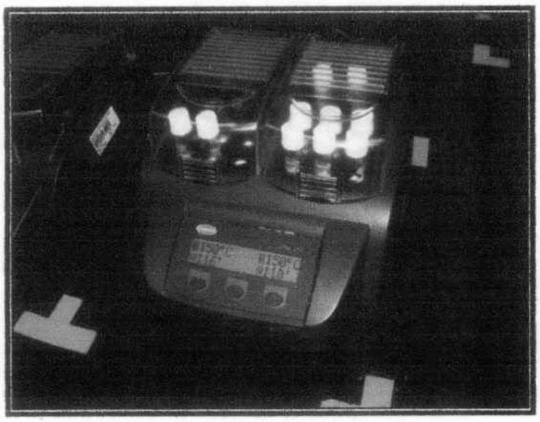
Three stages involved in the experiment which were an analysis of the fertilizer wastewater, analysis of plant uptake in plant and observation of plant growth.

3.2.1. Analysis of the fertilizer wastewater effluent

Sampling was done for 3 times a week for 2 weeks. The parameters for fertilizer wastewater analysis are listed as follows:

(a) Chemical Oxygen Demand (COD)

COD test was conducted according to the Reactor Digestion Method (3 to 150,20 to 1500, and 200 to 15,000 mg/L COD) by using the COD Reactor DRB 200 model and Spectrophotometer DR 2800 model. (see Figure 9)



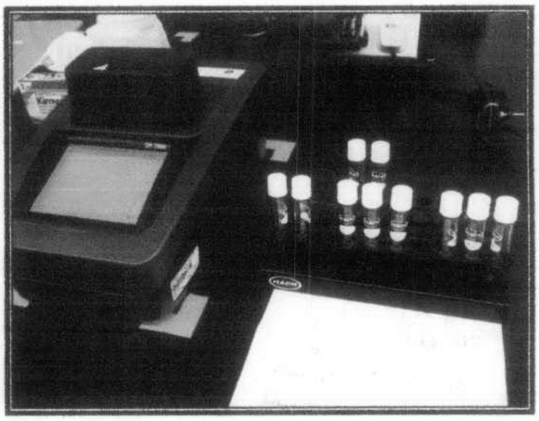
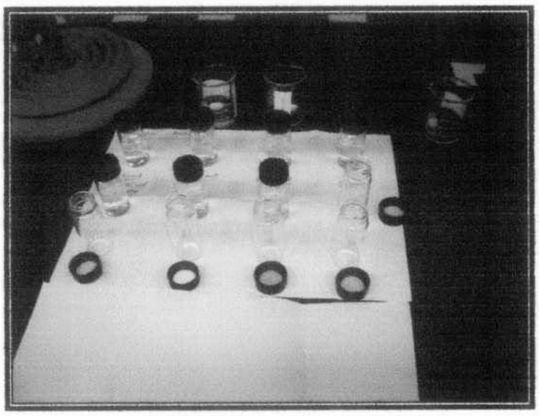


Figure 9 (left) and (right) : The figure show the equipment used inside the lab for COD Test (COD Reactor DRB 200 reactor, COD Digestion Reagent vials, and Spectrophotometer DR 2800)

(b) Ammonia Nitrogen (NH_3-N)

NH_3-N analysis was done according to the Nessler Method HR (0.02 to 2.5 mg/L NH_3-N) by using the Spectrophotometer DR 2800 model. (see Figure 10)



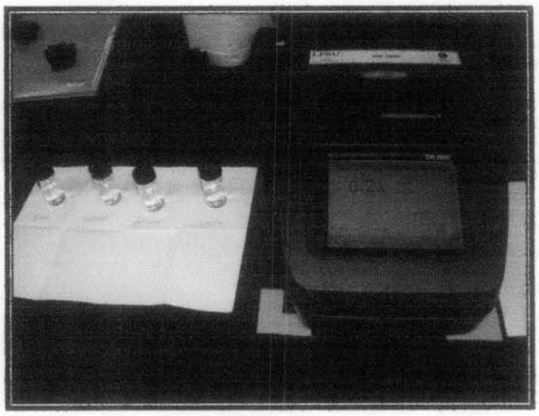


Figure 10 (left) and (right) : The figure shows the equipment used inside the lab for Ammonia test (Ammonia Nitrogen Reagent set, and Spectrophotometer DR 2800)

(c) Nitrate Nitrogen ($NO3^{-}$-N)

$NO3^{-}$-N analysis was conducted according to the Cadmium Reduction Method HR (0.3 to 30.0 mg/L $NO3^{-}$-N) by using the Spectrometer DR 2800 model. (see Figure 11).

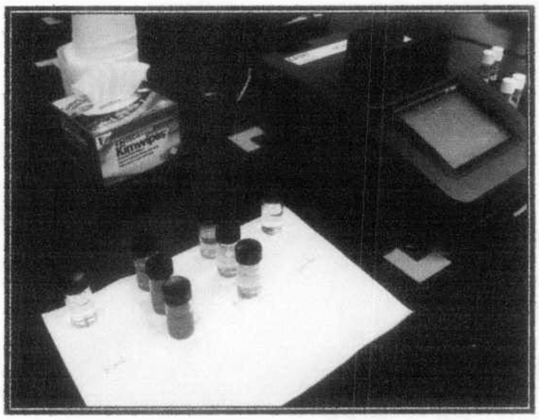


Figure 11 (left) and (right) : The figure shows the equipment used inside the lab for Nitrate test (Nitraver 5 Nitrate Reagent Powder Pillow, sample cell 10mL round with cap, and Spectrophotometer DR 2800)

(d) Nitrite Nitrogen (NO_2^{-}-N)

NO_2^{-}-N analysis was conducted according to the Diazotization Method LR (0.002-0.300 mg/L NO_2^{-}-N) by using the Spectrometer DR 2800 model. (see Figure 12)

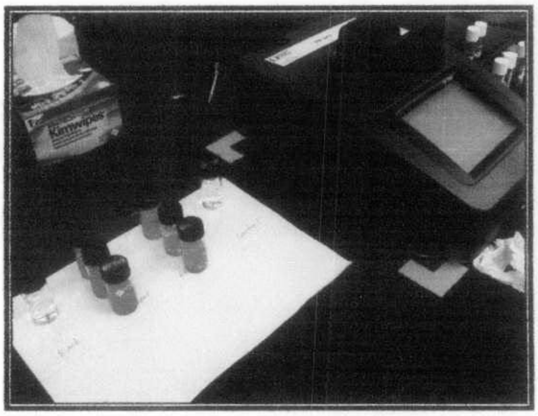


Figure 12 (left) and (right) : The figure shows the equipment used inside the lab for Nitrite test (Nitraver 3 Nitrate Reagent Powder Pillow, sample cell 10mL round with cap, and Spectrophotometer DR 2800)

3.2.2. Observation of Plant Growth

The plant growth was observed by measuring the leaf length and observing the physical appearance of the leaves for wilting signs according to Soltan and Rashed, 2003.

CHAPTER 4
RESULTS & DISCUSSIONS

4.1 Introduction

In this chapter, there are two main aspects being considered. The aspects are the pollutants removal in the fertilizer wastewater, and the effect of the wastewater to plant growth. A sample was taken from the influent of the wetland system and analysis was conducted on COD, ammonia, nitrate, and nitrite. The experiments were conducted for 27 days to get the raw data, starting from March to early April 2008 (refer Table A2-A13 in the Appendix). Sampling works were carried out for about 3 times a week. Table 1 shows the initial quality of the fertilizer wastewater from the Petronas Fertilizer Plant in Kedah before the experiment was started.

Table 4: Initial quality of the fertilizer wastewater effluent

Parameter	mg/L
COD	85
Ammonia nitrogen (NH_3-N)	45
Nitrate nitrogen (NO_3-N)	72
Nitrite nitrogen (NO_2^-)	31
Total Phosphorus (PO_4^{3-})	30

The value for COD is exceeding the limit for discharge for standard A but within the limit for standard B. The other parameters are not specified by the standard. (refer Table A-1 in the Appendix). Percentage removal after 27 days of treatment is summarized in Table 2. The result shows that the wetland system can remove all the parameters ranging from 47% to 83% at the end of the treatment.

Table 5 : Removal efficiency for fertilizer wastewater after 27 days of treatment

Parameter	Control (mg/L)	Removal (%)	Wetland (mg/L)	Removal (%)
COD	102	**-20**	45	**47**
NH_3-N	30	**33.33**	10	**78**
NO_3-N	100	**-39**	12	**83**
NO_2^-	17	**45**	6.1	**80**
PO_4^{3-}	7.5	**75**	5.7	**81**

4.2 Pollutant Removal

4.2.1. Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) is the total amount of oxygen required to completely oxidize all the organic matter and chemical constituents in a wastewater sample. Figure 13 shows the percentage removal of COD for both control and wetland system.

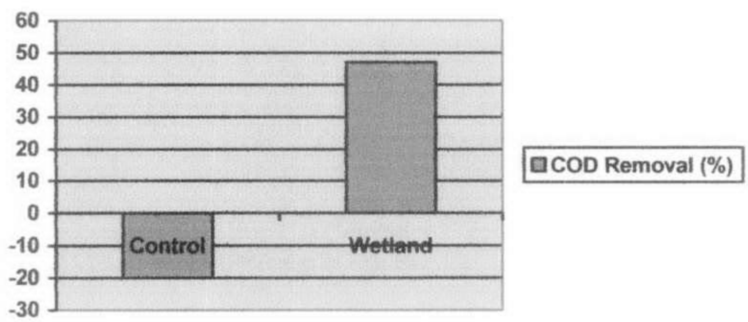


Figure 13 : Percentage removal of COD in the control and the wetland system

COD in control experiment is increase instead of decrease throughout the experiment. This is due to the algal growth in the control. The removal efficiency of COD in the wetland system was quite low, which is just an average of 47% removal. Still, the system provides the suitable effluent which is in the range of the Standard A limit.

COD removal efficiency in the control experiment is increasing because of the algae decay that released throughout the treatment process and recycled back the organic and inorganic matter in the wastewater (Crites and Tchobanoglous, 1998). The removal efficiency which is low in the wetland system most likely cause by the wastewater that contained a lot of refractory compounds that were not biodegradable (Yoo *et al*.,2001). Physical or chemical process is needed to remove this compound rather than the biological process.

4.2.2. Ammonia Nitrogen (NH_3-N)

Figure 14 shows the removal efficiency of ammonia nitrogen in both control and the wetland system throughout the experiment.

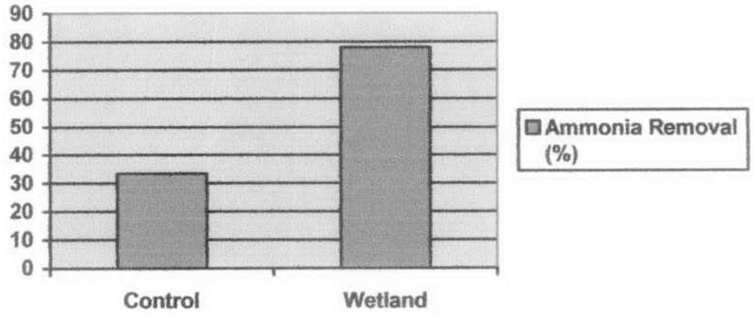


Figure 14: Percentage removal of ammonia in the control and wetland system

The difference between the results is due to the plants that provided an aerobic zone in the root for nitrification to be occurred (Lim and Polprasert, 1998). The lower removal efficiency in the control system is due to the fact that the wastewater contained less *Nitrosomonas* and *Nitrobacter* for ammonia oxidation.

4.2.3. Nitrate Nitrogen (NO_3^--N)

Figure 15 shows the NO_3^--N removal efficiency in the control and wetland system throughout the experiment.

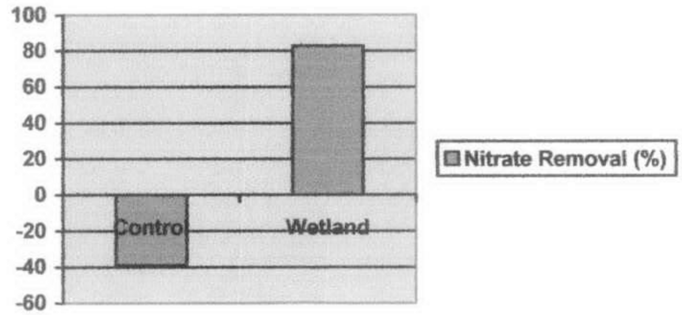


Figure 15 : Percentage removal of nitrate nitrogen in the control and wetland system

NO_3^--N removal in the wetland system occurs primarily through the denitrification process. The organic carbon in wetland was supplied by the vegetation and as used as an energy source for heterotrophic bacteria (Bastviken *et al.*, 2005).

4.2.4. Total Phosphorus (PO_4^{3-})

Figure 16 shows the PO_4^{3-} removal efficiency in control and wetland system throughout the experiment.

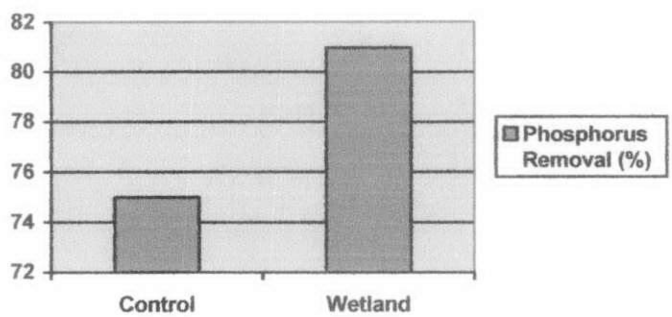


Figure 16 : Percentage removal of phosphorus in the control and wetland system

The phosphorus removal efficiency is low in the control experiment compared to the wetland system. The wetland system was found to be effective in PO_4^{3-} removal. The major principle mechanisms of phosphorus reduction are the adsorption of soluble phosphorus on substrate particles and precipitation with calcium or aluminum ion (Kadlec and Knight, 1996).

4.3. Observation of Plant Growth

The plant weight and the length of the root were recorded before and after the experiment. Table 3 shows the initial and final weight and root length of the plant.

Table 6. Plant weight and root length before and after the experiment.

Section	Initial Root Length (m)	Initial Weight (kg)	Final Root Length (m)	Final Weight (kg)	Difference In Length (m)	Weight Increase (kg)
1	0.20	0.155	0.38	0.352	0.18	0.197
2	0.18	0.178	0.24	0.301	0.06	0.123
3	0.22	0.243	0.27	0.312	0.05	0.069

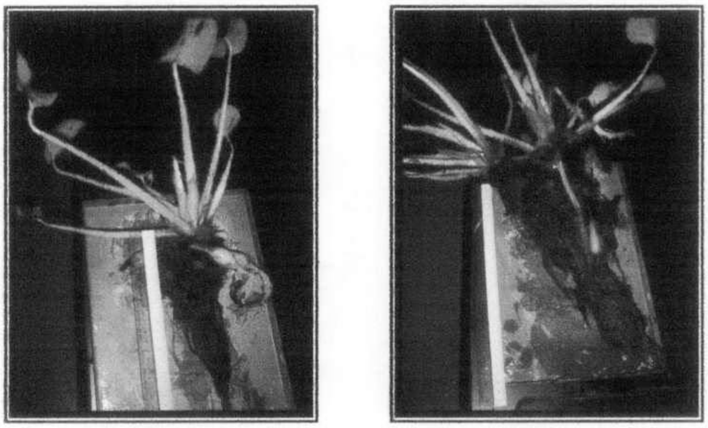


Figure 17 : Root length of the wetland plant, plant from section 1 (left) initial length and (right) final length.

Figure 18 : The initial weight of the wetland plant in section 1 (0.155kg)

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The results indicate that the ammonia, phosphorus, nitrate, and COD, were removed by the wetland system containing *water hyacinth.* After 24 hours of treatment, the wetland system gives the highest removal efficiency of nitrate nitrogen and phosphorus, which were 47% and 30% respectively. After 27 days of treatment, the wetland system is capable of removing 47% of COD and 83% of nitrate nitrogen which is the highest removal throughout the experiment. The preliminary test for a month shows that the system can work as expected with loading rate of 0.025 kg COD /m^3/day, 0.013 kg ammonia /m^3/day, 0.021 kg nitrate /m^3/day, 0.01 kg nitrite /m^3/day, and 0.01 kg phosphorus /m^3/day.

From here, it can be concluded that the *water hyacinth* is an effective aquatic plant for a wetland system for the removal of nutrients from fertilizer wastewater.

5.2. Recommendations

The plant harvesting could be done in the wetland to increase the growth of the plants, and to improve the efficiency of treatment performance (Mbuligwe, 2005). There are more additional studies can be conducted to get the better understanding about the processes/ mechanism that involved in the constructed wetland. Below are some recommendations for future research:

(i) To use the various flowrate to circulate the fertilizer wastewater through the wetland system;

(ii) To apply more than one type of plants to treat the fertilizer wastewater in the constructed wetland;

(iii) To apply the plant harvesting to prevent recycling of accumulated metals when the plants decomposed.

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APPENDIX

Table A1 : Parameter Limits of Effluent of Standard A and B

NO	PARAMETER	UNIT	STANDARD A	STANDARD B
1	Temperature	C	40	40
2	pH	-	6.0-9.0	5.5-9.0
3	BOD at 20°C	mg/l	20	50
4	COD	mg/l	50	100
5	Suspended Solid	mg/l	50	100
6	Mercury	mg/l	0.005	0.05
7	Cadmium	mg/l	0.01	0.02
8	Chromium hexa valents	mg/l	0.05	0.05
9	Arsenic	mg/l	0.05	0.1
10	Cyanide	mg/l	0.05	0.1
11	Lead	mg/l	0.1	0.1
12	Chromium trivalent	mg/l	0.2	0.1
13	Copper	mg/l	0.2	1
14	Manganese	mg/l	0.2	1
15	Nickel	mg/l	0.2	1
16	Tin	mg/l	0.2	1
17	Zinc	mg/l	1	1
18	Boron	mg/l	1	1
19	Iron	mg/l	1	4
20	Phenol	mg/l	0.001	1
21	Free Chlorine	mg/l	1	2
22	Sulphide	mg/l	0.5	0.5
23	Oil and Grease	mg/l	Not detectable	10

Source : Environmental Quality (Sewage and Industrial effluents) Regulations 1978 Department of Environment Malaysia

Table A2 : Initial quality of fertilizer wastewater effluent from the PETRONAS Fertilizer Plant in Kedah

Parameter	mg/L
COD	85
NH_3-N	45
NO_3-N	72
NO_2^--N	31
PO_4^{3-}	30

Table A3 : Quality of fertilizer wastewater effluent after 24 hours of treatment

Wednesday – 5th March 2008		
	Control	Wetland
COD (mg/L)	86	87
NH_3-N (mg/L)	20	24
NO_3-N (mg/L)	60	52
NO_2^--N (mg/L)	35	32
PO_4^{3-} (mg/L)	23	21

Table A4 : Quality of fertilizer wastewater effluent after 3 days of treatment

Friday – 7th March 2008		
	Control	Wetland
COD (mg/L)	92	80
NH_3-N (mg/L)	25	22
NO_3-N (mg/L)	55	68
NO_2^--N (mg/L)	40	30
PO_4^{3-} (mg/L)	17	16

Table A5 : Quality of fertilizer wastewater effluent after 8 days of treatment

Wednesday – 12th March 2008		
	Control	Wetland
COD (mg/L)	109	73
NH_3-N (mg/L)	21	19
NO_3-N (mg/L)	53	72.5
NO_2^--N (mg/L)	37	28
PO_4^{3-} (mg/L)	10	5.4

Table A6 : Quality of fertilizer wastewater effluent after 9 days of treatment

Thursday – 13th March 2008		
	Control	Wetland
COD (mg/L)	138	65
NH_3-N (mg/L)	21	17
NO_3-N (mg/L)	50	75
NO_2^--N (mg/L)	39	26
PO_4^{3-} (mg/L)	8.4	4.7

Table A7 : Quality of fertilizer wastewater effluent after 10 days of treatment

Friday – 14th March 2008		
	Control	Wetland
COD (mg/L)	136	65
NH_3-N (mg/L)	19	20
NO_3-N (mg/L)	52	50
NO_2^--N (mg/L)	37	27
PO_4^{3-} (mg/L)	6.2	4.3

Table A8 : Quality of fertilizer wastewater effluent after 13 days of treatment

Monday – 17th March 2008		
	Control	Wetland
COD (mg/L)	127	75
NH_3-N (mg/L)	12	21
NO_3-N (mg/L)	64	50
NO_2^--N (mg/L)	21.2	21.1
PO_4^{3-} (mg/L)	5.3	5.1

Table A9 : Quality of fertilizer wastewater effluent after 17 days of treatment

Friday – 21st March 2008		
	Control	Wetland
COD (mg/L)	91	78
NH_3-N (mg/L)	26	22
NO_3-N (mg/L)	46	68
NO_2^--N (mg/L)	26	27
PO_4^{3-} (mg/L)	5.6	7.3

Table A10 : Quality of fertilizer wastewater effluent after 18 days of treatment

Saturday – 22nd March 2008		
	Control	Wetland
COD (mg/L)	86	77
NH_3-N (mg/L)	17	23
NO_3-N (mg/L)	86	88
NO_2^--N (mg/L)	18	21.1
PO_4^{3-} (mg/L)	6.5	6.7

Table A11 : Quality of fertilizer wastewater effluent after 21 days of treatment

Tuesday – 25th March 2008		
	Control	Wetland
COD (mg/L)	96	55
NH_3-N (mg/L)	19	20
NO_3-N (mg/L)	96	26
NO_2^--N (mg/L)	19.7	3.7
PO_4^{3-} (mg/L)	7.0	7.7

Table A12 : Quality of fertilizer wastewater effluent after 26 days of treatment

Tuesday – 1st April 2008		
	Control	Wetland
COD (mg/L)	100	48
NH_3-N (mg/L)	25	10
NO_3-N (mg/L)	100	17
NO_2^--N (mg/L)	15	5.0
PO_4^{3-} (mg/L)	7.2	6.0

Table A13 : Quality of fertilizer wastewater effluent after 27days of treatment

Thursday – 2nd April 2008		
	Control	Wetland
COD (mg/L)	102	45
NH_3-N (mg/L)	30	10
NO_3-N (mg/L)	100	12
NO_2^--N (mg/L)	17	6.1
PO_4^{3-} (mg/L)	7.5	5.7

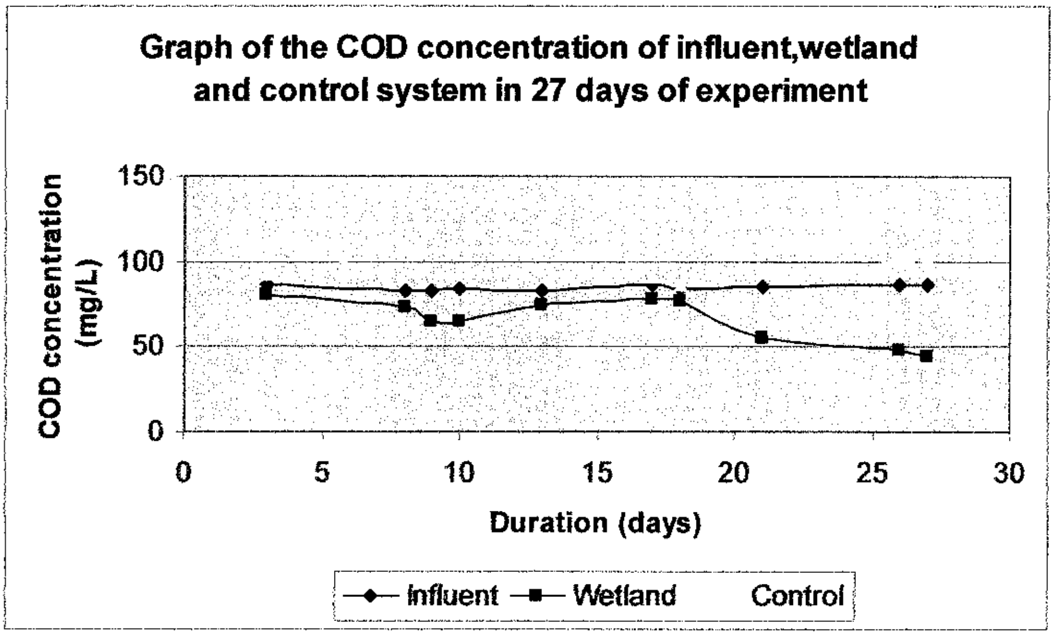

Figure 19 : Graph of the COD concentration of influent, wetland and control system in 27 days of experiment

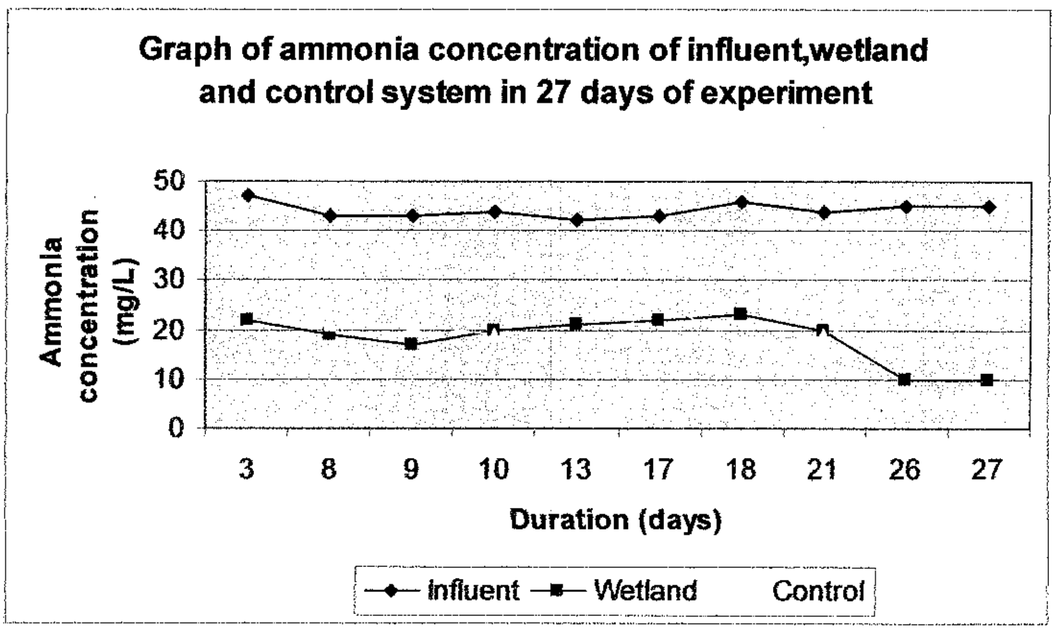

Figure 20 : Graph of the ammonia concentration of influent, wetland and control system in 27 days of experiment

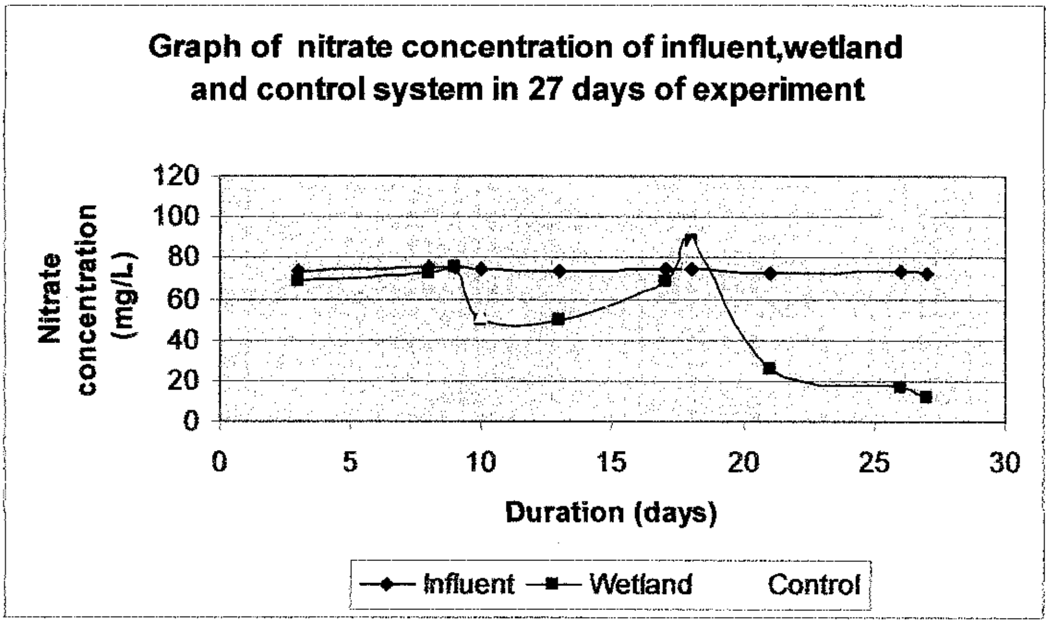

Figure 21 : Graph of the nitrate concentration of influent, wetland and control system in 27 days of experiment

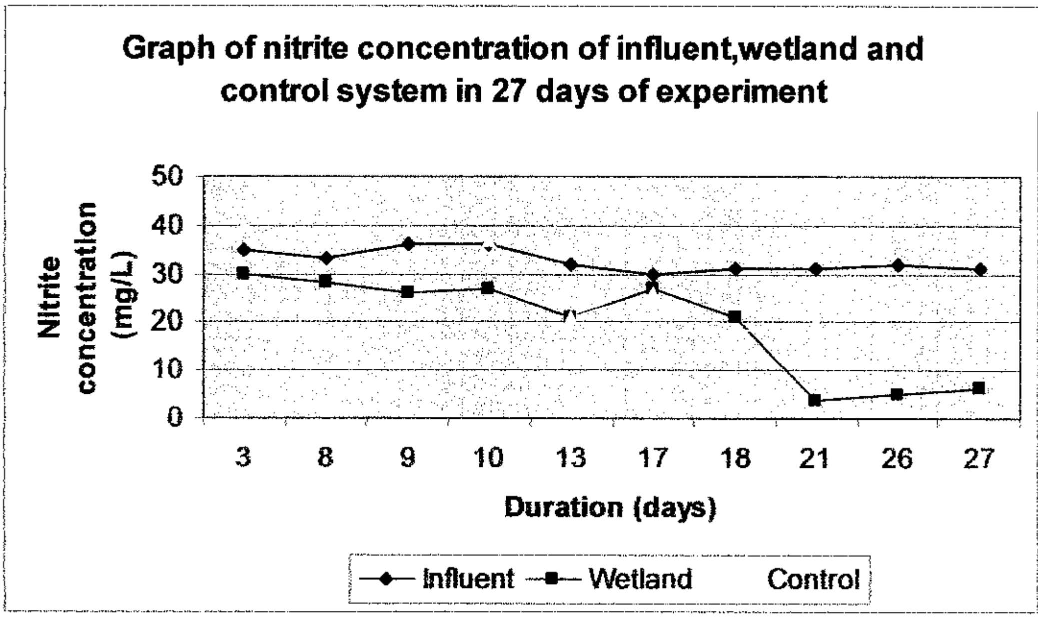

Figure 22 : Graph of the nitrite concentration of influent, wetland and control system in 27 days of experiment

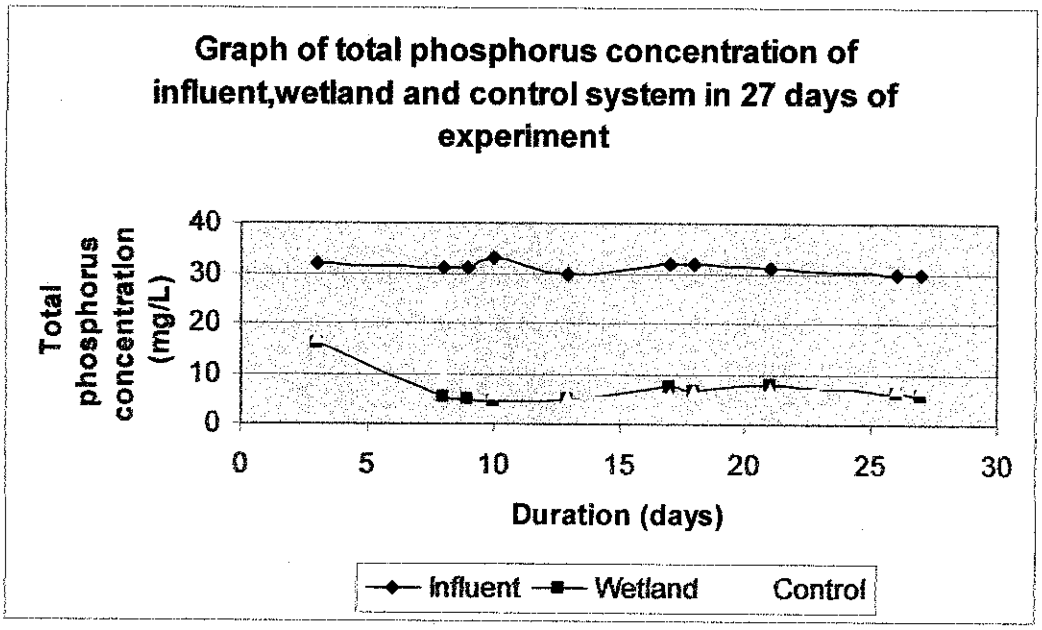

Figure 23 : Graph of the total phosphorus concentration of influent, wetland and control system in 27 days of experiment