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

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BORANG PENGESAHAN STATUS TESIS

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

SESI PENGAJIAN : **2008/2009**

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A thesis submitted in fulfilment of the requirements for the award of the degree of Bachelor of Chemical Engineering (Biotechnology)

Faculty of Chemical & Natural Resources Engineering
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30 APRIL 2009

DECLARATION

I hereby declare that this thesis entitled "*Municipal Wastewater Treatment 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 thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Special Dedication to my beloved mother and father,

My family members that always love me,

My friends, my fellow colleague and all faculty members.

For all your Care, Support and Believe in me.

Sincerely,
Muhammad Hanafi Bin Ahmad

ACKNOWLEDGEMENT

Bismillahirrahmanirahim,

Allhamdulillah, I am so thankful to Allah S.W.T for giving me patient and spirit throughout this project and the research is successfully complete.

I am indebted to my supervisor, Madam Noor Ida Amalina Ahamad Nordin, lecturer from Faculty of Chemical and Natural Resources Engineering, University Malaysia Pahang for her advice, insightful comments and generous support. Thank for your guide and without your guide this research will not complete and well organized. And not forgetting to my panels, Madam Rohaida Che Man and Miss Zatul Iffah Mohd Arshad for your brilliant ideas that you gave to me during my final project presentation, thank you.

I am grateful to extend my special gratitude to all lecturers and Jps of FKKSA of University Malaysia Pahang (UMP) especially to Mr. Zaki, Mr. Razak and Mr. Hisham that involve indirectly in this project for their invaluable time, guidance and advice.

My sincere appreciation also goes to my colleagues for all their support and guidance during my report completion. Thanks to Diana Madi, Siti Nurbaya Mustafa Kamal and Nur Anis Mat Ariffin.

And last but not least, thanks to my beloved family for their prayed and support.

ABSTRACT

The lab-scale of surface flow constructed wetland (SF) was applied to treat municipal wastewater for removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). The aim of this study was to determine the percentage removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) at different concentration of wastewater and at different number of treatment cycle by using constructed wetland treatment system. Two different concentration of wastewater were used which is diluted wastewater and non diluted wastewater and the treatment system was run for 10 days of treatment. The sample also treated with one treatment cycle and two treatment cycles. For the purpose of this study, the treatment system consists of 4 stages of treatment and it took 10 days to complete one cycle treatment, while for two cycle treatment it took 20 days. The 1st and 3rd stage is treated by gravel, while 2nd and 4th stage is treated by *Pistia stratioes*. From result obtained, it shows that treatment system with diluted wastewater by two treatment cycle was more efficient and gave the highest percentage removal of COD (92.5%) and TSS (91.4%), while DO level increased by 120%. Hence, the removal of COD and TSS complied with the requirement of the sewage effluents standard. Results from this study indicate that the Surface Flow Constructed Wetland is suitable and can be develops as one of the technology treatment system in the future.

ABSTRAK

Satu kajian berskala makmal bagi Tanah Bencah Beraliran Permukaan telah dijalankan untuk merawat sisa air kumbahan setempat bagi penyingkiran Keperluan Kimia Oksigen (COD) dan Pepejal Terampai (TSS). Tujuan kajian adalah untuk melihat peratusan penyingkiran Keperluan Kimia Oksigen (COD) dan Pepejal Terampai (TSS) bagi sisa air kumbahan setempat pada kepekatan yang berbeza dan pada bilangan kitaran rawatan yang berbeza dengan menggunakan Sistem Rawatan Tanah Bencah. Dua kepekatan sisa air kumbahan setempat yang telah digunakan ialah sisa air kumbahan yang telah dicairkan dan sisa air kumbahan tanpa pencairan. Sistem rawatan telah dijalankan selama 10 hari rawatan. Sisa air kumbahan setempat itu juga dirawat pada kitaran yang berbeza iaitu dengan satu kitaran rawatan dan dua kitaran rawatan. Dalam kajian ini, satu kitaran rawatan tersebut terdiri daripada 4 aras dimana ia mengambil masa selama 10 hari untuk melengkapkan satu kitaran rawatan, manakala untuk dua kitaran ia mengambil masa selama 20 hari. Aras 1 dan aras 3 adalah rawatan dengan menggunakan batu kelikir, manakala aras 2 dan 4 rawatan dengan menggunakan *Pistia stratiotes.* Hasil kajian mendapati, sistem rawatan dengan menggunakan sisa air kumbahan setempat yang dicairkan dengan dua kitaran rawatan memberi peratusan penyingkiran Keperluan Kimia Oksigen (COD) yang tertinggi iaitu 92.5% dan penyinggkiran Pepejal Terampai (TSS) sebanyak 91.4% selain peningkatan oksigen terlarut (DO) sebanyak 120%. Keputusan kajian ini juga mematuhi had piawaian pembuangan sisa air kumbahan setempat yang telah ditetapkan. Kesimpulannya, Tanah Bencah Beraliran Permukaan adalah amat praktikal untuk digunakan sebagai salah satu kaedah sistem rawatan bagi merawat sisa air kumbahan setempat secara semulajadi.

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LIST OF ABBREVIATIONS

COD	-	Chemical Oxygen Demand
TSS	-	Total Suspended Solid
BOD	-	Biochemical Oxygen Demand
DO	-	Dissolve Oxygen
SFCW	-	Surface Flow Constructed Wetland
SSFCW	-	Subsurface Flow Constructed Wetland
SF	-	Surface Flow
SSF	-	Subsurface Flow
FWS	-	Free Water Surface
SS	-	Suspended Solid

LIST OF SYMBOLS

CO_2	-	Carbon Dioxide
CH_4	-	Methane
N_2	-	Nitrogen gas
NH_3	-	Ammonia
^oC	-	Degree Celsius
%	-	Percentage
mg/l	-	milligram per liter

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

A constructed wetlands or known as an artificial wetland or wetpark is one of the technology treatment system that have been used internationally and effectively to improve our water quality and to treat various kinds of wastewater. The constructed wetlands act as a biological filter by removing contaminant or pollutants such as heavy metals, organic materials, and also nutrients from the wastewater which involved several physical, chemical and biological process in the transformation and consumption of organic matter within the wetland.

Usually the constructed wetland system consists of three elements which is water or wastewater that needs to be treat, aquatic plants act as a filter or absorber, and also microorganism that can degrade all the contaminant or pollutant in the wastewater. There are several advantages by applying the constructed wetlands system compared to the other conventional treatment. It is very economically and cost effectively, simple and easy to operate, and no complex technology is needed.

In designing the good wetland, the main biological component in the constructed wetland is the aquatic plants (macrophyte). However, it is important in determining the appropriate macrophyte species that can survive in the wastewater environment, because only a suitable macrophyte can treat a high concentration of pollutant in the wastewater. Recently, floating aquatic macrophyte systems are much better to use compared to the emergent macrophyte treatment system in term of nutrient uptake efficiency, especially macrophyte that has a large roots system. Several study documented that floating macrophyte such as *Pistia Stratiotes* (water lettuce) and *Eichhornia crassipes* (water hyacinth) have the capability to remove a large amount of pollutant, capability to survive at any wastewater environment and also has the highest growth rate (Sooknah *et al.*, 2004).

The aim of this study is to investigate the effectiveness of applying the constructed wetland treatment system in order to remove the pollutant by using floating aquatic species. In this research study, *Pistia Stratiotes* is preferred to use as a macrophyte in the constructed wetland. It is very economically and environmental friendly to use the constructed wetland system rather than conventional treatment system. The conventional treatment system now uses a chemical reagent and still contributes to pollution when react with certain substance compared to the constructed wetland which are treating the water naturally.

1.2 Problem Statement

Wastewater pollution has always been a major problem throughout the world. One of the main sources of the pollution is from municipal wastewater. Usually, municipal wastewater comes from residential area, restaurant, cafeteria, or agricultural effluent. This municipal waste consists of organic and inorganic waste includes food scraps waste oils and detergent. This waste is sometime very toxic to the certain aquatic life.

Basically, municipal wastewater contains high level of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). This high level of Chemical Oxygen Demand (COD) results low Dissolve Oxygen (DO) in water and this can lead to mortality of aquatic live. In addition, suspended solid such as organic and inorganic material can cause dirt and odor to the water.

Usually, municipal wastewater will undergo pretreatment before it will discharge into the river. The conventional sewage treatment involve physical, chemical and biological process which are very complex process, required highly cost and still contribute to pollution because it use chemical reagent to treat the wastewater. This conventional treatment system is not environmental friendly.

At the same time, some premise such as restaurant or cafeteria are preferred to discharge all their waste directly into the drain or river without any pretreatment. That waste usually contains mixture of waste oil, waste powder, chemical reagent such as detergent and many more. As a result, this waste can cause water pollution and can affect our water quality after it enters the waterway. Beside that, this wastewater also can cause odor or bad smell to our environment.

In this research study, an alternative method is suggested by using the constructed wetland system for treating the municipal wastewater. This constructed wetland system also has a potential to be developed as one of the wastewater treatment technology. This is because the constructed wetland system provides various advantages which are cost effectively, where it is easy to operate and environmental friendly to other wildlife and ecosystem.

1.3 Scope of Research Work

In this experiment, the parameters that are considered are Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). The treatment system consists of 4 stages of treatment and vegetated with *Pistia Stratiotes.*

The scopes of the study are:

i. To investigate the removal efficiency of COD and TSS in treatment system by using different concentration of wastewater.

ii. To investigate the removal efficiency of COD and TSS in treatment system by varies the number of treatment cycle.

iii. To determine the Dissolve Oxygen (DO) level in the wastewater.

1.4 Objectives of Study

The objectives of the study are to determine the percentage removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) in municipal wastewater and to determine the Dissolve Oxygen (DO) level in the municipal wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Wetland

Wetland is an area consisting of soil, plant and water where the soil is covered by water or saturated with moisture such as marsh, swamp or bog. Wetland are defined as land where the water surface is near the ground surface for long enough each year to maintain saturated soil conditions, along with the related vegetation (Sherwood *et al.,* 1995). The Convention of International Importance (The Ramsar Convention 1971) again define wetland as; “Land inundated with temporary or permanent water that is usually slow moving or stationary, shallow fresh brackish or saline where the inundation determine the type and productivity of soils and plant and animals communities”. Generally wetland can be categorized into two, which is natural wetland and constructed wetland.

2.1.1 Natural Wetland

Natural wetland is a naturally occurring wetland and variously called swamp, marshes, bog, and pond and it is usually characterized by their plant type, water and geographic condition (Sherwood *et al.*, 1995).

2.1.2 Constructed Wetland

Constructed wetland is an opposite of natural wetland where it is define as engineer-made equivalent of natural wetlands, and designed to reproduce and intensify the wastewater treatment processes that occur in natural wetlands (Hammer *et al.,* 1994). They were first introduced to treat wastewater by K.Siedel in 1952 in Germany (Chen *et al.,* 2007). Basically constructed wetland treatment systems consist of four major components which are soil or gravel, water or shallow pond, aquatic plant or macrophyte and also microorganism. . In general constructed wetland has been use to be a good solution to treat the polluted water and restored the ecosystem health (Chen *et al.,* 2007).

2.1.2.1 Constructed Wetland Treatment System

Constructed wetlands system is widely applied for the purification of domestic waste, stormwater runoff, and also industrial effluent. They act as biological filter which involve physical, chemical, and biological reaction which all participate in the reduction of organic, nutrient and microbiological loads (Brix, 1993; Vincent *et al.,* 1994).

Compared to the conventional treatment system, constructed wetland is usually considered to be one of the most promising technologies to treat wastewater due to the low cost operation and construction compared to the traditional one, simple operation and maintenance and also favorable environmental appearance (Buchberger *et al.,* 1995). Constructed wetland also can be operated in different scales and high expenditure for sewage collection systems can be saved.

Although the purpose of constructed wetland is to treat various kind of waste water, it also provides other purposes as well. A well designed constructed wetland has appealing appearance to serve as an artificial landscape and can serve as wildlife habitats and restored the ecosystems health.

2.1.2.2 Types of Constructed Wetland

In general, there are two basic designs for the constructed wetland that are commonly used in treatment system; Surface Flow Constructed Wetland (SFCW) and Subsurface Flow Constructed Wetland (SSFCW) (Chen *et al*., 2007).

Surface Flow Constructed Wetland (SFCW) are the most commonly use and remain primary choice for water treatment. It is also called Free Water Surface Wetland (FWS), because of wastewater flow across on the top of the surface of the bed. Surface Flow Constructed Wetland is shallow, earthen basins planted with rooted, emergent wetland vegetation (National Engineering Handbook, 2002). The wastewater enters at one end of a line excavation and exit at the other end. Figure 2.1 shows the basic concept of Surface Flow Constructed Wetland.

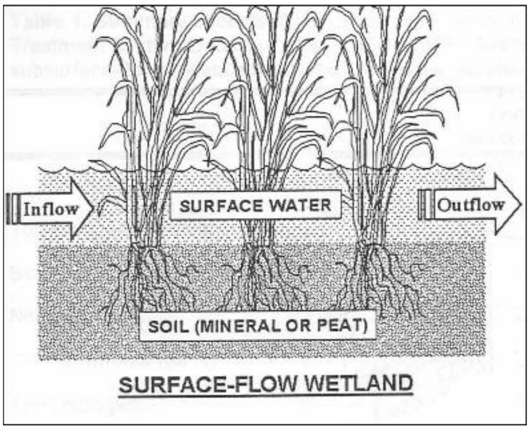


Figure 2.1: Basic concept of Surface Flow Constructed Wetland

In Subsurface Flow Constructed Wetland (SSFCW), the water level is maintained below the surface of the bed (gravel) and the effluent move through the medium below the surface, approximately mid-depth. The water level maintained below the surface of the bed can reduces mosquito breeding and fewer odor problems. In this wetland, water enters through an inlet distributor and flows slowly either horizontally or vertically below the ground surface until it reach the outlet of the system (Trevor, 2004). While Subsurface Flow Constructed Wetlands are successfully treating the wastewater, their still appears limited, where the porous bed can be easily plugged with solids and also relatively expensive for most operation (National Engineering Handbook 2002). The basic design for this constructed wetland is shown in Figure 2.2.

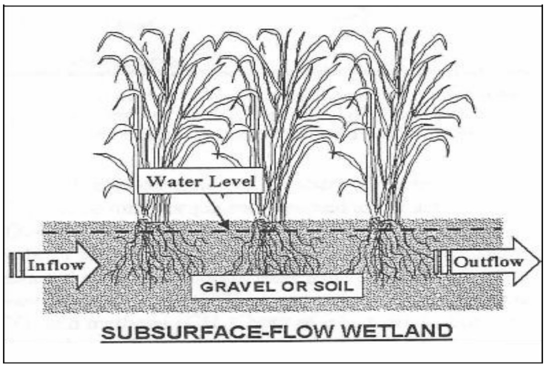


Figure 2.2: Basic concept of Subsurface Flow Constructed Wetland

2.2 Vegetation (Macrophyte)

Macrophytes or aquatic plant are the conspicuous plants that dominated wetland and normally found growing in association water whose level is at or above the surface of soil. These macrophytes include emergent species, submerged species and floating species (Sherwood *et al.,* 1995).

The role of macrophyte as an essential component of constructed wetland for wastewater treatment is well established (Perkins and Hunter,2000). Macrophytes have a positive effect and capable in enhancing pollutant removal within the system by either assimilating them directly or by providing an environment for surface microbial attachment to transform and uptake pollutant. Beside that, macrophyte can stabilizes the surface of the bed, supply reduces carbon and oxygen in the rhizosphere, decrease current velocity of water, and insulated the surface against frost in winter. (Brisson *et al.,* 2008). Beside, macrophyte can eliminate the disturbing smell of sewage water and reduce inlet odor (Zimmels *et al.,* 2006).

Usually macrophyte that are good tolerance to local condition, have a high growth rate and have flourishing rhizophore system are selected due to their excellent reproduce, ability pollutant removal and also oxygen transportation in the wetland (Chen *et al.*, 2007). In addition, plant species with varying root depth have a greater opportunity of pollutant removal. A basic knowledge about their characteristic in the wetland is essential for successfully treatment wetland (Kadlec, 1996).

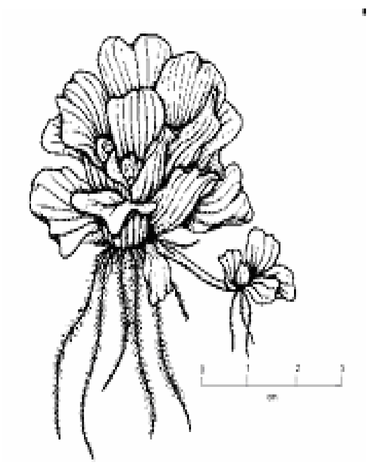
2.2.1 Floating Macrophytes

Floating macrophytes are widely used in Surface Flow Constructed wetland and known have a greatest potential for wastewater treatment. This species includes water lettuce (*Pistia stratiotes*), water hyacinths (*E.crassipes*), pennyworth and duckweeds (*Lemna sp*). This plant can survive and grow in anaerobic condition because oxygen is transmitted from the leaves to the root mass. Floating macrophyte such as water hyacinths are capable of removing high level of biological oxygen demand (BOD), suspended solid (SS), metal, nitrogen and other organic materials (Sherwood *et al.,* 1995). The principal removal mechanisms are physical sedimentation and bacterial metabolic activity (USEPA, 1993).

2.2.2 *Pistia stratiotes* (Water lettuce)

Pistia is a genus of aquatic plant in the family Araceae, comprising single species, *Pistia stratiotes* often called water lettuce. It is a free-floating plant with many spongy, dusty green simple leaves and its root hanging submerged beneath floating leaves. The leaves are covered in very fine hairs and arranged in a spiral pattern from the center of the plant (Wikipedia, 2009). Submerged portions of *Pistia stratiotes* provide habitat for many micro and macro invertebrate. *Pistia stratiotes* also easily to grow and the growth habit can form thick floating mats on the surface of water. If these mats cover the entire surface of the pond they can cause oxygen depletion in the water and killing fish (Rivers, 2002). Table 2.1 summarized the ecological and characteristic of *Pistia stratiotes*.

Table 2.1: Ecological and characteristic of *Pistia stratiotes*

<table>
<tr><td rowspan="10">
Pistia stratiotes
(Water Lettuce)</td><td colspan="2">**Scientific Classification**</td></tr>
<tr><td>**Kingdom**</td><td>Plantae</td></tr>
<tr><td>**Order**</td><td>Alismatales</td></tr>
<tr><td>**Family**</td><td>Araceae</td></tr>
<tr><td>**Genus**</td><td>*Pistia*</td></tr>
<tr><td>**Species**</td><td>*P. stratiotes*</td></tr>
<tr><td colspan="2">**Characteristic**</td></tr>
<tr><td>**Roots**</td><td>Roots hanging submersed beneath floating leaves, feathery and hairy.</td></tr>
<tr><td>**Leaves**</td><td>Thick soft leaves are form in rosettes, parallel ridges (vein), with no leave steam.</td></tr>
<tr><td>**Habitat**</td><td>Growth in swamp area, river or pond.
Minimum growth temperature: 15^oC.
Optimum growth temperature: $22\text{-}30^oC$.
Maximum growth temperature: 35^oC.</td></tr>
</table>

2.3 Removal Mechanism in Constructed Wetland

To provide contaminant removal in a constructed wetland, it involves physical, biological and chemical process that operate concurrently as shown in Figure 2.3.

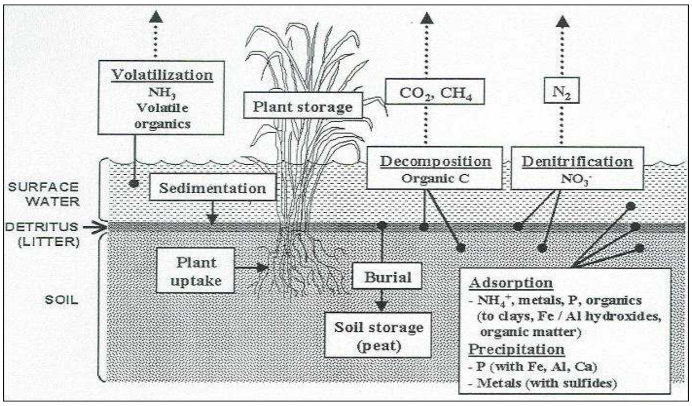


Figure 2.3: Summary of contaminant removal in wetland (DeBusk, 1999).

2.3.1 Physical Removal

The physical removal in constructed wetland involved of the sedimentation of suspended solid. In constructed wetland, typically the surface water moves very slowly, often laminar flow through wetland due to the resistance provided by root and floating plant and this flow promoted to the sedimentation of the suspended solid in the wetland (DeBusk, 1999). In addition, the present of gravel filtered mostly of the suspended solid and provide opportunities for TSS separation by gravity sedimentation (El-Khatib and El Gohary, 2003)

2.3.2 Biological Removal

Biological removal is the most important for contaminant removal in wetlands and this recognized by plant uptake. Contaminant such as nitrate, ammonium, phosphate, and certain toxic such as cadmium and lead are readily taken up by wetland plants. The rate of contaminant removal by plants depends on the plant growth rate and concentration of the contaminant in plant tissue. Algae and bacteria may also provide a significant amount of nutrient uptake but susceptible to the toxic effects of heavy metals. Microbial decomposer utilized the carbon, in organic matter as a source of energy and converting it to carbon dioxide CO_2, or methane CH_4 gasses. Microbial metabolism also provides removal of inorganic compound such as nitrate and ammonium in wetland and convert nitrate into nitrogen gasses N_2 and released to the atmosphere. This process calls denitrification (Debusk, 1999).

2.3.3 Chemical Removal

The most important chemical removal in wetland soils is sorption. Sorption is defined term for the transfer of ions from the solution phase (water) to the solid phase (soil). Adsorption refers to the attachment of ions to soil particles. Phosphate can also precipitate with iron and aluminum oxide to form new mineral compound (ferum and aluminum phosphate) which are potentially stable in the soil. Ammonia, NH_3 and many types of organic compound are volatile and are readily lost to the atmosphere from wetlands (William, 1999).

2.4 Operation and Maintenance in Constructed Wetland

Proper operation and maintenance will ensure that constructed wetlands operate as designed and that the objectives are achieved over the life of the system. Maintenance may be needed to control the spread of undesired plant species and also to remove the debris that will blocked the inlet and outlet flow in the wetland (William, 1995). Special requirements for the constructed wetland include harvesting of the vegetation and mosquito controls. Routine harvesting of vegetation may increase nutrient removal and prevent the dying plants falling in the water (California Stormwater BMP Handbook, 2003). One of the best ways to reduce the mosquito breeding is by introducing the mosquito fish in the wetland such as *Gambusia* fish and also bacteria insecticides such as *Bacillus thuringienss israeliensis* (Robert *et al.*, 2003). To control the spreading of *Pistia*, mechanical harvesters and aquatic herbicides may also be used. Beside, insect are also being use to manage *pistia* such as *Neohydronomous affinis* (Wikipedia, 2009)

2.5 Municipal Wastewater

Generally, municipal wastewater that is collected using sewer system can be categorized into two primary types which are general wastewater and stormwater (Timothy, 2003). The characteristics of wastewater discharges will vary from location to location depending on population, land uses and ground water levels.

General wastewater is generated from resident homes, businesses, and industry includes typical waste from toilets, sinks, shower, laundry and so forth as well as any other wastes that people intentionally pour down the drain. Basically general wastewater contains biological, chemical, and physical contaminant that should be reduce prior to discharge to environment. Industrial waste may contained other contaminants such as metal, detergent, acid and base and therefore require pretreatment prior to discharge into environment (Timothy, 2003).

Stormwater is generated primarily from precipitation runoff from streets, parking lots and other surface. Basically stormwater are much more diluted than general wastewater. Roads and parking lots are subjected to spills of oil, gasoline, and other toxic fluids from automobile, as well as road salt. This contaminant can be carried by stormwater runoff into sewer systems and wastewater treatment facility (Timothy, 2003).

2.6 Standard Water Quality Measurement

In order to measure the quality of wastewater before it can be discharge to the river, several parameter need to be considered. For the purpose of this study, two parameter are considered; Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS).

Chemical Oxygen Demand is a measure of oxygen requirement of a sample that is susceptible to oxidation by strong chemical oxidant. Chemical Oxygen Demand test is used to indirectly measure the amount of organic compound in water, while Total Suspended Solid (TSS) is a measured of small solid particles which remain in suspension in water as a colloid and it is used as one indicator of water quality.

Table 2.2 shows the maximum level for this parameter according to the Environmental Protection Agency, EPA. The Environmental Quality Act (EQA) 1974 specifies two standards for effluent discharge, effluent that is discharged upstream of a water supply intake should meet Standard A, while effluent that is discharged downstream has to meet Standard B.

Table 2.2: Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979

Parameters	Standard A	Standard B
Chemical Oxygen Demand (COD), mg/l	50.0	100.0
Total Suspended Solid (TSS), mg/l	50.0	100.0

CHAPTER 3

METHODOLOGY

This chapter described on the procedure of the experiment conducted, which includes information on the construction and operation of the wetland cell, plant preparation, sampling procedure, and laboratory analysis. The framework of study is summarized as shown in Figure 3.1.

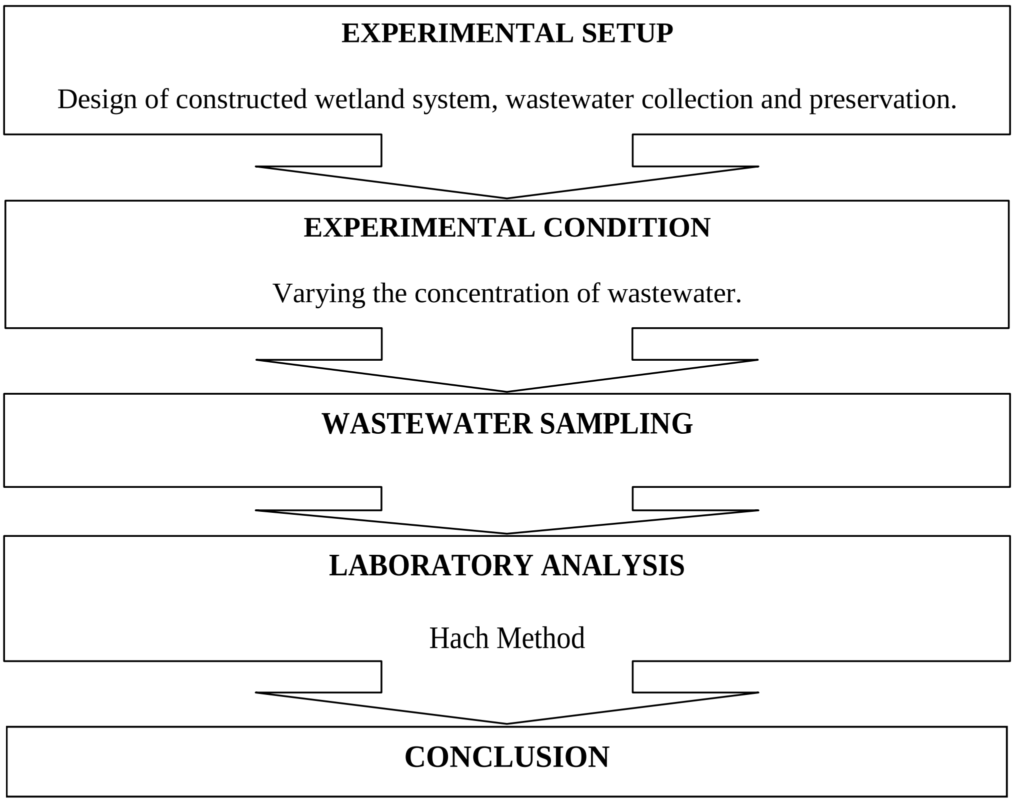


Figure 3.1: Framework of study.

3.1 Experimental Setup

3.1.1 Constructed Wetland Design

The design of the treatment systems used in this study was Surface Flow Constructed Wetland (SF). The treatment system consists of 4 stages of treatment. Five identical plastic containers with 15 liters capacity were used in this experiment as a wetland cell. Two of the wetland cell consists of a shallow layer of wastewater and gravel, and the other two wetland cells consist of macrophyte canopy on the above of the wastewater. One container without macrophyte and gravel was used as a control system. Figure 3.2 shows the wetland design that was used in this study.

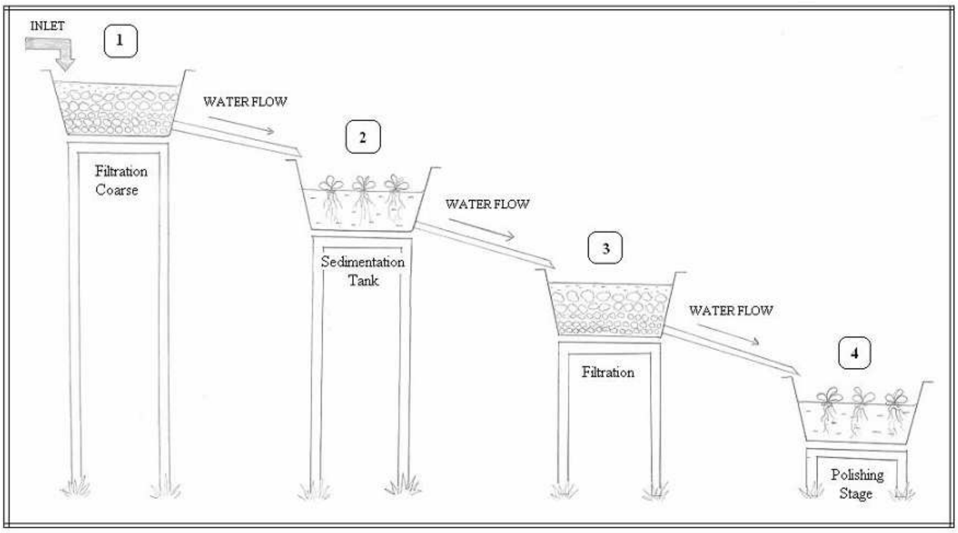


Figure 3.2: Wetland design

3.1.2 Macrophyte

In this study, *Pistia stratiotes* or water lettuce were chosen as the vegetation component in the treatment system and this macrophyte can be found in swamp area. For this study, *Pistia stratiotes* were obtained in fresh water pond at Perkampungan Beserah. The collected *Pistia stratiotes* were then planted in a container filled with freshwater to prevent the plants from dying and to support the floating plants with cleaning roots.

3.1.3 Sample Preparation

The wastewater used in this study was food processing wastewater. It is collected from the cafeteria effluent from University Malaysia Pahang. The wastewater sample is collected at least one day before experiment started to ensure the purity of the waste and also to ensure no degradation of pollutant occur in the wastewater.

3.2 Experimental Condition

The experiment is conducted under a shaded open area of FKKSA laboratory. The shaded area will avoid the rain water enter the experiment system and will provide a sufficient amount of sunlight and air for macrophyte to grow. The treatment system was a batch type system.

In this experiment, one treatment cycle consist of 4 stages of treatment as shown in Figure 3.2. The process begun from stages 1 called filtration coarse. Duration of this stage is 1 day. After 1 day, sample from stage 1 allowed to flow into stages 2 called sedimentation tank and was left for 4 days. Next, sample goes into stages 3 called filtration tank. In stages 3, sample was left for 1 day. Finally, sample goes into stages 4 called polishing stage and left for 4 days. Thus, the whole process took 10 days to complete 1 cycle treatment.

For the purpose of this study, the designated experiment consists of two set of experiment, where the concentration of wastewater and the number of treatment cycle used in this treatment process is varied. First set of experiment is treatment with non diluted sample (concentrated) and the second set of experiment is treatment with diluted sample. Both set of experiment is treated with one cycle treatment which is 10 days of treatment and treated with two cycle treatment which is 20 days of treatment. One set of experiment without undergo treatment process is set for control system.

3.3 Wastewater Sampling

The sampling of treated wastewater was taken and recorded every day for 20 days. For this experiment the sample was taken every 24 hour by collecting two samples from treatment system, and one sample from controlling system.

3.4 Laboratory Analysis

The analysis of the sample was carried out in the Basic Science Lab of the FKKSA Laboratory. As for this study, the parameter that analyzed was; Chemical Oxygen Demand (COD), Total Suspended Solid (TSS) and Dissolve Oxygen (DO).

For COD analysis, the Colorimetric Determination Method 8000 was used in examining the concentration of Chemical Oxygen Demand in the sample. COD Digestion Reactor and Hach DR2800 Spectrophotometer were used in this analysis to detect the parameter studied. The concentration of COD can be measured directly using Hach DR 2800.

For TSS analysis, the TSS test was used to determine the TSS concentration in the wastewater. This test involved filtration of the samples by using glass fiber filter and the residue retained on the filter were dried at 103 ^{O}C for 1 hour and weighted. The differences between final weight and initial weight gave the amount of suspended solid in the sample.

For Dissolve Oxygen (DO) analysis, Dissolved Oxygen Meter was used and the value was measured directly.

Table 3.1: Summarized of experimental analysis.

Parameter studied	**Analysis method**	**Analytical Equipment Used**
Chemical Oxygen Demand (COD)	Colorimetric Determination Method 8000.	• COD Digestion Reactor. • Hach DR2800 Spectrophotometer
Total Suspended Solid (TSS)	Filtration method using glass fiber filter.	• Glass fiber filters 70mm. • Vacuum pump
Dissolve Oxygen (DO)	Measured directly using Dissolve Oxygen Meter.	Dissolve Oxygen Meter

Table 3.1 above summarized of all analysis method that was used in this study. Figure of analytical equipment used during the experiments are shown in the appendices section for review.

CHAPTER 4

RESULT AND DISCUSSION

In this chapter, all the data obtained from the experiment were analyzed and discussed. The results were include the removal efficiency of Chemical Oxygen Demand and Total Suspended Solid in the wastewater by varying the number of treatment cycle and varying the concentration of wastewater. For analysis, all the results were summarized and presented into graph and figures. The raw data tables relating to the experiment are shown in appendices section as for review.

4.1 Observation from the Experiment

The first observation that has been made from the experiment was the odor and the color of the wastewater before undergo treatment process and after treatment process. After completed the treatment process the color of the wastewater changed from dark, brownish and oily into slightly clear. The odor also less after undergo treatment process. This can be explained by the presence of gravel and *Pistia* that contribute to the removal mechanism in the treatment system. For control system, the color still cloudy and oily and gave unpleasant odor. Table 4.1 summarized the observation from the experiment.

Table 4.1: Experimental observation

	Before Treatment			**After Treatment**		
	Non Diluted Wastewater	**Diluted Wastewater**	**Control System**	**Non Diluted Wastewater**	**Diluted Wastewater**	**Control System**
Color	Dark, brownish and oily	Dark, brownish and oily	Dark, brownish and oily	Slightly Clear	Slightly Clear	Cloudy and oily
Odor	Unpleasant odor	Unpleasant odor	unpleasant odor	Odorless	Odorless	Unpleas ant odor

4.2 Varying the Concentration of Wastewater

In this treatment process, the concentration of the wastewater was varied, which is diluted wastewater and non diluted wastewater and one as a control system. The difference concentration of wastewater was used in this treatment process to indicate which concentration has the highest percentage removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS).

4.2.1 COD Reduction

The initial and final COD concentration for diluted, non diluted wastewater and control system are shown in Figure 4.1. The COD level was measured in terms of concentration (mg/l). From Figure 4.1, the concentration of COD in the wastewater decreased over time. Initially, before undergo treatment process; the concentration of COD in the wastewater was around 560 mg/l to 630 mg/l.

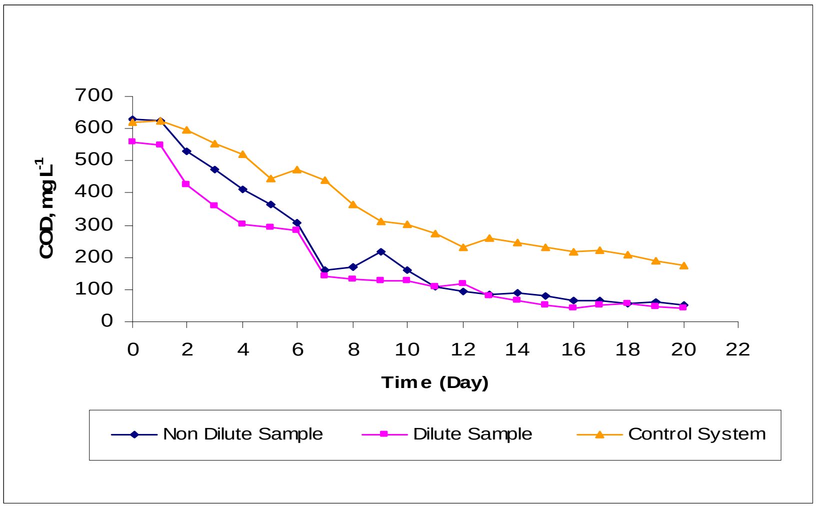


Figure 4.1: Concentration of COD in the wastewater.

As shown in Figure 4.1, the COD level for non diluted wastewater decreased from it initial 630 mg/l to 54 mg/l after 20 days of treatment and the percentage removal was 91.43%. For diluted wastewater, the COD level drop from 560 mg/l to approximately 42 mg/l after 20 days of treatment and the percentage removal was around 92.5%. While for control system, the COD level decreases from 619 mg/l to 175 mg/l after 20 days and the percentage removal was only 71.73% approximately. Figure 4.2 depict the percentage removal for both diluted wastewater and non diluted wastewater, and also control system for 20 days of treatment.

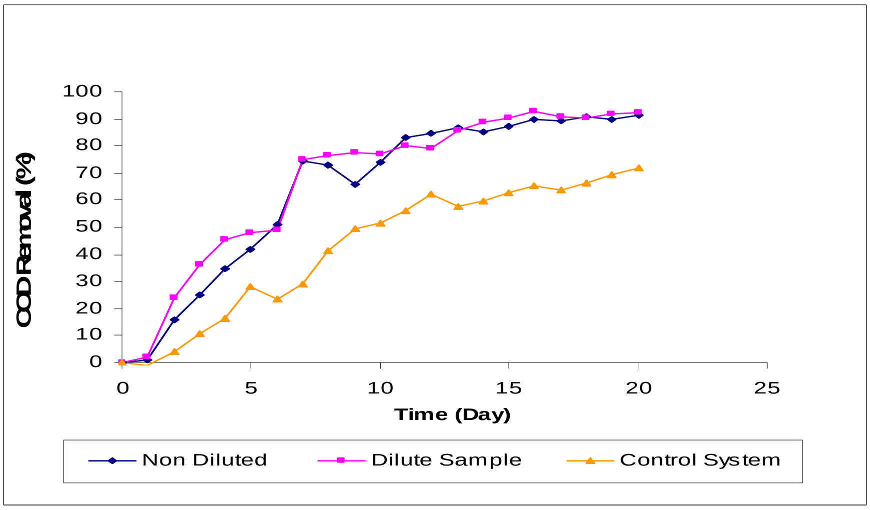


Figure 4.2: Percentage removal of COD in the wastewater

Based on Figure 4.2 above, treatment system with diluted wastewater has the highest percentage removal of COD, 92.5%, followed by non diluted wastewater 91.43% while for control system the percentage removal was only 71.73%.

From that result, it shows that treatment system with diluted wastewater was more efficient in term of COD reduction. This can be explained by the presents of gravels and plants uptake which is *Pistia stratiotes* that contribute to the removal mechanism in the treatment system. As from literature, *Pistia stratiotes* were more efficient in a more diluted wastewater compared to the concentrated wastewater (Zimmels *et al.*, 2007).

As a comparison to the standard water quality measurement as state by Environmental Quality Act 1974, after 20 days of treatment, the concentration of COD for diluted wastewater was 42 mg/l and complied Standard A (<50 mg/l) while for non diluted wastewater the concentration of COD was 54 mg/l and complied Standard B (<100 mg/l).

4.2.2 TSS Reduction

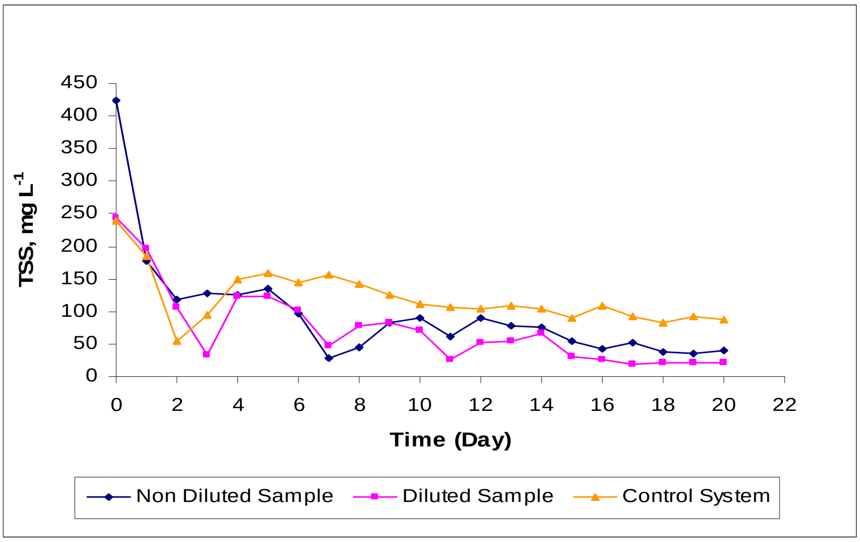


Figure 4.3: TSS level in the wastewater

Figure 4.3 present the result of Total Suspended Solid (TSS) for diluted wastewater, non diluted wastewater and control system in term of concentration (mg/l). Initially the amount of suspended solid in the wastewater was around 423 mg/l. Figure 4.3 shows that the amount of suspended solid in wastewater declined over time, same trend as COD reduction in wastewater.

From that result, it shows that the TSS level for both diluted and non diluted wastewater was kept below 50 (mg/l) after 20 days of treatment. For non diluted wastewater, the TSS level decreased from its initial 423 mg/l to 41 mg/l after 20 days of treatment. The percentage removal of TSS was about 90.31%. For diluted wastewater the TSS level decreased from 245 mg/l to approximately 21 mg/l after 20 days of treatment and the percentage removal was around 91.4%. For control system, the initial level of TSS was 239 mg/l and after 20 days, its drops to 87 mg/l, and the percentage removal was around 65.59% respectively. Figure 4.4 depict the percentage removal of TSS in wastewater after 20 days of treatment.

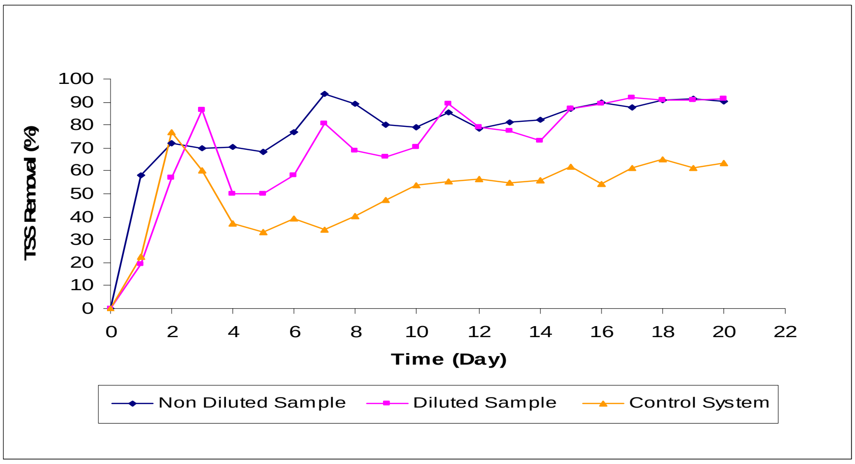


Figure 4.4: Percentage removal of TSS

Based on Figure 4.4, treatment systems with diluted wastewater has the highest percentage removal of TSS compared to non diluted wastewater and also control system. For diluted wastewater the percentage removal of TSS was 91.4%, followed by non diluted wastewater 90.31% and for control system only 65.59%.

Same as COD reduction, the reduction of TSS can be explained by the combination of gravels and *Pistia* roots that filtered and trapped most of the suspended solid during treatment process. Basically the removal of suspended solid is not totally depends on the concentration of wastewater, but it depend on the amount of suspended solid that contain in the wastewater. As from literature, macrophytes may play a role in free water surface wetland by dampening current velocities and wave energy, thus allowing suspended sedimentation to settle out (Brisson *et al.*, 2008).

By referring to the standard water quality measurement as state by Environmental Quality Act 1974, the concentration of TSS for both non diluted wastewater and diluted wastewater after 20 days of treatment complied Standard A, which is below 50 mg/l.

4.3 Varying the Number of Treatment Cycle

Besides varying the concentration of wastewater, the number of treatment cycle also varied. The sample of wastewater were treated with one treatment cycle and also treated with two treatment cycles. For one cycle it took 10 days to complete, while for two cycles, sample from cycle one was recycling again for another 10 days. The objective is to investigate the removal efficiencies of COD and TSS by vary the number of treatment cycle, beside to find the optimal time for the treatment process.

4.3.1 COD Reduction

Figure 4.5 present the COD level of wastewater for diluted wastewater, non diluted wastewater and control system in different treatment cycle. The initial concentration of COD for diluted wastewater was 560 mg/l and for non diluted wastewater was 630 mg/l while for control the COD concentration was around 619 mg/l.

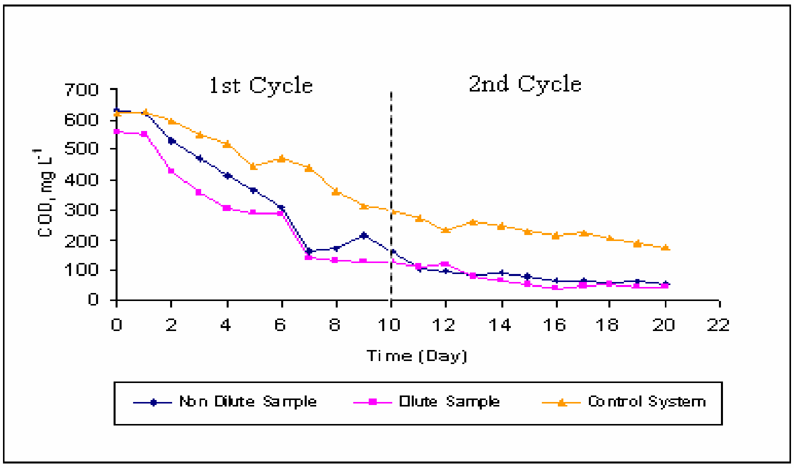


Figure 4.5: Concentration of COD in wastewater at different treatment cycle

As shown in Figure 4.5, the concentration of COD for two treatment cycle is lowered compared to the concentration of COD for one treatment cycle. For one treatment cycle, the concentration of COD for non diluted wastewater decrease from 630 mg/l to 163 mg/l. For diluted wastewater, the COD level drop from it initial 560mg/l to 129 mg/l while for control system, the COD level decrease from 619 mg/l to approximately 301 mg/l. For two treatment cycle, which is after 20 days of treatment, the concentration of COD for non diluted wastewater down to 54 mg/l and for diluted wastewater the COD level drop to 42 mg/l, while for control system the COD level was 175 mg/.

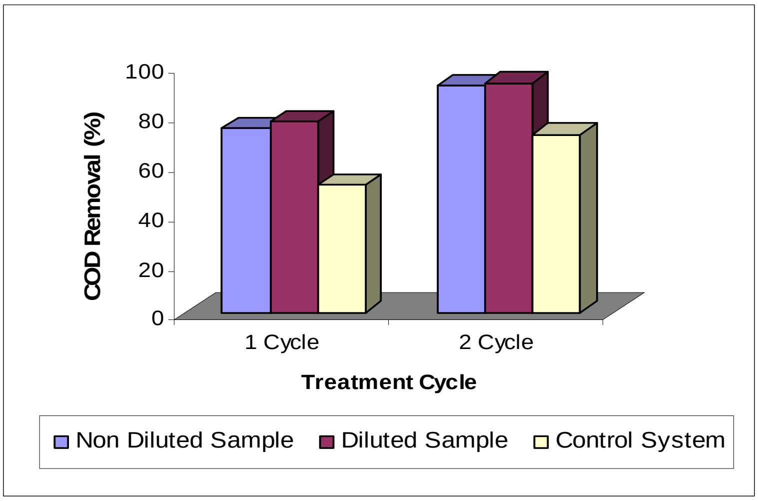


Figure 4.6: Percentage removal of COD at different cycle

As a comparison, Figure 4.6 depicts the final percentage removal of COD after completed both 1 treatment cycle and 2 treatment cycle. From that figure, it shows that two treatment cycles is more efficient and gave the highest percentage removal of COD for diluted wastewater, non diluted wastewater and control system. For non diluted wastewater, after completed 1 treatment cycle, the percentage removal of COD was 74.13%, while for 2 cycles the percentage removal was around 91.43%. For diluted wastewater, after completed 1 treatment cycle, the percentage removal of COD was 76.96%, while after 2 cycle, up to 92.5% removal. For control system, the percentage removal of COD was around 51.37% after 10 days, while after 20 day, the percentage removal was 71.73% respectively. In the other words, the percentage removal of COD was increased as the number of treatment cycle increased.

4.3.2 TSS Reduction.

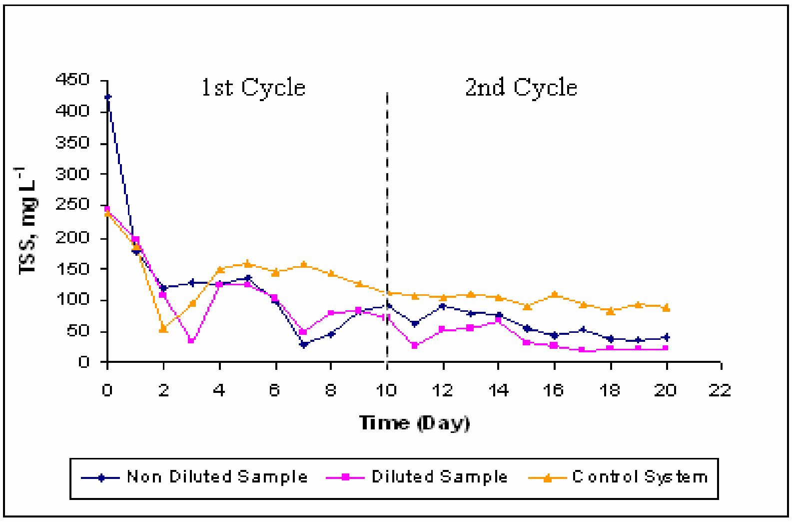


Figure 4.7: TSS Levels at different treatment cycle.

Figure 4.7 shows the TSS level for both 1 treatment cycle and 2 treatment cycles. For 1 treatment cycle, the TSS level for non diluted wastewater decreased from its initial 423 mg/l to approximately 89 mg/l (78.96% removal) and for diluted wastewater the TSS level decreased from 245 mg/l to 72 mg/l (70.61% removal). For control system, the TSS level was decreased from 239 mg/l to 111 mg/l (53.55% removal). However, after completed 2 treatment cycle, the TSS levels for non diluted wastewater was down to 41 mg/l (90.31% removal) while for diluted wastewater it down to 21 mg/l (91.4% removal). For control system, the TSS level was only 87 mg/l (63.59% removal).

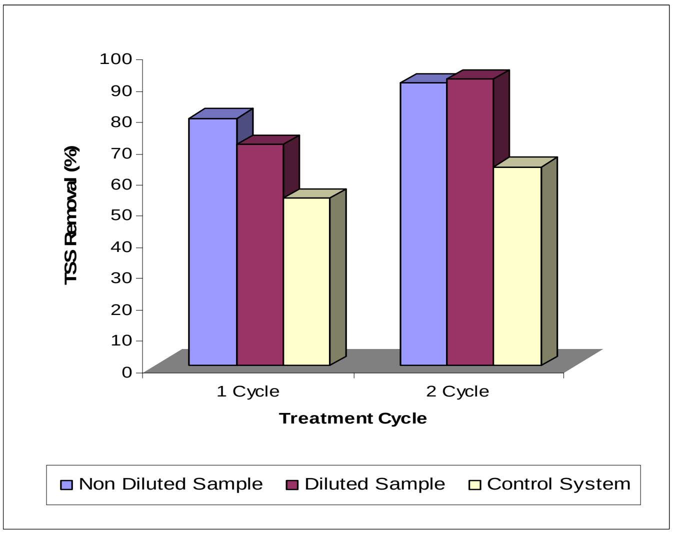


Figure 4.8: Percentage removal of TSS at different cycle

Figure 4.8 shows the percentage removal of TSS for both 1 treatment cycle and 2 treatment cycles. It shows that 2 treatment cycle gave the highest percentage removal of TSS and more efficient than one treatment cycle, same as COD reduction. In the other words, the percentage removal of TSS was increased as the number of treatment cycle increased.

4.4 Dissolve Oxygen Level

In these studies, the Dissolve Oxygen (DO) level also was tested. The DO level was tested along 20 days. Figure 4.9 depict the Dissolve Oxygen Level (DO) in term of concentration (mg/l).

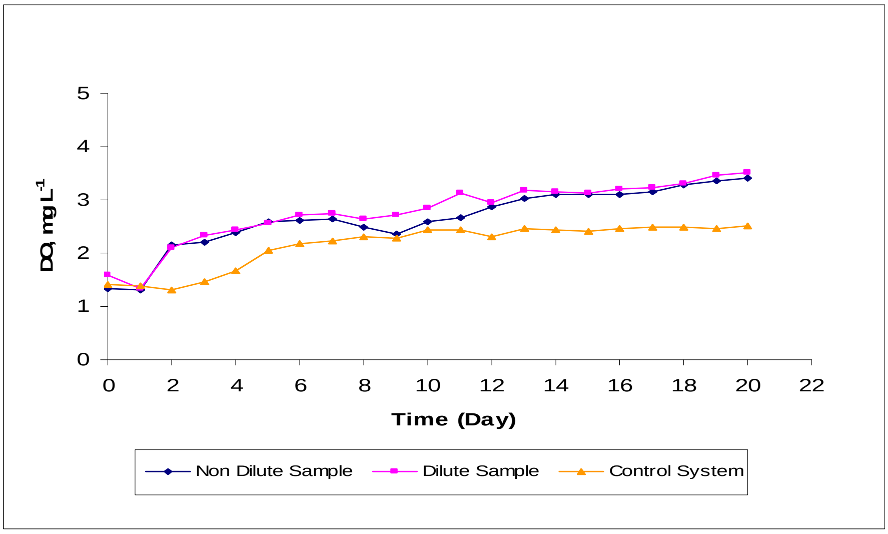


Figure 4.9: Dissolve Oxygen level in wastewater

As shown in Figure 4.9, the DO level for non diluted wastewater, diluted wastewater and control system was increased over time. The initial DO level for non diluted wastewater was around 1.34 mg/l and after 20 days of treatment, it increased to 3.42 mg/l. For diluted wastewater, the initial level of DO was 1.59 mg/l, and after 20 days of treatment it up to 3.51 mg/l. While for control system, the initial level of DO was around 1.42 mg/l and after 20 days the DO level was only 2.52 mg/l.

The increasing of DO level can be explained by the present of *Pistia* that mediated transfer oxygen to the rhizosphere, by leakage from roots and increased aerobic degradation in the wastewater (Brix, 1997). As DO level in water drops below 5.0 mg/l, aquatic live is put under stress, while DO level below 1-2 mg/l can result in large fish killed.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study was successfully conducted for treating the municipal wastewater by using constructed wetland treatment system. The lab-scale study has proved that constructed wetland capable in reducing the Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) beside increase the Dissolve Oxygen (DO) level in wastewater. The removal of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) in wastewater was due to the present of gravels and *Pistia stratiotes,* which contribute to the physical, chemical and biological removal in the constructed wetland treatment system. This study shows that, treatment system with diluted wastewater by two treatment cycle was more efficient and gave the highest percentage removal of COD (92.5%) and TSS (91.4%), while DO level increased by 120%. Hence, the removal of COD and TSS complied with the requirement of the sewage effluents standard. Results from this study indicate that the Surface Flow Constructed Wetland is suitable and can be develops as one of the technology treatment system in the future.

5.2 Recommendation

There are several recommendations proposed in order to increase the efficiencies of constructed wetland treatment system:

- An outdoor experimental should be setup in order to study the surrounding effect on the pollutant removal in constructed wetland.
- Various types of macrophyte should be use in order to find which macrophyte can yield a higher percentage removal of COD and TSS.
- Further study must be conduct to study another additional factor that can increase the effectiveness of constructed wetland on pollutant removal such as effect of aeration in constructed wetland and effect of bacteria in constructed wetland.

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APPENDIX A

RAW DATA

Table A.1: Experimental Result

Cycle	Stages	Day	COD (mg/l)			TSS (mg/l)			DO (mg/l)		
			ND	D	C	ND	D	C	ND	D	C
1	Initial	0	630	560	619	423	245	239	1.34	1.59	1.42
	Gravel	1	622	549	626	178	197	185	1.30	1.33	1.38
	Vegetated	2	530	426	595	118	106	55	2.15	2.09	1.30
		3	473	358	552	127	33	95	2.20	2.33	1.46
		4	413	305	519	125	123	150	2.38	2.49	1.67
		5	365	291	445	134	122	159	2.58	2.56	2.05
	Gravel	6	308	286	473	98	103	145	2.62	2.71	2.18
	Vegetated	7	161	140	440	28	47	157	2.65	2.75	2.23
		8	170	131	362	45	77	142	2.49	2.63	2.30
		9	216	127	314	84	83	126	2.37	2.73	2.28
		10	163	129	301	89	72	111	2.58	2.84	2.43
2	Gravel	11	107	110	272	61	26	107	2.67	3.12	2.44
	Vegetated	12	96	118	233	90	52	104	2.88	2.98	2.30
		13	84	79	261	79	55	108	3.03	3.19	2.47
		14	92	64	248	76	66	105	3.10	3.16	2.43
		15	79	53	230	54	35	91	3.09	3.12	2.41
	Gravel	16	64	41	216	26	43	109	3.11	3.20	2.45
	Vegetated	17	66	50	224	33	40	93	3.16	3.22	2.50
		18	58	55	208	39	36	84	3.27	3.30	2.49
		19	63	46	190	36	28	93	3.35	3.47	2.46
		20	54	42	175	41	21	87	3.42	3.51	2.52

ND = Non Diluted sample, **D =** Diluted sample, **C =** Control sample

APPENDIX B

EQUATION

B.1: Total Suspended Solid Determination:

$$\text{TSS (mg/L)} = \frac{(A - B) \times 1000 \text{ mL/L}}{\text{Sample volume, mL}}$$

Where;

A = weight of filter + dried residue, mg

B = weight of filter, mg

B.2: Dilution Factor:

$$\text{Dilution Factor} = \frac{\text{Total Volume, L}}{\text{Volume Sample, L}}$$

Where;

Total Volume = Volume sample + Volume water

APPENDIX C

DESIGNATED EXPERIMENT

C.1 Wastewater Sample

 

Figure C.1: Sample of wastewater

C.2 Treatment System

APPENDIX D

ANALYTICAL EQUIPMENT

D.1: Chemical Oxygen Demand (COD) Analysis:

Figure D.1 (a): Digital Reactor Block 200

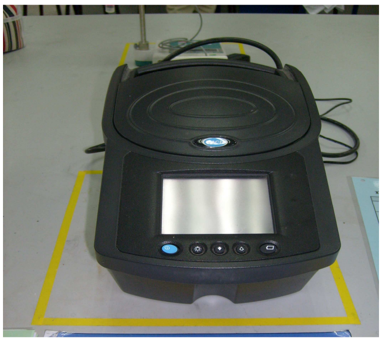

Figure D.1 (b): DR2800 Portable Spectrophotometer

Figure D.1 (c): COD reagent

D.2: Total Suspended Solid (TSS) Analysis:

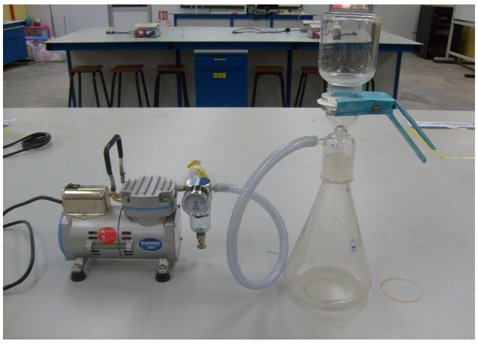

Figure D.2 (a): Vacuum pump

Figure D.2 (b): Glass fiber filter

Figure D.2 (c): Oven

Figure D.2 (d): Analytical weight

D.3: Dissolve Oxygen (DO) Analysis

Figure D.3: Dissolve Oxygen Meter