COMBINING OILY WASTEWATER WITH DOMESTIC WASTEWATER FOR FURTHER TREATMENT BY BIOFILTRATION METHOD

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by

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CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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TRONOH, PERAK

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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 references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SITI SUHAIRI BINTI MUHAMMAD IDIRIS

ABSTRACT

Issues concerning stormwater runoff quality and it impact on the ecosystem of the receiving water bodies have lead towards stormwater best management practice. One of the stormwater management practices is the use of biofiltration systems that allow variety of pollutants removal mechanisms. There are three main mechanisms of pollutants removal involved within the system which are physical, chemical and biological processes. Current application of the biofiltration focuses mainly on treating ordinary stormwater runoff but not for oily stormwater runoff. This study examines the potential application of biofiltration system in treating oily wastewater with addition of domestic wastewater. Laboratory scale biofiltration columns consisting of sand for bottom layer, activated carbon for middle layer and planting media for the top layer were used in this study. Four columns were constructed and the combined wastewater was left in the system for a period of 2 days, 4 days, 7 days and 10 days for each columns. The parameters for influent and effluent wastewater in term of chemical oxygen demand (COD), total organic carbon (TOC), total suspended solid (TSS), turbidity, nutrients content (ammonia-nitrogen, nitrate-nitrogen and total phosphorus), and zinc were analyzed. The hydraulic conductivity of the filter media was 0.0177 mm/sec and the pH of the soil was 7.61. The results indicate reduction of all the pollutants after treatment. The biofiltration system able to remove up to 90% of COD, 35% of TOC, 88% of TSS, 70% of turbidity, 77% of ammonia-nitrogen, 86% of nitrate-nitrogen, and 86% of phosphorus after 10 days of retention time. According to Environmental Quality (Sewage Industrial Effluent Regulations, 1979), the effluents quality meets the standard A limit.

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ABBREVIATIONS

BMPs	Best Management Practices
COD	Chemical Oxygen Demand
TOC	Total Organic Carbon
TSS	Total Suspended Solid

CHAPTER 1

INTRODUCTION

1.1. Background of study

Stormwater runoff is an important water resource because of its abundant volume. However, the resulting runoff from urban areas is also a concern as a growing pollution source for many receiving water bodies because of the increased loading of toxic contaminants from urban areas.

Biofiltration systems are increasingly being used to improve the quality of stormwater runoff in order to reduce stormwater pollution. Biofiltration is the process of biological removal of contaminants or nutrients as fluid passes through media or a biological system. The nutrients N and P, in the soluble forms that are readily available for uptake, are of particular concern because of their capacity to lead to eutrophication in the water. Suspended solids and heavy metals such as Pb, Zn, Cu, and Cd are also of concern (Davis *et al.*, 2003). Studies have indicated that effluent quality can be improved by incorporating plants within biofiltration system (Jennifer *et al.*, 2007).

Biofiltration is among the best management practice technologies (porous pavement, detention/retention ponds, wetlands, partial exfiltration trenches, infiltration trenches, and vegetated swales) that have been developed for urban runoff management (Shutes *et al.*, 1997). Filtration and sorption of runoff through a specially constructed biofiltration system is an effective treatment method. Biofiltration systems improve water quality by assimilating and transforming organic, inorganic, and toxic constituents through processes such as infiltration, sorption, precipitation, and binding by organic colloidal material or adsorption of metal-ligand complexes. For a common biofiltration reactor, the soil layer is covered with a thin mulch layer where the filtration and sorption might mainly occur. Some plants also play important roles in biofiltration systems for the removal of pollutants. They not only take up nutrients, but are also able to adsorp and accumulate metals (Am Jang *et al.*, 2005).

This study focuses on the development of a biofiltration system to treat the oily wastewater from gas station to meet the effluent standards. Effect of addition of activated carbon to the performance of the system is also investigated.

1.2. Problem statement

Stormwater runoff that uptake the effluent waste water from municipal sewage and petrol stations are having high concentration of pollutants. Since biofiltration system is inexpensive and readily available, their utilization for the removal of suspended solid, nitrogen, and phosphorus is gaining attention as a simple, effective, and economical means of wastewater treatment. However, there are still questions to be answered regarding pollutants removal capacity and efficiency for waste water from septic tank and oily wastewater treatment.

The conventional septic systems can contaminate ground water with dissolved solids, nitrate, anoxic constituents (manganese, iron, and hydrogen sulfide), organic compounds, and microorganism. Contaminant concentration can exceed the allowable standards that protect human health and the aesthetic qualities of domestic water.

Later development of septic tank system in Malaysia has adapted a direct effluent discharged into the storm drain. Consequently the effluent may have serious environment problems to surface water. Among the common problems is odor problem and nutrients from the septic tank effluent. This will obviously pollute the stormwater in the drain that finally enters into nearby waterbodies. The waterbodies that are receiving stormwater will have dramatic change in its ecosystem.

Another source of stormwater pollution is oily wastewater from the gas stations. Every gas station should be equipped with an oil trap to separate oil from the oily wastewater and then the effluent will flow into the storm drain. The oil trap is not 100% efficient to remove the oil. Oily wastewater can be classified as toxic wastewater and can cause harm to the living organism in the stormwater such as small fish. Oil is lighter than water so it will form a thin oil film on the surface of the water and may cause reduction of light transmission into the water. Such films also retard oxygen uptake by water and can cause a lower dissolved oxygen concentration and the death of many organisms (Dufus, 1980).

1.3. Objectives

The main objectives of this study are as follows:

1. To determine the feasibility of biologically treating oily wastewater with addition of domestic wastewater using biofiltration method.
2. To examine the efficiency of biofiltration systems for the combined treatment of oily wastewater with domestic wastewater.

1.4. Scope of study

This project will examine the characteristics of the oily and domestic wastewater as the influent for the biofiltration system. The oily wastewater sample was taken from the PETRONAS gas station at Bandar Universiti and the domestic wastewater was taken from the effluent from UTP sewerage treatment plant. The study focuses on the pollutant removal of COD, TOC, TSS, turbidity, ammonia-nitrogen, nitrate-nitrogen, total phosphorus and zinc by the filter media consisting of soil, activated carbon, and sand layers.

CHAPTER 2

LITERATURE REVIEW

2.1. Stormwater Quality

Stormwater runoff is a primary factor in the degradation of many streams and other water bodies. The adverse impacts of this and other sources of pollution include closures of shellfish waters, fish kills, and reduction of aesthetics, which consequently reduces fishing and recreational values of downstream waters (Hunt, 2003). Stormwater runoff may contain many pollutants, including toxic organic oils, suspended solid, surfactants, nutrients and many metals. All impermeable surfaces, including rooftops and parking lots, contribute to the pollution loads found in stormwater runoff.

Many of the pollutants in stormwater runoff can be toxic to plants, aquatic animals, and humans. Nitrogen is particularly toxic to aquatic organisms in its ammonia state (NH_3). Ammonia is regarded as highly toxic to most species of invertebrates and fish when in concentrations of 0.1 to 0.5 mg/L (Hunt, 2003). Additionally, nitrite-nitrogen (which fortunately converts to nitrate or N_2O) causes methemoglobin, which makes oxygen bonds with hemoglobin difficult, in both aquatic species and humans. Nitrates cause little harm to humans but can quickly convert to nitrite once inside the body. If present at high enough levels in infants, methemoglobinemia may develop, which is a documented source of infant mortality. Because of this concern, nitrates in drinking water have a maximum contaminant level of 10 mg/L. Once the NO_3^--N concentration is over 10 mg/L, water is considered unsafe for consumption.

Of all nutrients, nitrogen removal in wastewater and, subsequently, stormwater is considered of utmost importance (Kadlec and Knight, 1996). Nitrogen's principal constituents (ammonia-nitrogen and nitrate-nitrogen) are the cause not only of increased toxicity, but also eutrification of surface waters. Eutrified surface waters have decreased oxygen content, which in turn makes life difficult for aquatic life such as macrophytic plants and animals. Phosphorus is similarly responsible for eutrification and oxygen reduction (Kadlec and Knight, 1996) as excess phosphorus will cause algae blooms.

Zinc toxicity is highly variable among plants and most animals. Zinc limits in drinking water are in great part due to aesthetic reasons. This is also true for iron, which can color drinking water at high concentrations. Iron, in elevated concentrations, can replace toxic metals when sorbed to hydroxide ions, which makes other toxic substances mobile and available for plant or animal intake. Iron is a catalyst that enables other, more toxic, substances to damage aquatic life.

Aluminum is considered moderately toxic to fish and other organisms in surface water. In comparison, nickel is moderately to highly toxic to most aquatic plants such as duckweed (*Lemna minor*). However, nickel does not appear to be toxic to invertebrates and fish. Nickel is believed to be carcinogenic to humans because it was found to be so with tests performed on other mammals; although, there is no current evidence that nickel ingestion from food or water causes cancer in humans (Hunt, 2003).

If left untreated, pollutants found in stormwater runoff, such as nitrogen and phosphorus, can cause severe environmental degradation, especially on aquatic species, or adversely impact human health. Because of these impacts, measures are taken to minimize the problems; these measures are stormwater Best Management Practices (BMPs).

2.2. Oily Wastewater

Oily wastewater is one of the most concerned pollution sources due to its toxic and refractory characteristics. This kind of wastewater originates from a variety of sources such as crude oil production, oil refinery, petrochemical industry, metal processing, compressor condensates, lubricant and cooling agents, floor washing and car washing. The oily wastewater is considered as hazardous industrial wastewater because it contains toxic substances such as phenols, petroleum hydrocarbons, polyaromatic hydrocarbons which are inhibitory to plant and animal growth and also is mutagenic and carcinogenic to human being (Phan Thanh Tri, 2002).

Basically, the oil in the oily wastewater can be classified into three fractions: free oil, oil/water emulsion and soluble components. The oily wastewater is normally accompanied with emulsifier which is used in oil cleaning processes. While the free oil can be removed mostly by gravity oil separator, the other components of the oily wastewater cannot be removed simply by gravity separation.

Physical treatment of oily wastewater such as API gravity separator, dissolved air floatation (DAF), ultrafiltration etc. does not removes the pollutants completely but just transfer them to a more concentrated waste (Sholz and Fuchs, 2000). Therefore, there is a need to develop a more efficient treatment technique to treat oily wastewater to preserve the environment from water pollution.

2.3. Oil Trap/Interceptor

Oil trap/interceptor is a gravity separator, which utilizes the difference in specific gravity to trap hydrocarbons (usually oil and fuel) and to prevent these contaminants being discharged to the stormwater drainage systems.

Oil interceptor is needed because oil in the wastewater when mixed with other material present in sewage, they cause blockages and failure of pumps and can cause overflow in sewer drains. Besides, they also reduce the efficiency of sewage treatment and the quality of effluent being discharged into the environment.

All commercial premises that have wash pads or other open concrete areas which will come into contact with petrol or oil need to provide an oil interceptor. Examples of such premises are petrol stations, car wreckers, car yards, mechanical workshops, and vehicle/other wash facilities.

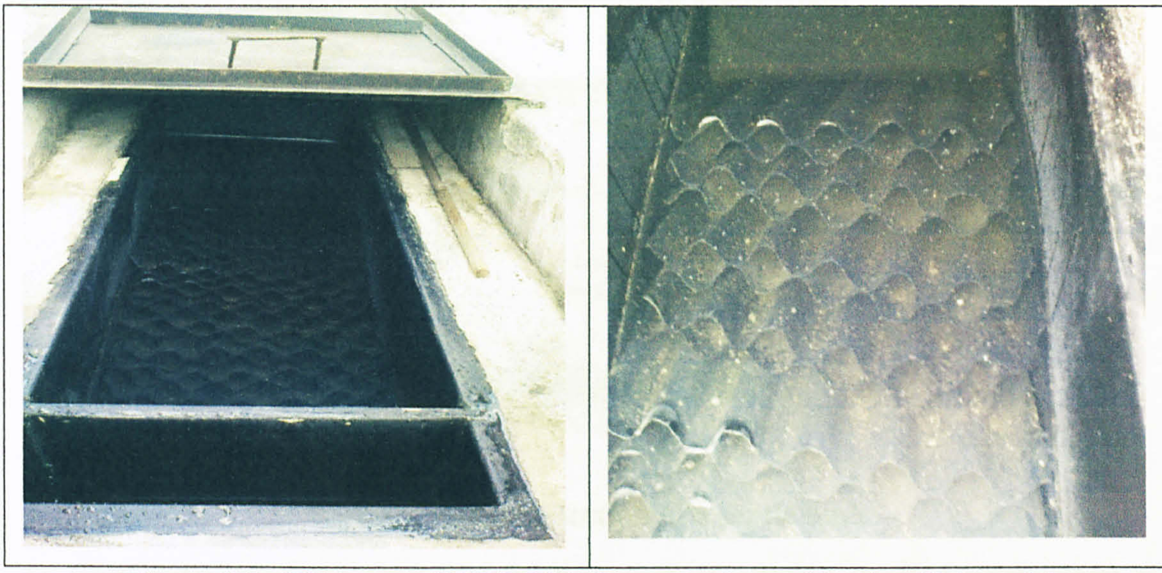


Figure 2.1: Oil trap at PETRONAS gas station at Bandar Universiti

2.4. Septic Tank

The septic tank is an enclosed receptacle designed to collect wastewater, segregate settleable and floatable solids (sludge and scum), accumulate, consolidate and store solids, digest organic matter and discharge treated effluent. Besides its role in standard subsurface soil absorption systems, the pre-treatment provided by septic tank is equally important in ensuring the success of other secondary treatment alternatives such as constructed wetlands, ponds, biofiltration systems, etc.

The septic tank is also a major component in sewer collection alternatives. The reason is simple; the primary-treated effluent discharged from the septic tank is mild, consistent, easy to convey and easily treated by either aerobic or anaerobic secondary processes (Bounds, 1997).

The purpose of a septic tank is to provide a receiving vessel for wastewater generated from a domestic dwelling to afford limited primary treatment. The primary treatment consists of sedimentation and floatation, and an anaerobic digestion. The clear water zone within the tank provide a suitable residency period (at least 24 hours) to allow lumps to disintegrate, settable material to sink, and floatable materials to rise (Patterson, 2003). Figure 2.1 shows a typically cross-section of a septic tank.

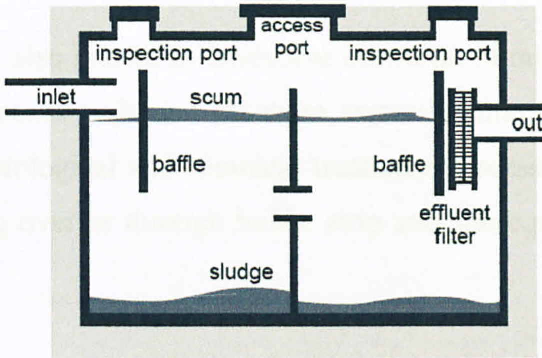


Figure 2.2: Cross-section of a septic tank

As wastewater enter the tank, an equal amount of effluent (treated wastewater) is discharged, usually at a slower rate due to the flow-compensating effect of the clear volume within the tank. The larger the clear volume of the septic tank, the more constant is the discharge quality with respect to TSS and, presumably to the other chemical components of wastewater. It is generally accepted that the quality reflects household behavior in its wastewater generation rate and the typical wastes disposed through the system (Patterson, 2003).

In doing its functions, septic tank does the following three things, remove solids from liquid, provide biological treatment, and stores scum and sludge. The liquid fractions that leave the septic tank and enter the drainage systems are called the effluent. The bacterial level in the effluent is quite high, contrary to popular belief. The effluent also contains nitrates (among other nutrients). Unfortunately, the septic tank is often the most disregarded component in the system. The performance and success of a properly sized tank relies on its structurally-adequate, watertight design and construction.

2.5. Biofiltration System

Biofiltration systems, also known as landscape detention of rain gardens, capture storm water and use engineered soils and plants to remove pollutants from runoff through variety of physical, biological and chemical treatment processes. The runoff's velocity is reduced by passing over or through buffer strip and subsequently distributed evenly along a ponding area.

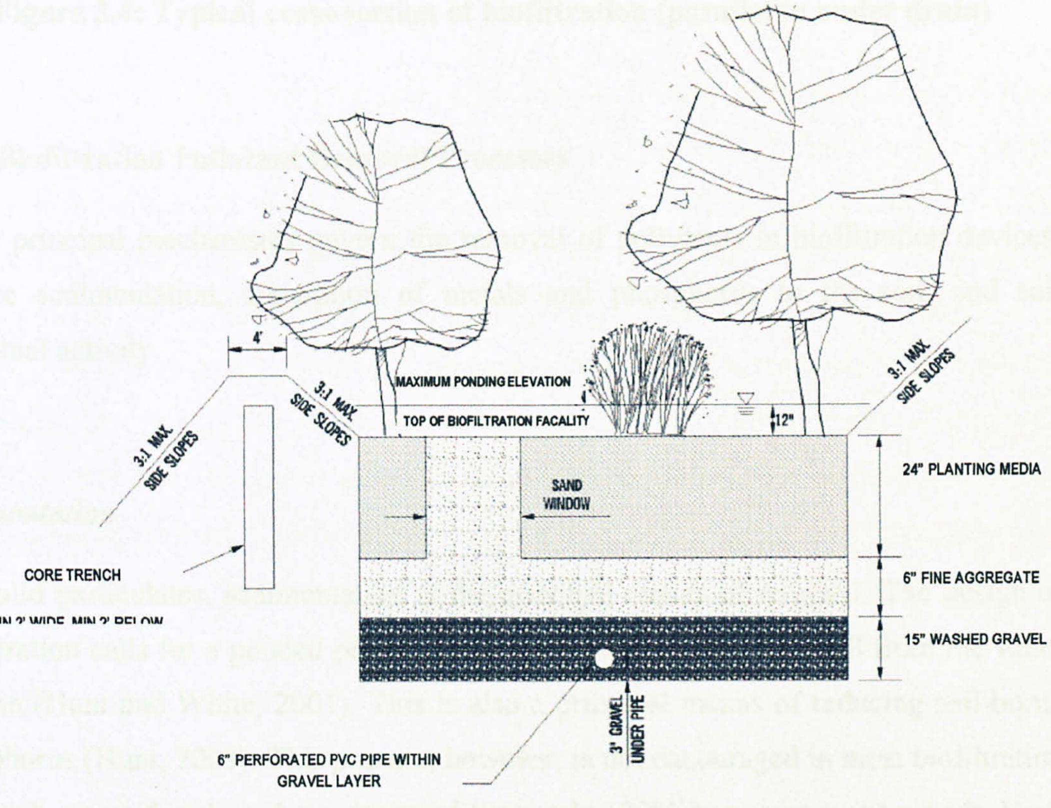


Figure 2.3: Typical cross-section of biofiltration (perpendicular to under drain)

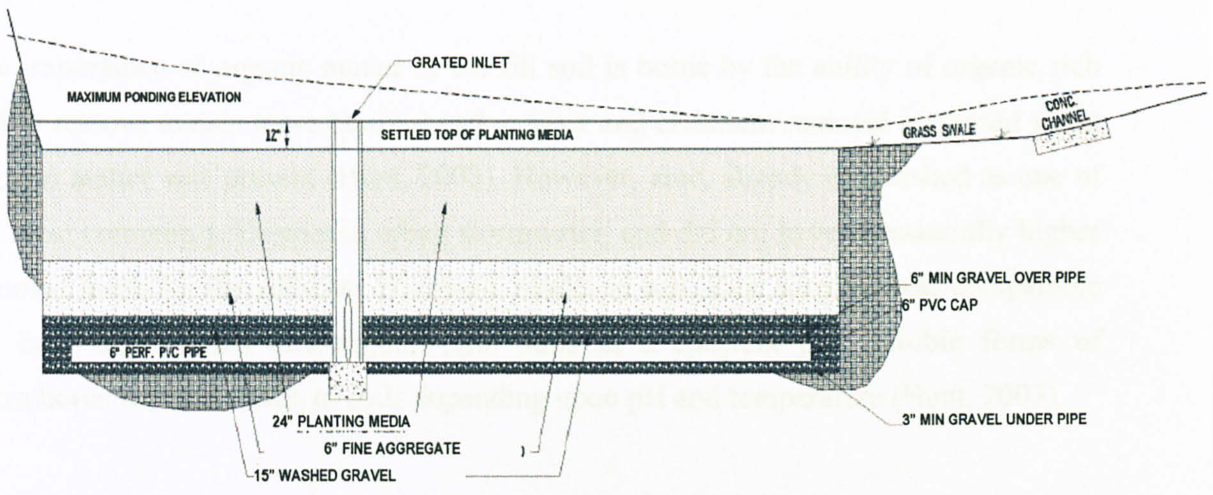


Figure 2.4: Typical cross-section of biofiltration (parallel to under drain)

2.5.1 Biofiltration Pollutant Removal Processes

Three principal mechanisms govern the removal of pollutants in biofiltration devices: surface sedimentation, adsorption of metals and phosphorus to the soil, and soil microbial activity.

Sedimentation

For solid particulates, sedimentation is the principal means of removal. The design of biofiltration calls for a ponded pool of water from which solids will fall from the water column (Hunt and White, 2001). This is also a principal means of reducing soil-borne phosphorus (Hunt, 2003). This process, however, is not encouraged in most biofiltration devices because they have been designed for nearly 100% impervious watersheds. High volumes of total suspended solids (TSS) often lead to the clogging of bioretention system, which is the primary reason why the use of biofiltration devices without a forebay is discouraged in unstable watersheds that have active construction (Hunt, 2003).

Sorption of metals to soils

The importance of organic matter in the fill soil is borne by the ability of organic rich soil to remove metals more easily. Lead, copper and cadmium removal increased when organic matter was present (Hunt, 2003). However, zinc, already established as one of the most common pollutants in urban stormwater, and did not have substantially higher removal levels by the addition of organic matter in soil. Zinc sorption was comparable for both organic-rich and organic-poor soils at a constant pH. Soluble forms of phosphorus will also sorbs to soils depending upon pH and temperature (Hunt, 2003).

Biological activity in soil

Two biological processes for nitrogen conversion occur within the soils of biofiltration areas: ammonification and nitrification. These microbial-led transformations are most apt to occur in aerobic zones of the soil layer (Hunt, 2003). Ammonification is the conversion of organic nitrogen to ammonia-nitrogen by bacteria. This process occurs at a much faster rate in aerobic environments, though, it can occur at a slower rate in anaerobic or anoxic zones. Ammonia-nitrogen is then converted to nitrate-nitrogen via the process of nitrification. Nitrification necessarily occurs in aerobic environments such as the one that exists in a well-drained biofiltration soil. The bacteria nitrosomonas and nitrobacter convert ammonia-nitrogen to nitrite and nitrate-nitrogen, respectively. The conversion from nitrite to nitrate occurs quickly as nitrite is much less stable than nitrate (Hunt, 2003). Typically, this is the end of the nitrogen transformations within a biofiltration area, meaning a net export of nitrate-nitrogen should be expected from biofiltration areas similar to that of sand filters. See Figure 2.4 for a simple illustration. Nitrate-nitrogen is in great part responsible for eutrofication and oxygen reduction of surface waters.

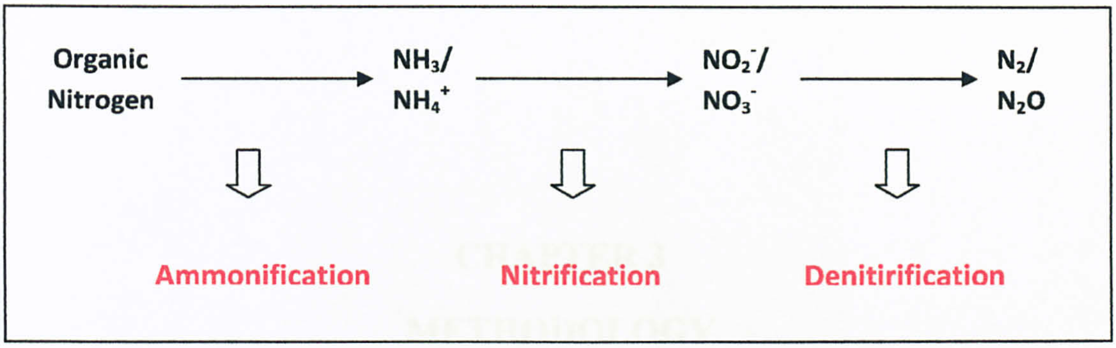


Figure 2.5: Biological transformation of nitrogen

Biofiltration devices typically specify a mulch layer. Common practice in Maryland calls for shredded hardwood mulch while in North Carolina, due to an abundance of pine trees, both shredded hardwood and pine straw mulches are used (Hunt, 2003). The mulch layer acts as a filter for pollutants in runoff, protects underlying soil from drying and eroding, and provides an environment for microorganisms to degrade organic pollutants. It also provides a medium for biological growth, decomposition of organic material, and adsorption and bonding of heavy metals.

Vegetative systems in biofiltration area enhance infiltration and provide a significant evapotranspiration component. Native species provide resistance to moisture change, insects, and disease; and provide uptake of runoff water and pollutants (Iowa Stormwater Management Manual, 2007). In addition, plant uptake of metal also contributes to the retention of dissolved metals at a slower rate.

CHAPTER 3

METHODOLOGY

3.1. Introduction

In this study, biofiltration was used as a method to treat a combination of oily wastewater from the gas station and effluent form wastewater treatment plant. The biofiltration column was used to represent the system. The details on the methodology used for this research are as follows:

3.2. Feed Wastewater

In this study, oily wastewater and domestic wastewater were used as the feed wastewater. The oily wastewater was taken from the influent of oil trap at the gas station. For the domestic wastewater, the sample was collected from the effluent from UTP sludge treatment plant. Both wastewaters were analyzed to determine their characteristics in term of total organic carbon (TOC), chemical oxygen demand (COD), total suspended solid (TSS), turbidity, nutrients content (ammonia-nitrogen, nitrate-nitrogen, and phosphorus) and zinc prior to mixing.

Figure 3.1: Sample collection at PETRONAS Gas Station at Bandar Universiti

3.3. Biofiltration system set-up

Laboratory scale of biofiltration systems was used in this study. A PVC column was used to represent the laboratory scale of the biofiltration system. The media used in the system include sand for the bottom layer, activated carbon, and soil for the top layer.

3.3.1. Overview of research plan

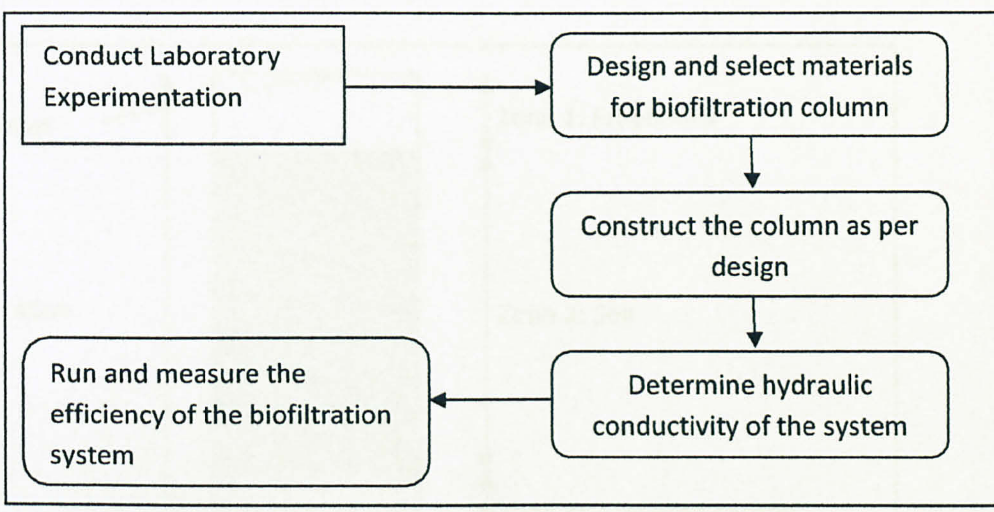


Figure 3.2: Research Methodology Flow Chart

3.3.2. Biofiltration fabrication

Biofiltration columns were designed and materials were selected during the first phase of the research. Then the columns were constructed as per design using the chosen materials. Once fabricated, the wastewater sample was allowed to flow through each column. Then, the effluent sample from the column was analyzed in term of TOC, COD, TSS, turbidity, nutrients contents and zinc. The results were then compared to the influent sample to measure the efficiency (percentage of pollutant removal) of the biofiltration system.

Designing and Material selection for Biofiltration Column

The principal objective of this part of the research was to design the column details. PVC pipe of 12 cm diameter was used as the biofilter column. A large pipe diameter was preferred because it minimized the edge effects often associated with smaller diameter pipes. The column was designed so that it would simulate a plug, or 12 cm diameter core, of a biofiltration area. Total pipe length used was approximately 45 cm. The column design is shown in Figure 3.3.

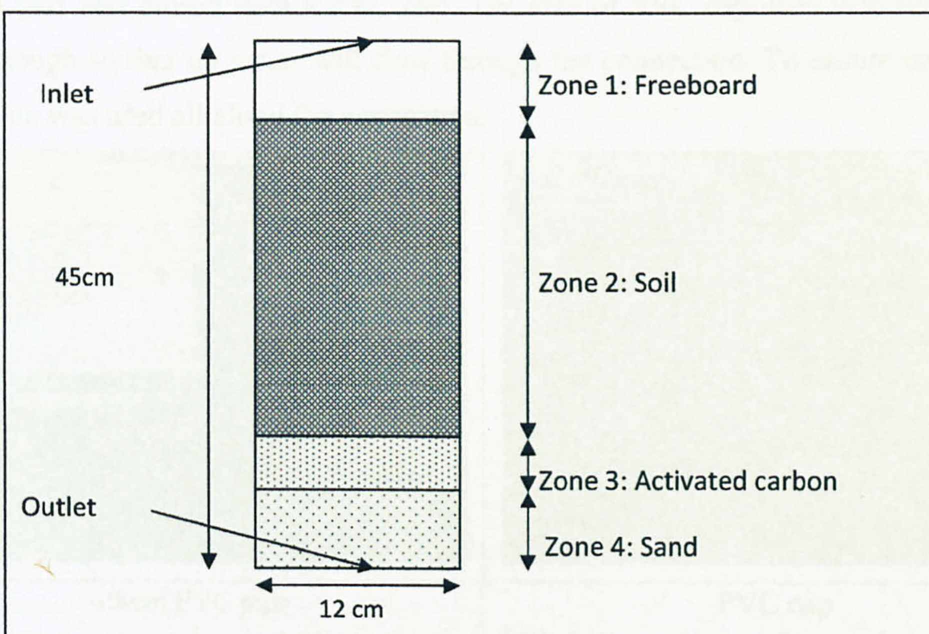


Figure 3.3: Column Design

Constructing Biofiltration Column

This step involved three principal actions:

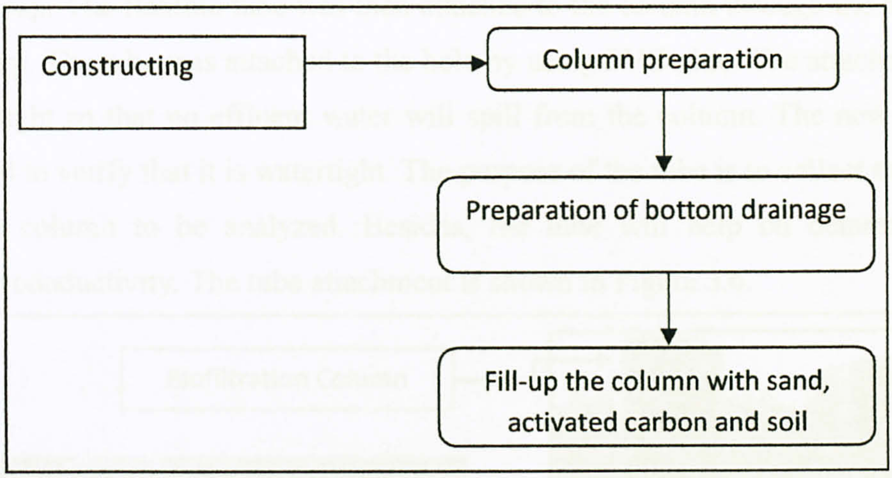


Figure 3.4: Construction of Biofiltration Column flow chart

<u>Column Preparation</u>

The pipe used was 12-cm diameter PVC pipe. The pipes were firstly washed to remove dirt and contaminants. Each column is nominally 45-cm long, but not exactly. The bottom part was closed with a PVC cap. The size of PVC cap used was suitable and tight enough so that no water will flow through the connection. To ensure no leakage, PVC glue was used all along the connection.

40-cm PVC pipe	PVC cap

Figure 3.5: PVC pipe and PVC cap

Preparation of bottom drainage

A flexible tubing was connected to the bottom of the column. A hole was drilled into the PVC cap. The flexible tube was then attached to the column through the hole at the bottom cap. The tube was attached to the hole by using PVC glue. The attachment must be watertight so that no effluent water will spill from the column. The new assembly was tested to verify that it is watertight. The purpose of the tube is to collect the effluent from the column to be analyzed. Besides, the tube will help on determining the hydraulic conductivity. The tube attachment is shown in Figure 3.6.

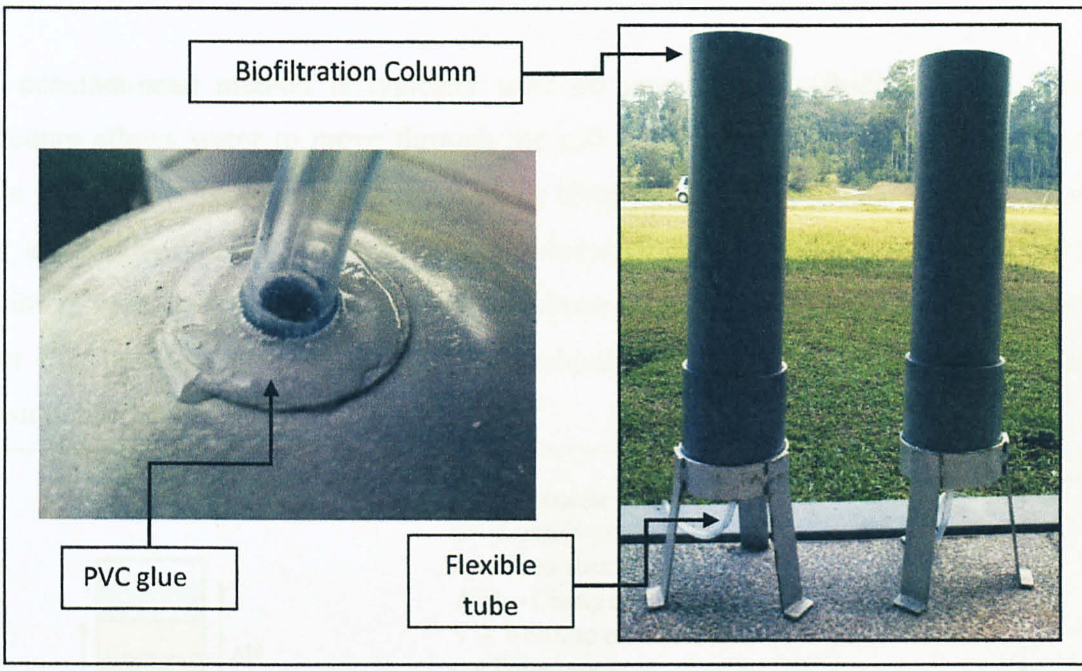


Figure 3.6: Column Design with flexible tube

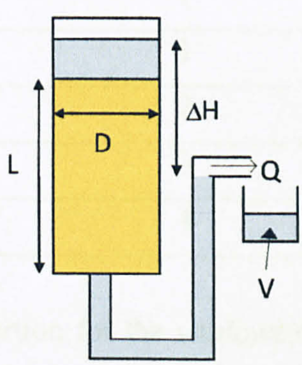
Packing the columns with sand, activated carbon and soil

The column was firstly fill with sand, then with activated carbon and lastly with soil. The column was filled in roughly 35 cm, by gently tamping to minimize differential settling. Because of the weight associated with each of the columns and the corresponding difficulty transporting them, the columns were filled near the location of the experiments.

Hydraulic Conductivity Determination

Before conducting the experiment, hydraulic conductivity of the filter was determined. Hydraulic conductivity describes the ability of the soil to let the water to flow through it. Hydraulic conductivity should not be too low or too high. The design standard for hydraulic conductivity of the soil mixture for the biofiltration system ranges from 0.0035 to 0.042 mm/sec (Hunt, 2003). If the value is too low, water will overflow from the system but if the value is too high, pollutant removal rate will be lower. Constant-head method was selected to determine the hydraulic conductivity.

The constant-head method is typically used on granular soil (Budhu, 2007). This procedure allows water to move through the soil under a steady state head condition while the quantity (volume) of water flowing through the soil specimen was measured over a period of time. By knowing the volume, V of water measured, length L of specimen, cross-sectional area A of the specimen, time t required for the quantity of water V to be discharged, and head ΔH, the hydraulic conductivity was calculated as shown in Figure 3.6 below:



D – Diameter (mm)
L – Length (mm)
A – Area (mm^2)
Δ H – Change in head (mm)
V – Volume of water (mm^3)
t – Time (sec)
Q – Flow rate (mm^3/sec)

Hydraulic conductivity:

$$K = \frac{QL}{A\Delta H}$$

Figure 3.7: Hydraulic conductivity determination

Once the columns were constructed, they were kept dry until the time to run the constant head test. The columns were filled with water from the top until saturated. Then the level of water was maintained throughout the process to ensure the head was constant. The level of flexible tube also was maintained as in Figure 3.6. then all the parameter required were determined. The flow rate was measured by collecting water from the flexible tube to a certain volume in the given time.

Wastewater Treatment by Biofiltration System

When all the preparations were done, the treatment of oily wastewater with addition of domestic wastewater was conducted. Four columns of biofilter were constructed. The method of testing was by batch experiment. All the columns were filled with wastewater until saturated in the same day. Then the effluents were collected in different day from different columns. The summary of sample collection day is shown in Table 3.1 below:

Table 3.1: Summary of sample collection day

Column number	Retention time
1	0 (immediate drainage)
1	2 days
2	4 days
3	7 days
4	10 days

The portion for the wastewater was one volume of oily wastewater to one volume of domestic wastewater [1:1].

3.4. Laboratory Analysis

Series of laboratory tests were conducted to analyze the characteristics of the feed wastewater and effluent from the biofiltration system. The laboratory tests were also conducted to investigate the biodegradation of oily wastewater and the efficiency of the biofiltration system in treating oily wastewater. The laboratory analyses were conducted to determine the quality of the effluent are as follows:

3.4.1. Chemical Oxygen Demand (COD)

Chemical oxygen demand, COD is used to characterize the organic strength of wastewater and pollution of natural water. It is the amount of oxygen required to oxidize an organic compound. The mg/L COD results are defined as the mg of O_2 consumed per liter of sample under conditions of this procedure.

The determination of COD content is performed by using HACH Method 8000. For determine the parameter of Total Chemical Oxygen Demand (TCOD), 2ml of wastewater sample will measured using micropipette and poured into a vial that containing potassium dichromate. The vial is then inverted gently for several times. The steps are repeated for samples of influent and effluent for each reactor of treatments. All samples are taken three times each, and then all vials together with a blank as an indicator are then placed inside the COD reactors, for two hours. After two hours, the vials will let it cold down in room temperature reading are taken using Spectrophotometer, and an average value will be calculated and recorded.

3.4.2. Total Organic Carbon (TOC)

Total organic carbon (TOC) is the amount of carbon bound in an organic compound. A typical analysis for TOC measures both the total carbon (TC) present as well as the total inorganic carbon (TIC). Subtracting the inorganic carbon from the total carbon yields TOC. To analyze TOC, 1020A TOC Analyzer is used.When carbon compounds are combusted in an oxygen-rich environment, the complete conversion of carbon to carbon dioxide (CO2) results. TC is determined when the nondispersive infrared (NDIR) detector detects the resulting CO_2. TIC is determined by measuring the CO_2 released following sample acidification. As the sample pH is lowered, carbonate and bicarbonate ions are converted to dissolved CO_2, which is purged from solution and swept into an NDIR. The NDIR is calibrated to display the mass of CO_2 detected. TOC is determined by performing separate TC and TIC analyses and subtracting the results.

3.4.3. Total Suspended Solid (TSS)

The total solids content of a wastewater is defined as all the matter that remains as residue upon evaporation at 103°C to 105°C. Matter that has a significant vapor pressure at this temperature is lost during evaporation, and is not defined as a solid. Total solids, or residue upon evaporation, can be classified as either suspended solids or filterable solids by passing a known volume of liquid through a filter. The filter is commonly chosen so that the minimum diameter of the suspended solids is about 1 micron.

To determine TSS, the samples are filtered with a 47 mm diameter glass-fiber filter disk. The filter disc is placed in the filter holder with the wrinkled surface upwards. Tweezers is used to handle filter disc in order to avoid adding moisture content from fingers that will caused weighing error. Certain amount of well mixed wastewater sample is filtered by applying vacuum to flask, and followed by washings with distilled water to ensure that all the solids have been filtered. The vacuum is released from the filtering system and the filter disc is gently removed. The disc then is placed on the watch glass. The filtrate is inspected to ensure that proper trapping of solids is accomplished on the disc.

Then the filter disc and watch glass are placed in drying oven 103 °C for half an hour. The filter disc and watch glass are removed from the oven and placed in incubator. Finally, the discs are carefully removed from the incubator and weighted using an analytical balance.

3.4.4. Nutrients contents

Nutrients contents consider for this research are phosphorus, ammonia and nitrate. To determine the total phosphorus, 0.5mL of sample is added to a Total and Acid Hydrolyzable Test Vial. The test vial is then added with one Potassium Persulfate Powder Pillow for Phosphonate. The vial is cap tightly and shakes to make sure the powder well dissolved in the sample. Then, the vial is inserted into the DRB200 Reactor which has been set into 150°C for 30 minutes. After 30 minutes, the vial is removed from the reactor and to cool to room temperature. Next, the vial is added with 2 mL of 1.54 N Sodium Hydroxide Standard Solution and well shake. The vial is inserted into cell holder and the reading is set to zero. Then one PhosVer 3 Powder Pillow is added into the vial and the vial is cap and well shakes. Finally, the vial is inserted into the cell holder and the reading will be recorded. The result is in mg/L PO_4^{3-}.

The ammonia content is determined by mixing the sample with Mineral Stabilizer, Polyvinyl Alcohol Dispersing Agent and Nesseler Reagent. Each reagent is added one by one and then inverted to mix. Next, the mix is pour into square sample cell and the cell is inserted into the cell holder to get the reading of ammonia content in the wastewater sample. The result is in mg/L NH_3-N.

The determination of nitrate content is simple than previous methods. 10Ml of sample is filled into a square cell. Then the sample is added with one NitraVer 5 Nitrate Reagent Powder Pillow and the stopper is inserted to shake the mix to make sure the entire powder pillow well mixed with the sample. Then the cell is put into the cell holder to get the reading of nitrate content in the sample. The result is in mg/L NO_3^--N.

CHAPTER 4

RESULTS AND DISCUSSION

4. Results and Discussion

In this chapter, all results of soil testing and water quality analysis are presented. The results are as follows:

4.1. Soil analysis

4.2.1. Particle Size Distribution

In this project, sand and soil were used as the filter media for the biofiltration system. Dry sieving was done to investigate the particle distribution of sand and soil. The particle size distributions for both media are shown in Figure 4.1 and Figure 4.2.

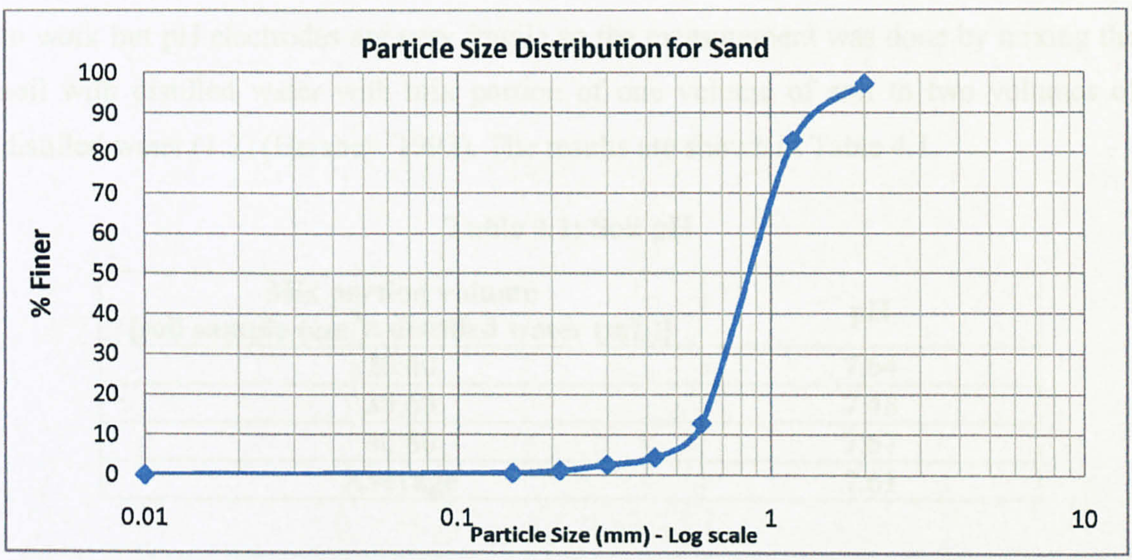


Figure 4.1: Particle Size Distribution for Sand

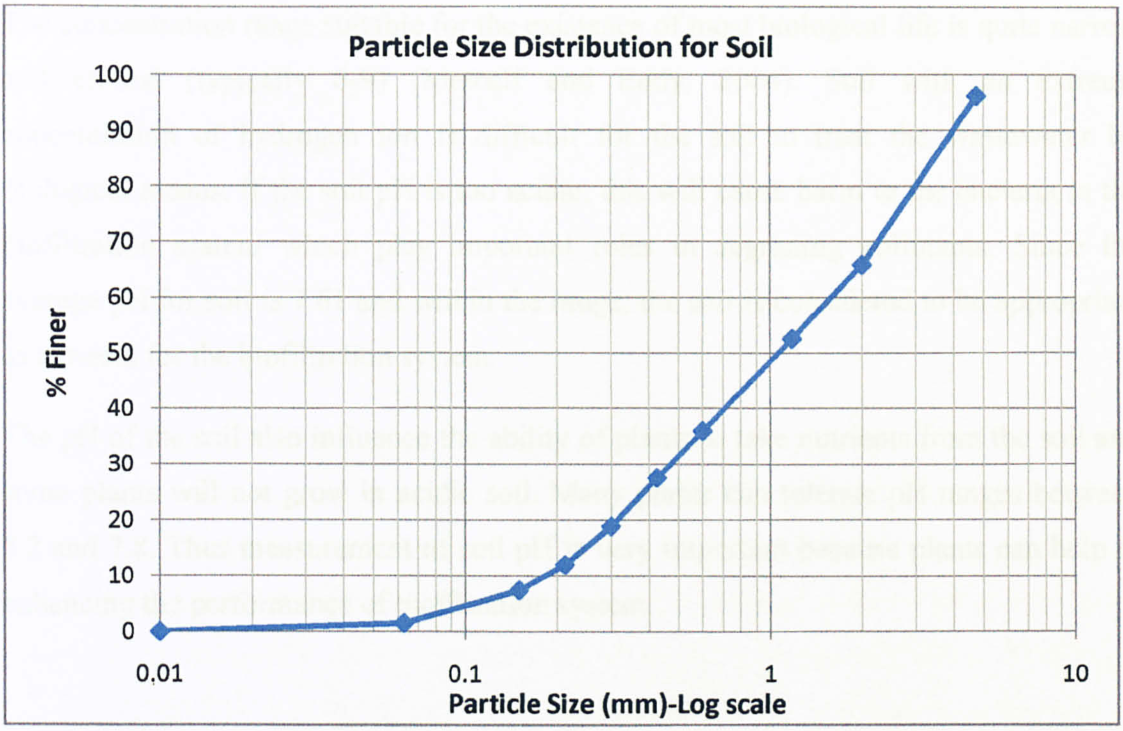


Figure 4.2: Particle Size Distribution for Soil

4.2.2. Soil pH

The measurement of soil pH was conducted to ensure optimum biological process within the soil can occur. The soil was dry, and the pH electrode needs to be immersed to work but pH electrodes are very fragile so the measurement was done by mixing the soil with distilled water with mix portion of one volume of soil to two volumes of distilled water (1:2) (Hershey, 1992). The results are shown in Table 4.1.

Table 4.1: Soil pH

Mix portion volume [soil sample (cm^3): distilled water (mL)]	pH
20:40	7.64
30:60	7.48
40:80	7.67
Average	**7.61**

The concentration range suitable for the existence of most biological life is quite narrow and critical (typically 6-9) (Metcalf and Eddy, 2004). Soil with an extreme concentration of hydrogen ion is difficult for the soil to treat the wastewater by biological means. If the soil pH is too acidic, this will cause harm to the bacteria in the biofiltration system which play important roles in degrading pollutants. Since the average pH for soil is 7.61 and within the range, the soil is considered to be appropriate as a media for the biofiltration system.

The pH of the soil also influence the ability of plants to take nutrients from the soil and some plants will not grow in acidic soil. Many plants can tolerate pH ranges between 5.2 and 7.8. Thus measurement of soil pH is very important because plants can help in enhancing the performance of biofiltration system.

4.2.3. Hydraulic Conductivity

The inputs for the constant head permeability test are presented in Table 4.2 and the details of the results are shown in table 4.2 and table 4.3.

Table 4.2: Parameters for hydraulic conductivity, *K* calculation

Parameter	Approximate value
Diameter, D (mm)	120
Area, A (mm^2)	11311.20
Change in Head, ΔH (mm)	260
Length, L (mm)	360

From Darcy's Law, hydraulic conductivity:

$$K = \frac{QL}{A \Delta H}$$

Table 4.3: Hydaulic Conductivity, *K*

Column	Volume, *V* (mm^3)	Time, *t* (s)	Flow Rate, *Q* (mm^3/s)	Hydraulic conductivity, *k* (mm/s)
1	142,000	960	147.92	0.0181
2	135,000	960	140.63	0.0172
3	138,000	960	143.75	0.0176
4	140,000	960	145.83	0.0179
			Average	**0.0177**

The hydraulic conductivity depends on the soil type, particle size and pore size. From Table 4.3, the average hydraulic conductivity for the filter media used is 0.0177 mm/sec (63.72 mm/hr).The test for all four columns showed that the hydraulic conductivity of the filter media in each column was more than the minimum requirement of the hydraulic conductivity for bioretention/biofiltration system of 0.0035mm/sec (Hunt, 2003).

4.2. Wastewater Quality Analysis

For this part, the effluent quality were compared with the influent quality to measure the pollutant removal efficiency.

4.2.1. Chemical Oxygen Demand (COD)

Chemical oxygen demands (COD) of the influent and effluent wastewater were determined and the results are as in Table 4.4 below. The COD values for effluent wastewater were varies with the retention time.

Table 4.4: Chemical Oxygen Demand (COD)

Chemical Oxygen Demand, COD (mg/L COD)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
681.67	30.33	356.00	52.67	75.00	96.00	74.67	34.00

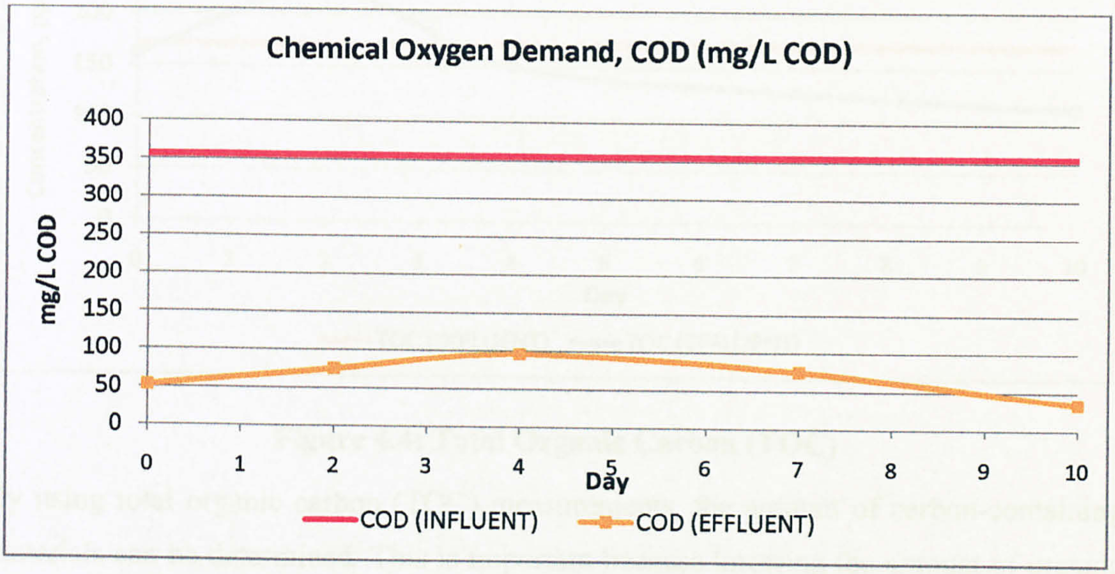


Figure 4.3: Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate acid solution. As shown in Figure 4.3, the effluent COD was lower than the influent. But the reductions were varies with the days of sampling. After 4 days until 10 days, the COD values were decreasing. The percentage removal of COD is 90.45% after ten days.

4.2.2. Total Organic Carbon (TOC)

The total organic carbons (TOC) of influent and effluent wastewater were tested and the results were analyzed as shown in Table 4.5 and Figure 4.4 below.

Table 4.5: Total Organic Carbon (TOC)

Total Organic Carbon, TOC (ppm)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
306.14	36.40	171.27	161.95	224.27	150.61	126.66	111.10

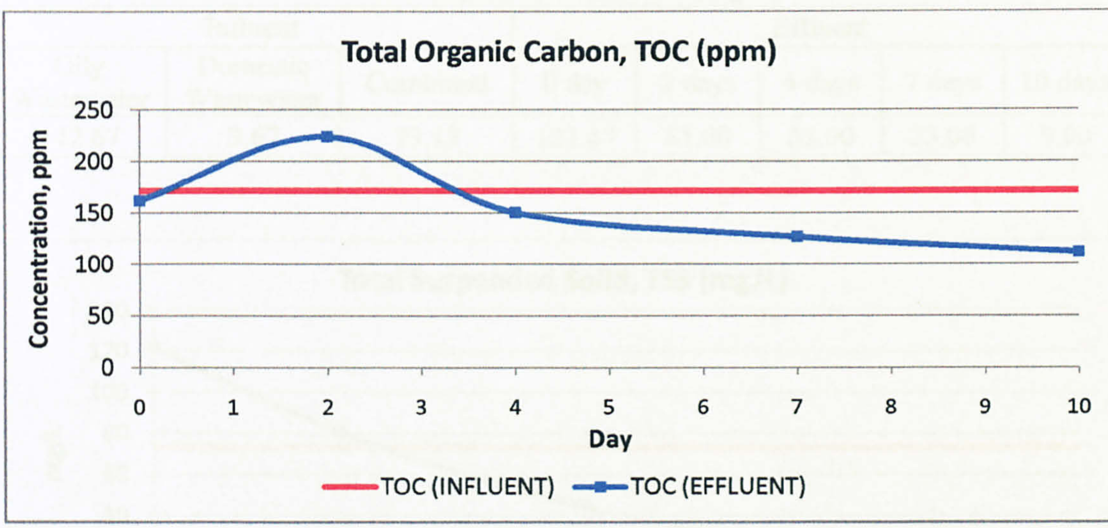


Figure 4.4: Total Organic Carbon (TOC)

By using total organic carbon (TOC) measurements, the amount of carbon-containing materials can be determined. This is important because knowing the amount of organic carbon in a wastewater or stormwater runoff is an indicator of the organic character of the water. The high carbon or organic content may indicate more oxygen is required for degradation and unfavorable conditions for aquatic life, such as the depletion of oxygen and the presence of toxic substances.

From figure 4.4 it can be observed that when the effluent was collected immediately after feeding, there was small reduction of TOC. This may due to the absorption by the filter media. But when the effluent was collected after 2 days, the TOC was higher than the influent. This increased may due to leaching from the soil itself. Then the TOC kept on decreasing after 4, 7 and 10 days. This indicates there were reductions of TOC and the removal is 35.13% after ten days.

4.2.3. Total Suspended Solid (TSS)

Details results of total suspended solid (TSS) for the influent and effluent wastewaters are shown in Table 4.6 and Figure 4.5 below.

Table 4.6: Total Suspended Solid (TSS)

Total Suspended Solid, TSS (mg/L)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
142.67	3.67	73.17	121.67	81.00	52.00	23.00	9.00

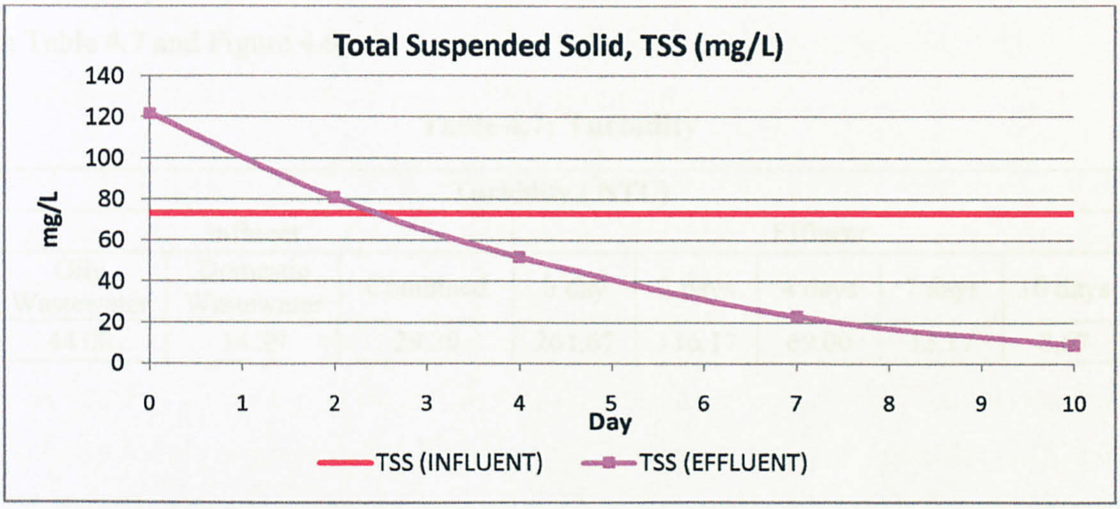


Figure 4.5: Total Suspended Solid (TSS)

Sedimentation and filtration are primary mechanisms for removing total suspended solids (TSS). Sedimentation occurs because water slows down once it enters the biofiltration system. Faster-moving water has more energy and is, therefore, able to carry sediment, trash, and other debris. Once the water slows down inside the biofiltration system, it loses its ability to carry these pollutants; thus, suspended particles tend to settle to the bottom of biofiltration sytem. Because the inflow water must pass through the various layers of filter media, some pollutants can be trap by the filter media. This process called filtration.

From Figure 4.3, shows that effluent TSS value was much higher than the influent TSS when the effluent were collected immediately after feeding and after 2 days of retention. This is because most of the particle from the soil in the biofiltration system was washed out with the effluent. After 2 days, the TSS values were decreasing from 81 to 9 mg/L TSS after ten days. The percentage of TSS removal is 87.69% after ten days.

4.2.4. Turbidity

Besides TSS, turbidity is also an important parameter to identify the wastewater quality. The turbidity of influent and effluent wastewater were determined and the results are as in Table 4.7 and Figure 4.6.

Table 4.7: Turbidity

Turbidity,(NTU)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
44.00	14.39	29.20	261.67	116.17	69.00	13.17	8.67

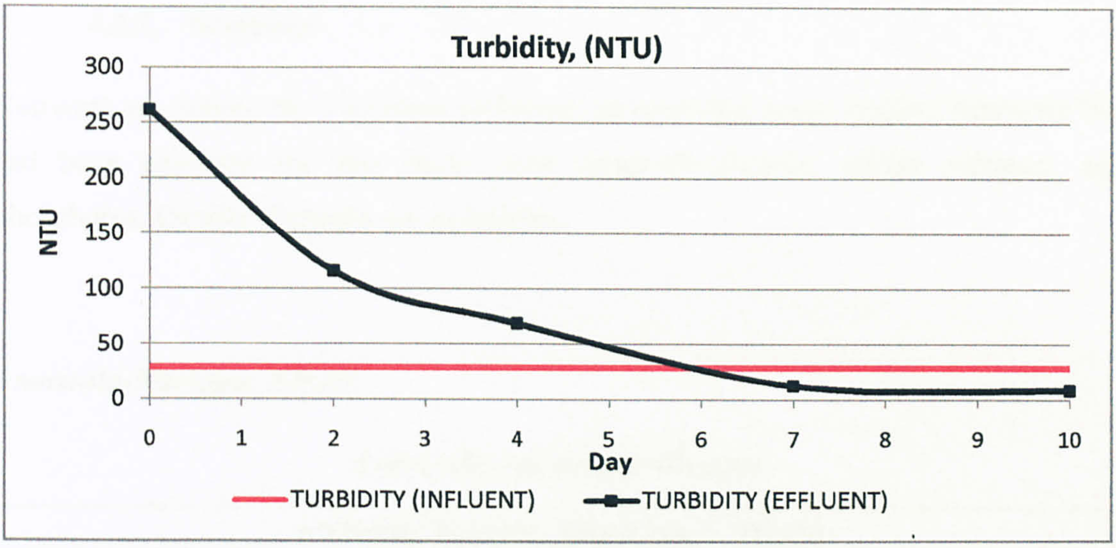


Figure 4.6: Turbidity

Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water. Turbidity is closely related to total suspended solids (TSS), but also includes plankton and other organisms. Same with TSS, turbidity also was removed during sedimentation and filtration process.

From Figure 4.4, the turbidity of effluents collected directly after feeding, after 2 days and 4 days were higher than the influent. This is because some of the particle from the filter media such as clay and silt were washed out with the wastewater during the initial stage. The removal of turbidity after ten 10 days is 70.30%. The influent turbidity was quite low but biofiltration system increases the turbidity and required longer retention time to reduce the turbidity. This indicates that biofiltration system is not very effective in removing turbidity in short time. To overcome this problem, further study is required regarding the designing suitable filter media for the biofiltration system.

4.2.5. Nutrients

Nutrients are among the important pollutants in receiving water bodies. Nutrients that had been analyzed for this study were ammonia-nitrogen, nitrate nitrogen, and phosphorus. Details of results are as follows:

Ammonia-Nitrogen, NH_3-N

Table 4.8: Ammonia-Nitrogen

Ammonia-Nitrogen, NH_3-N (mg/L NH_3-N)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
1.80	14.40	8.10	4.45	4.20	1.85	2.85	2.35

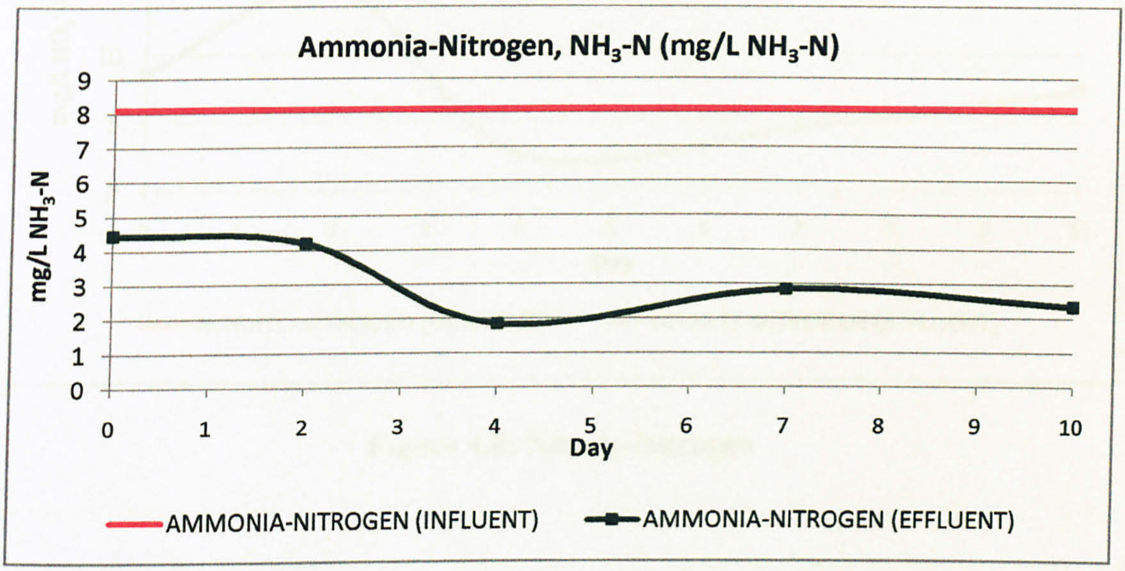


Figure 4.7: Ammonia-Nitrogen

Nitrate-Nitrogen, NO_3^-N

Table 4.9: Nitrate-Nitrogen

Nitrate-Nitrogen, NO_3^--N (mg/L NO_3^--N)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
16.75	18.75	17.75	8.75	15.00	2.50	4.50	7.35

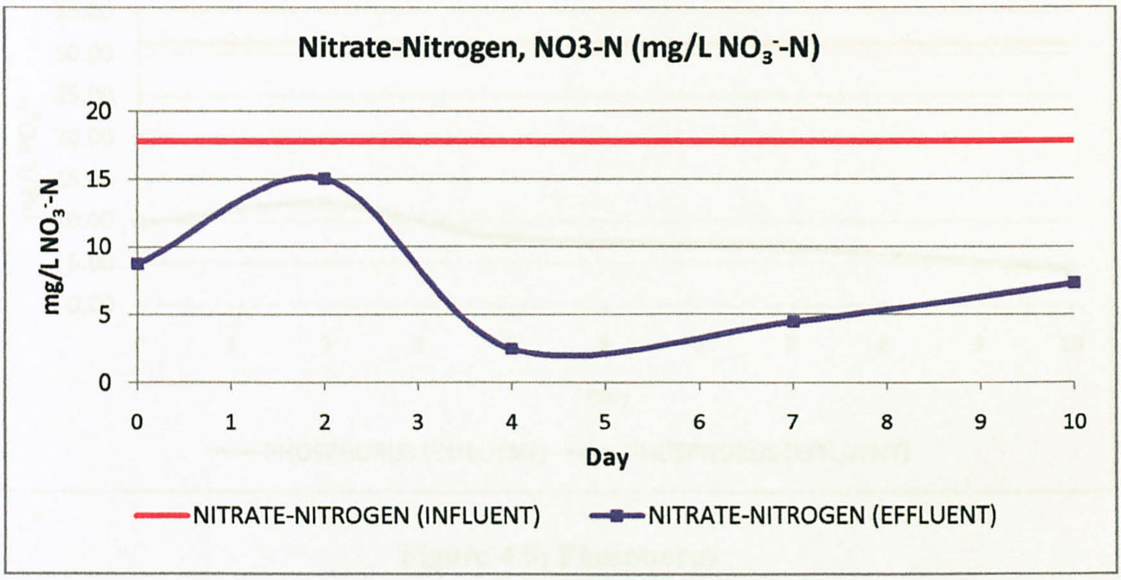


Figure 4.8: Nitrate-Nitrogen

Phosphorus

Table 4.10: Phosphorus

Phosphorus, (mg/L PO_4^{3-})							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
37.88	24.60	31.24	9.78	12.08	8.03	6.88	4.25

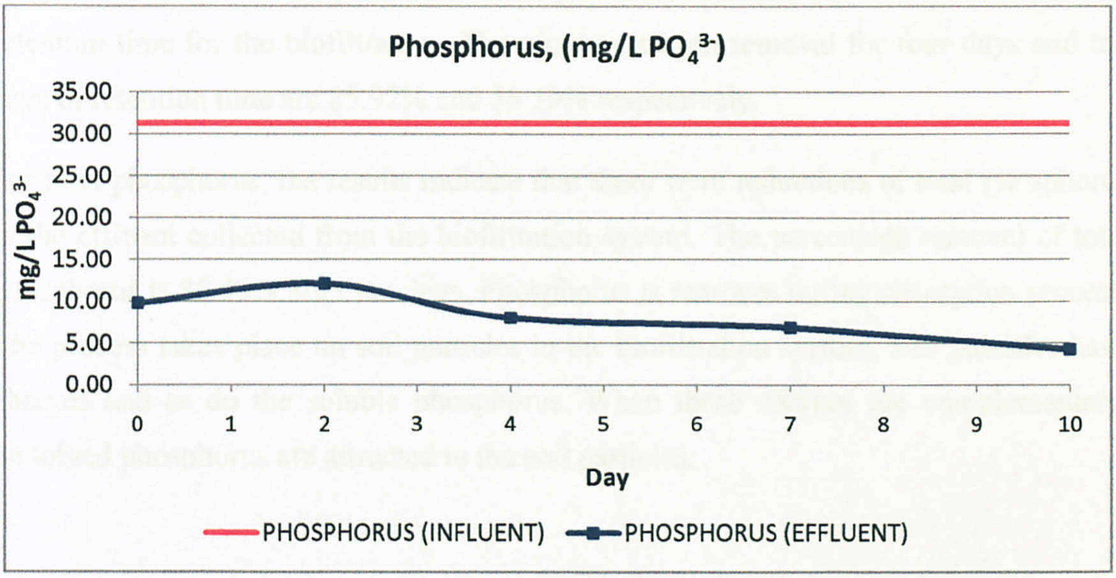


Figure 4.9: Phosphorus

Nutrients like nitrogen and phosphorus are nutrients that have most impact to the environment due to eutrophication. Eutrophication can result results in an overgrowth of algae, weeds, and other aquatic plants and lead to reduction of dissolved oxygen in the water bodies.

Figure 4.7, showed that there were reductions of ammonia-nitrogen during the treatment using biofiltration system. Ammonia-nitrogen were decreasing probably due to nitrogen conversion occurred during the treatment. Ammonia-nitrogen was converted to nitrate nitrogen by nitrification process was indicated by increases in nitrate detected in the effluent. The effluent collected immediately after feeding was lower than 2 days of retention time maybe because of absorption of pollutants to the soil media. The removal of ammonia-nitrogen is 70.99% after ten days.

From figure 4.8, the graph showed that removal of nitrate-nitrogen was not very good as the others. The possibility that increased retention time would increase the amount of nitrate-nitrogen removal does not appear in the graph. It is likely that there were nitrification and denitrification occurred in the biofiltration system. Increased amount of nitrate-nitrogen because of nitrification process and decrease amount of nitrate-nitrogen because of denitrification process. Four day of retention time seem to be the optimum retention time for the biofiltration. The nitrate-nitrogen removal for four days and ten days of retention time are 85.92% and 58.59% respectively.

For total phosphorus, the results indicate that there were reductions of total phosphorus in the effluent collected from the biofiltration system. The percentage removal of total phosphorus is 86.40% after ten days. Phosphorus is removes during absorption process. The process takes place on soil particles in the biofiltration system. Soil particles have charges and as do the soluble phosphorus. When these charges are complementary, dissolved phosphorus are attracted to the soil particles.

4.2.6. Zinc (Zn)

Zinc also had been analyzed in this study. The results of zinc removal are shown in Table 4.11 and Figure 4.10.

Table 4.11: Zinc

Zinc, Zn (mg/L Zn)							
Influent			Effluent				
Oily Wastewater	Domestic Wastewater	Combined	0 day	2 days	4 days	7 days	10 days
0.35	0.25	0.30	0.25	0.35	0.20	Below detection limit	Below detection limit

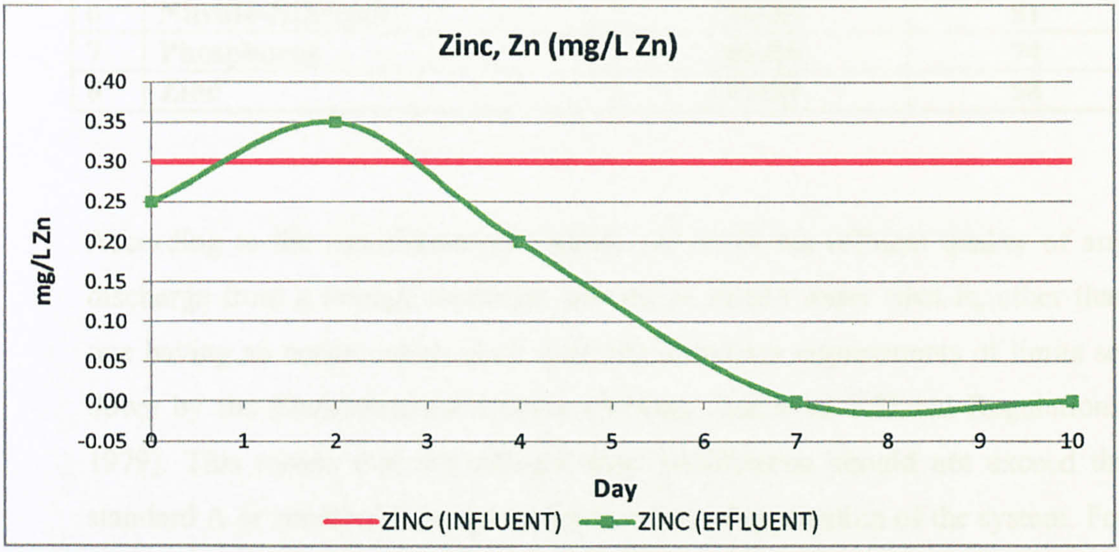


Figure 4.10: Zinc

Like phosphorus, zinc also removed during adsorption process. The dissolved zinc with positive charges were attracted to the particle in the soil that having opposite charges. The values of zinc kept on reducing after 2 days of retention time. After 7 and 10 days, zinc in the effluents were very low and below the detection limit. This shows that biofiltration system also can remove metal like zinc.

4.3.Discussion

Below are summary of percentages removal of pollutants by biofiltration method. The calculation show that all the pollutants can be removed up to 50% except for TOC.

Table 12: Summary of Pollutants Removal

No	Parameter	Percentage Removal (%)	Average Removal (%)
1	COD	73-90	82
2	TOC	5-35	20
3	TSS	29-88	59
4	Turbidity	55-70	63
5	Ammonia-Nitrogen	45-77	61
6	Nitrate-Nitrogen	16-86	51
7	Phosphorus	61-86	74
8	Zinc	17-99	58

According to the Environmental Quality Act 1974 the effluent quality of any discharge from a sewage treatment process to inland water (that is, other than one having an ocean outlet) shall meet the minimum requirements of limits set down by the Environmental Quality (Sewage Industrial Effluent Regulations, 1979). This means that the effluent from biofiltration should not exceed the standard A or standard B based on the location of application of the system. For the Interim National Quality Water Standard (INQWS), this standard only applicable for the receiving water bodies. According to standard A and B, only limits for COD, TSS and zinc are available for this study. From the results, COD was below the Standard B limit and only meet the Standard A limit after 10 days of retention time. For TSS, after 2 days and above of retention time, the results were below standard B limit and below standard A limit after 7 and 10 days of retention time. For zinc, the values were too low and below both standard A and B. As a conclusion, the effluents from biofiltration system were below standard B limits.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

As the name suggest, biofiltration system is one of biological treatment method in removing pollutants from wastewater.

According to Metcalf and Eddy (2004)

The overall objectives of the biological treatment of wastewater are to

1. Transformed (oxidize) dissolved and particulate biodegradable constituents into acceptable end products.
2. Capture and remove suspended and nonsettleable colloidal solids
3. Transform and remove nutrients such as nitrogen phosphorus

Results from the studies showed that all the three objectives mention above were achieved by the biofiltration system method. For the first objective, the measurements used were COD and TOC. The average percentage removal of COD and TOC are 82% and 20% respectively.

For the second objective, the measurements used were TSS and turbidity. The results showed reduction of TSS and turbidiy were decreaing when retention times were increase. The average percentage removal for TSS and tubidity are 59% and 63% respectively.

To ensure third objective is achieved, the amount of ammonia-nitrogen, nitrate-nitrogen and phosphorus in the influent and effluent wastewater were analyzed. Results showed that there were biological processes occurred in the biofiltration system because there were reduction of nutrients content in the effluent collected compared to influent wastewater. The average percentage removal of ammonia-nitrogen, nitrate-nitrogen, and phosphorus are 61%, 51% and 74% respectively.

As a conclusion, biofiltration system has a potential for treating oily wastewater and domestic wastewater. The pollutants removal are >50% except for TOC.

5.2. RECOMMENDATION

In improving the performance of biofiltration system, further studies are required to:

1. Understand in deep about the biofiltration system and pollutants removal process in it.
2. Determine the most efficient design configuration for both laboratory scale and real field application.
3. Determine the most suitable filter media for the system and affect of introducing plants into the system.
4. Determine the performance of biofiltration system in long term for pollutants removal and clogging mechanism.

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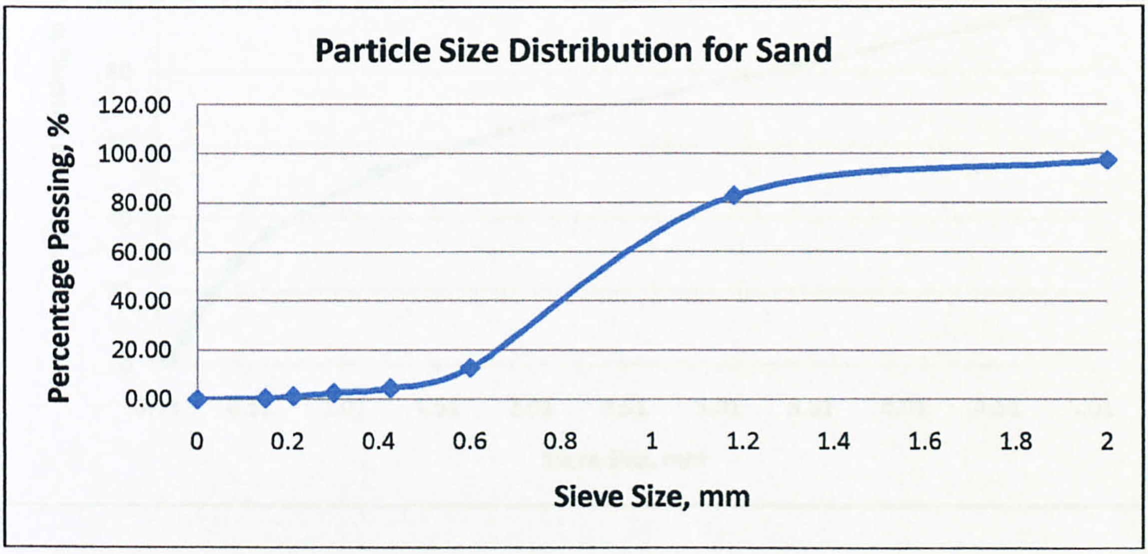
APPENDICES

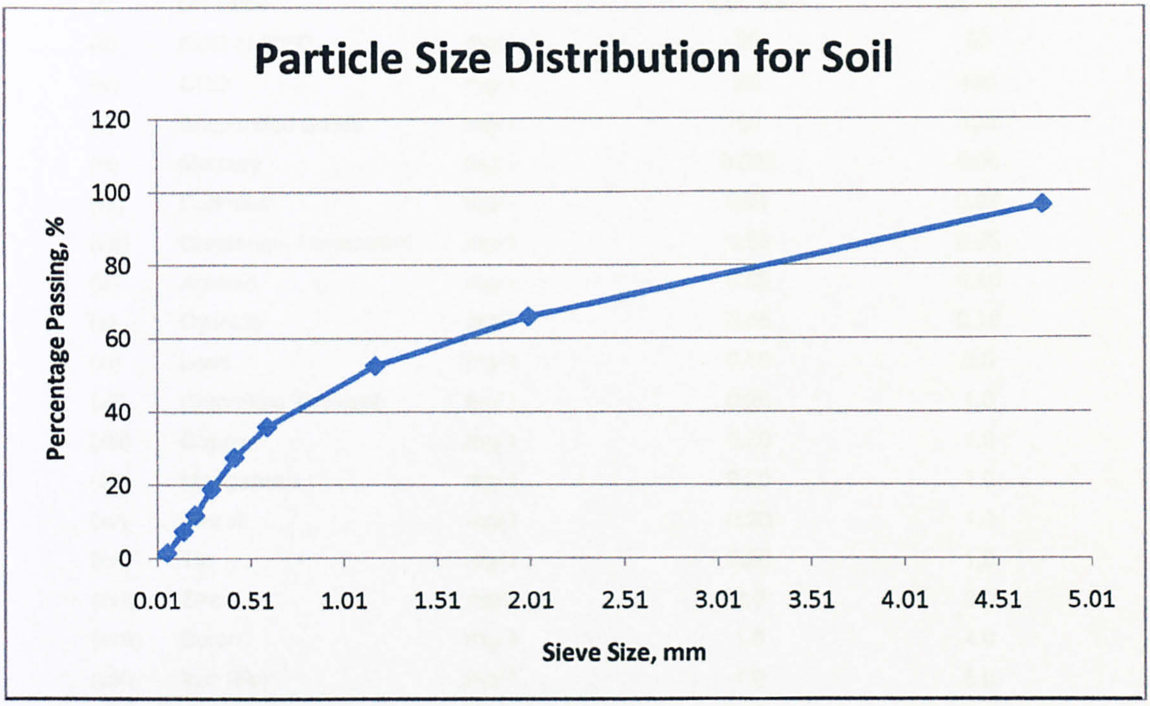
APPENDIX 1-1: Particle Size Distribution for Sand

sieve size (mm)	weight of sieve (g)	sieve + weight of sand (g)	weight retained (g)	Percentage retained (%)	Percentage passing (%)
2	453.82	469.80	15.98	2.66	97.34
1.18	435.03	520.30	85.27	14.22	83.12
0.6	405.00	827.00	422.00	70.36	12.76
0.425	385.30	435.34	50.04	8.34	4.42
0.3	354.60	365.80	11.20	1.87	2.55
0.212	343.60	351.90	8.30	1.38	1.17
0.15	348.40	352.90	4.50	0.75	0.42
pan	393.60	396.10	2.50	0.42	0.00
Total	3119.35	3719.14	599.79		



APPENDIX 1.2: Particle Size Distribution for Soil

Sieve size (mm)	Weight retained (g)	Percent retained (%)	Total passing (%)
4.75	18.48	3.70	96.30
2.00	151.95	30.39	65.91
1.18	66.56	13.31	52.60
0.60	82.71	16.54	36.06
0.43	42.01	8.40	27.65
0.30	43.70	8.74	18.91
0.21	34.66	6.93	11.98
0.15	22.50	4.50	7.48
0.06	29.48	5.90	1.58
pan	7.92	1.58	0.00
Total	499.97		



APPENDIX 2-1: Parameter Limit of Effluent of Standard A and B

Discharge Quality Standard
The effluent quality of any discharge from a sewage treatment process to inland water (that is, other than one having an ocean outlet) shall meet the minimum requirements of the Environmental Quality Act 1974 and the limits set down by the Environmental Quality (Sewage Industrial Effluent Regulations, 1979).

ENVIRONMENTAL QUALITY ACT 1974

ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS) REGULATIONS 1979

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

PARAMETER LIMITS OF EFFLUENTS OF STANDARDS A AND B

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

- Note:
  Standard A criteria applies only to catchments areas located upstream of drinking water supply off-takes

APPENDIX 2-2: Interim National Water Quality Standards for Malaysia (INWQS)

Receiving Water Quality Standard

Under the Interim Water Quality Standard (INWQS), Malaysian rivers are classified according to the six Classes.

INTERIM NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA (INWQS)

Parameters	(Units)	Classes					
		I	IIA	IIB	III	IV	V
Ammonical Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2
BOD	mg/l	1	3	3	6	12	> 12
COD	mg/l	10	25	25	50	100	> 100
DO	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5-8.5	6.5 - 9.5	6 - 9	5 - 9	5 - 9	
Colour	TCU	15	150	150			
Electrical Conductivity	mmhos/cm	1000	1000		-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	$^o/_{oo}$	0.5	1	-	-	-	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solids	mg/l	500	1000	-	-	-	-
Total Suspended Solids	mg/l	25	50	50	150	300	> 300
Temperature	°C	-	Normal +2	-	Normal +2	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Caliform*	counts/100ml	10	100	400	5000 (2000)@	5000 (2000)	-
Total Coliform	counts/100ml	100	5000	50000	50000	50000	>50000

Note:-

N **No visible floatable materials/debris or No objectionable odour or No objectionable taste**

* **Geometric Mean**

@ **Maximum not to be exceeded**

INTERIM NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA (INWQS) (continued)

Parameters	(Units)	Classes				
		I	IIA / IIB	III@	IV	V
Al	mg/l	NATURAL	-	(0.06)	0.5	LEVELS ABOVE IV
As	mg/l		0.05	0.4 (0.05)	0.1	
Ba	mg/l		1	-	-	
Cd	mg/l		0.01	0.01* (0.001)	0.01	
Cr(VI)	mg/l		0.01	1.4 (0.05)	0.1	
Cr(III)	mg/l		0.05	2.5	-	
Cu	mg/l		1	-	0.2	
Hardness	mg/l		250	-	-	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	
Fe	mg/l		0.3	1	1 (leaf) 5 (others)	
Pb	mg/l		0.05	0.02* (0.01)	5	
Mn	mg/l		0.1	0.2	0.2	
Hg	mg/l		0.001	0.004 (0.0001)	0.002	
Ni	mg/l		0.05	0.9*	0.2	

Se	mg/l	E	0.01	0.25	0.02	
Ag	mg/l	V	0.05	0.0002	-	
Sn	mg/l	E	-	0.004	-	
U	mg/l		-	-	-	
Zn	mg/l	L	5	0.4*	2	
B	mg/l		1	(3.4)	0.8	
Cl	mg/l		200	-	80	
Cl_2	mg/l		-	(0.02)	-	
CN	mg/l		0.02	0.06 (0.02)	-	
F	mg/l		1.5	10	1	
NO_2	mg/l		0.4	0.4 (0.03)	-	
NO_3	mg/l		7	-	5	
P	mg/l		0.2	0.1	-	
Si	mg/l		50	-	-	
SO_4	mg/l		250	-	-	
S	mg/l		0.05	(0.001)	-	
CO_2	mg/l		-	-	-	
Gross-a	Bq/l		0.1	-	-	
Gross-b	Bq/l		1	-	-	
Ra-266	Bq/l		< 0.1	-	-	
Sr-90	Bq/l		< 1	-	-	

Note:-

@ **Maximum (unbracketed) and 24-hour average (bracketed) concentrations**

Class	Uses
I	Conservation of natural environment
	Water supply I - practically no treatment necessary (except by disinfection of boiling only) Fishery I - very sensitive aquatic species
IIA	Water supply II - conventional treatment required
	Fishery II sensitive aquatic species
IIB	Recreational use with body contact
III	Water supply III - extensive treatment required
	Fishery III - common, of economic value and tolerant species
IV	Irrigation
V	None of the above

Note:
The Department of Environment (DOE) initiated the development of Receiving Water Quality criteria for Malaysia in 1985 which aimed at developing a water quality management approach for the long term water quality of the nation's water resources. The Water Quality Consultancy Group of the Institute of Advanced Studies, University of Malaya was commissioned in 1985 to undertake Phase I Study for the development of water quality criteria and standards for Malysia. The study recommended that Malaysian rivers be classified according to the six classes