Treatment of Landfill Leachate using Groundwater Treatment Plant Sludge

by

Nadia Amena bt Iskandar

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JULY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

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.

(NADIA AMENA BT ISKANDAR)

ACKNOWLEDGEMENT

All praises to Allah, the Almighty for enabling me to have the courage and determination to complete the one year Final Year Project with success. I would like to express my heartfelt thanks and gratitude to my FYP supervisor, Assoc. Prof. Dr. Shamsul Rahman Mohamed Kutty, for his continuous guidance, constructive critisms and invaluable contribution. Secondly, my thankfulness is also for my second FYP supervisor, Assoc. Prof. Dr. Hasnain Mohamed Isa, for his guidance and continuous ideas for improvement. I would also like to express my gratitude to Wastewater Engineering postgraduates' student, especially to Mr. Welly Herumurti who never stops helping me throughout my research on this project. My appreciation is also dedicated to Wastewater Engineering technicians, Mr. Khairul Anuar and Yusyawaty for always helping me during lab sessions, and last but not least, to all Final Year Wastewater Engineering students, especially to Faiz Afzan, Mat Sahnizam, Alia Hafiza, Siti Haida and Norfazliana for their support, help and ideas in completing my project

I shall always remain deeply indebted to all of you.

LIST OF ABBREVIATION & NOMENCLATURES

ABBREVIATION

GWTPS	Groundwater Treatment Plant Sludge
PBLS	Pulau Burung Landfill Site
FL	Filtered Leachate
UL	Unfiltered Leachate
AAS	Atomic Absorption Spectrophotometer
COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solids
XRF	X-Ray Fluorescent
SEM	Scanning Electron Microscope
Co	Influent Concentration
Ct	Effluent Concentration

NOMENCLATURES

HCl	Hydrochloric Acid
H_2SO_4	Sulfuric Acid
Zn	Zinc
Ni	Nickel
Cd	Cadmium
$Zn(NO_3)_2$	Zinc Nitrate
$Cd(NO_3)_2$	Cadmium Nitrate
$Ni(Cl)_2$	Nickel Chloride

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Municipal landfill is designed to collect, operate and manage solid waste that produced mainly from household, industrial solid-waste, factories, and construction and demolition debris. It helps to protect human population and environment from being exposed to polluted surroundings that can be dangerous to human health. However, municipal landfill also produces a highly-polluted liquid which is also known as landfill leachate. This liquid moves at the base of landfill and need to be collected before it penetrates into the ground.

Landfill leachate is formed when water passes through waste at landfill area and is one of the most contaminants and environmental hazards (Ahmad el-Gendi, 2003). It usually contains both dissolved and suspended material since many organic and inorganic compounds are transported in when the water flow through the waste. The contents of leachate basically depend on the waste at the landfill. Usually, leachate consists of dissolved organic matter, suspended solids and heavy metals like lead (Pb), copper (Cu), zinc (Zn) and cadmium (Cd). Since leachate is produced daily and the contents are dangerous to human health, treatment is obligatory and low cost treatment is certainly needed.

Adsorption technique is well known to be the most economically and effective method to remove heavy metal from waste water. Low cost or waste adsorbent is highly desirable because it can be continuously supplied during the treatment process.

Meanwhile, Groundwater Treatment Plant Sludge (GWTPS) is a waste produced from the treatment of groundwater. Every day, around 5 tonnes of sludge are produced and this had caused problem to groundwater treatment plant. The numbers of sludge are increased day by day but the treatment and disposal costs are very high. This is due to the contents of the sludge that contains high amount of metals such as iron, aluminum and manganese.

Due to this scenario, this study was conducted to test the ability of GWTPS in treating landfill leachate. Adsorption technique was applied in this fixed bed continuous study. The landfill leachate sample is originated from Pulau Burung Landfill Site (PBLS), while GWTPS was obtained from Chicha Treatment Plant, Kelantan.

1.2 Problem Statement

The rapid population growth, rising urbanization and industrialization in most municipalities has resulted in increasing amount of waste and refuse from year to year in Malaysia. The amount of solid waste generated in Peninsular Malaysia went up from 16,200 tons per day in 2001 to 19,100 tons in 2005, an average of 0.8 kilogram per capita per day. Forecasts have shown that this number will increase further in coming years.

This increment of waste generation will increase the volume of leachate generated per day. Since leachate characteristic was similar to toxic waste due to content of heavy metals such as lead and cadmium (Rasool et al., 2007), treatment of leachate is obligatory. The danger that can be caused by leachate is if it enters any watercourse, it can lower the dissolved oxygen (DO) content. The high concentrations of dissolved nutrients contains in the leachate will be the source of food for aerobic micro-organisms. These organisms grow rapidly and will consume large amount of oxygen from the water around them. Besides, methane and other toxic gaseous produced from the degradation of organic materials at landfill can dissolved easily in leachate. Currently, activated carbon is used as the adsorbent in treating landfill leachate that applies the concept of adsorption. However, the market price for activated carbon is expensive where the cost can reach from USD 500 to USD 2000 per tonne. Due to this problem, this study was conducted with the aim to replace the activated carbon with GWTPS which is free of charge.

1.3 Objectives of the Study

The main objectives of this study is to utilize waste/low cost material for landfill leachate treatment and to investigate the effectiveness of GWTPS as an adsorbent for COD and heavy metals (Ni, Zn and Cd) removal from leachate sample using Column Method.

1.4 Scope of Study

The research covers:

a) Characterizing landfill leachate sample from Pulau Burung Landfill Site.

b) Characterizing groundwater treatment plant sludge sample taken from Chicha Treatment Plant, Kelantan.

c) Comparison on COD removal for filtered and unfiltered leachate sample.

d) Study the effect of bed height on COD and heavy metals removal.

e) Determine the best heavy metal removed by the GWTPS.

f) Determine the new breakthrough time and volume for the new design column using scale-up approach.

CHAPTER 2

LITERATURE REVIEW

2.1 Leachate

Leachate is formed when the refuse moisture content exceed its field capacity, which is defined as the maximum moisture that can be retained in a porous medium without producing downward percolation (N.Calace et al., 2000). It contains soluble organic and inorganic compound since it has passed through various types of refuse which came from household, industry wastes and many more. Leachate formation creates a non-uniform and intermittent percolation of moisture through the refuse mass which results in the removal of these soluble from the refuse and their dissolution in the leachate. Beside surface water and groundwater supplies, landfill leachate may also cause marine water pollution and trans-boundary contamination (Mavros et al., 2007). Therefore, landfill leachate treatment is required as an essential part of the solid management (Ahmad el-Gendi, 2003).

2.1.1 Chemical Characteristic

Leachate is affected by the landfill age, ambient air temperature, and precipitation and refuse permeability, depth and waste composition (N. Calace et al., 2000). For instance, the newly dumped leachate that mainly caused by the organic acids is found to have higher concentration of COD and BOD compared to leachate that age older (Ahmad el-Gendi, 2003). Moreover, each landfill leachate produces different pollutant concentration. According to Metcalf and Eddy (2001), the domestic and industrial waste have a wider range of pollutant concentration compared to municipal landfill.

2.1.2 Flow Rate Characteristic

Landfill leachate is very viscous due to the organic and inorganic particles that dissolved in the fluid. The volumetric flow of leachate was often fairly small as compared with other wastewater such as domestic, industrial and agricultural runoff (Noorida, 2006).

2.2 Landfill Leachate Treatment

Treatment of landfill leachate can be performed in many ways. Wide range of high to low technologies is available for partial or full, on-site treatment of municipal landfill leachate. However, the high technology treatment, such as aerobic or reverse osmosis, is very costly beside require skilled labours and service after closure of the solid waste site (Ahmad el-Gendi, 2003). Two examples for types of leachate treatment are listed below:

2.2.1 Biological Treatment

There are two categories for biological treatment. The first group is aerobic treatment while the second group is anaerobic treatment. The examples for aerobic treatment are ponds, lagoons, reed beds, activated sludge treatment, sequencing batch reactor (SBR), rotating biological contractors (RBC) and trickling filters. Meanwhile, the examples for the second group are digesters, fixed film reactors such as UASB, anaerobic filters and anaerobic lagoons (Ahmad el-Gendi, 2003). In aerobic treatment, microorganisms are used to oxidize the dissolved and particulate carbonaceous organic matter into simple products and additional biomass (Metcalf & Eddy, 2004). The advantage of using these microbes is the possibility of heavy metals adsorption. Few microbes can degrade few types of heavy metals. Meanwhile, anaerobic treatment is efficient in treating young landfill leachate due to its high content of BOD and COD. The cost effectiveness, low sludge production and the useful methane gas produced (Ahmad el-Gendi, 2003) has made anaerobic treatment as one of the popular method. However, biological treatment produces sludge that contains toxic heavy metals and specific organic compounds that is expensive to dispose. Skilled labour and services needed to operate biological treatment also had increase the cost of treatment (Ahmad el-Gendi, 2003).

2.2.2 Physical or Chemical Treatment

Activated carbon adsorption, ion exchange and reverse osmosis are the example of physical/chemical treatment. These treatment processes can produce high quality effluents and remove toxic substance from leachate. Nevertheless, these steps require high cost and skilled labour (Ahmad el-Gendi, 2003).

2.2.3 Activated Carbon adsorption

The common adsorbent, activated carbon, has good capacity of removal of pollutants (Han et al., 2007). Activated Carbon is manufactured by the carbonization and activation of carbonaceous material, almost exclusively of vegetable origin such as coconut shells, walnut shells, and wood, coal, peat and fruit stones. This feed material is put through pyrolisis (heated at high temperature in the absence of oxygen), the carbonized product from which is practically inactive with a specific surface area on the order of several m^2/g. Highly developed porosity (large surface area) is attained only by activating the carbonized material with, for example steam or carbon dioxide at temperatures from 700 to 1100°C. Typical values for active carbon specific area may average 1000 m^2/g but in some products may be 4000 m^2/g. Micropores give an adsorbent its strong adsorption potential. Active carbon has little selectivity capabilities and mainly used as a universal adsorbent of high adsorption power (John Shellenbarger, 1985).

2.3 Pulau Burung Landfill Site

Pulau Burung Landfill Site implemented two methods of leachate treatment; flocculation and coagulation method and adsorption method. For adsorption method, Powdered Activated Carbon (PAC) has been used as the adsorbent because of the efficiency in treating leachate. This technology removes organic contaminants from wastewater and minimizes the inhibitory effects of process wastewater containing toxic organic compounds. Moreover, powdered activated carbon wastewater treatment systems can treat liquid wastes with a chemical oxygen demand (COD) in excess of 60,000 parts per million (ppm), including toxic volatile organic compounds in excess of 1,000 ppm. Treatability studies have shown that the system can reduce the concentration of specific toxic organic chemicals to below the detection limit.

Figure 1: Leachate Pond at PBLS

Figure 2: Flocculation and Coagulation Tank

Figure 3: Adsorption Column

The characteristic of landfill

leachate from PBLS is given in the table below. This characteristic is compared to the Standard B of the Environmental Quality (Sewage & Industrial Effluent) Regulation 1979, under Environmental Quality Acts of Malaysia, 1974.

Table 1: Characteristic of PBLS Leachate

Parameter	Value (mg/L)	Standard B (mg/L)
Ph	7.8- 9.4	5.5- 9.0
COD	1533- 3600	100
BOD	48- 1120	50
Turbidity	50- 450 (NTU)	-
Suspended Solid	159- 1120	100
Colour	2430- 8180 (PtCo)	-
Zinc	0.1-1.8	1.0
Copper	0.1-0.4	1.0
Manganese	0.6-1.1	1.0
Cadmium	<0.04	0.02
Iron	0.32- 7.5	5.0

(H.A. Aziz et al., 2005)

2.4 Adsorption

Adsorption is a process where solid is used for removing a soluble substance from the liquid (Metcalf & Eddy, 2001). Weber, (1972) has described it as the adhesion of liquid to the surface of solids with which they are in contact. The adsorbing material is known as adsorbent whereas the constituents adsorbed is the adsorbate (Weber, 1972). The adsorption process may occur through physical, chemical or ion-exchange processes. Physical adsorption on the external surface of a particle is based on Van der Waals forces of attraction. Chemical adsorption is characterized by the formation of chemical associations or bonds between ions or molecules from solution and the surfaces of particles which is mainly covalent (Weber, 1972;

Reynolds, 1995). Adsorption is affected by pH, ionic strength, and the composition of the solution phase (Lester, 1987). The adsorption principal will be applied for this study when the leachate flows passing through the groundwater sludge.

A successful adsorption process not only depends on the adsorption performance of the adsorbents, but also on the constant supply of the materials for the process. So it is preferable to use low cost adsorbents, such as an industrial waste, natural ores, and agricultural byproducts (Han et al., 2007).

2.5 Column Adsorption

The effectiveness of the adsorbent is best described by batch method. However, the data obtained under batch conditions are generally not applicable to most treatment systems (such as column operations). Hence, there is a need to perform dynamic studies using columns (Han et al., 2007).

Column adsorption allows the adsorption process when the sample is flowing through the adsorbent. The effluent of the sample is tested at time intervals to determine the breakthrough curve. Time zero is when the first drop of effluent collected. As the time increases, the concentration of the parameter will increase too.

Initially the adsorbent is fresh with all its adsorption sites. None of the material to be removed escapes from the column. However, as the time passes, the adsorbent is getting exhausted and can no longer adsorb the material effectively. Hence, the concentration in the effluent rises up from zero (Han et al., 2006). When all the adsorption sites are occupied, the effluent concentration will be the same as the influent concentration.

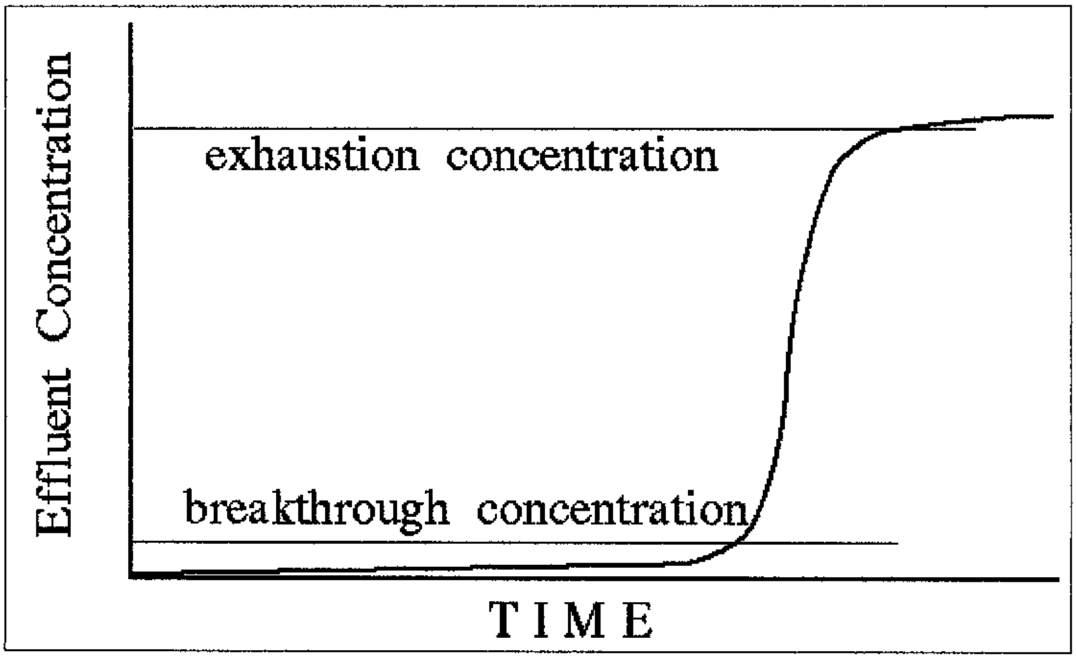


Figure 4: Example of Concentration Graph

**Source : Aksu and Gonen, Prediction of breakthrough curves*

2.6 Breakthrough

Breakthrough occurs when the effluent concentration reaches five percent of the influent value. Exhaustion of the adsorption bed is assumed to occur when the effluent concentration is equal to ninety-five percent of the influent concentration. At complete exhaustion, the effluent concentration is equal to the influent concentration (Metcalf and Eddy, 2004).

2.7 Breakthrough Curve

The connection between the flow rate of the influent and time when determining adsorption process using column method can be described by a breakthrough curve. The initial influent concentration, flow rate and bed depth do affect the breakthrough curves (Lester, 1987).

The parameters that affect the breakthrough curves are; the bed length, bed void fraction, flow rate and pellet diameter. Bed length and flow rate are fixed by design, so it is recommended that the bed void fraction be measured more accurately and minimized to increase the breakthrough time of the column. A more accurate estimate of the bed void fraction would greatly enhance the accuracy of the model. The pellet diameter also suggested to be minimized as much as allowable, avoiding a large pressure drop across the purifier. A continuous fixed bed study will be carry out by using groundwater sludge as adsorbent for the removal of suspended solids and heavy metals from leachate sample. The effects of important factors, such as the bed height of sludge, period of adsorption and the influent concentration of leachate should have been taken into consideration during the column test study. Based on the previous studies conducted by Lester (1987), it is confirmed that the breakthrough curves were dependent on flow rate, initial concentration and bed depth. Only breakthrough of the effect at different bed height will be discussed in this report. The area above the breakthrough curve represents the mass of the adsorbate adsorbed within the column (Metcalf and Eddy, 2004).

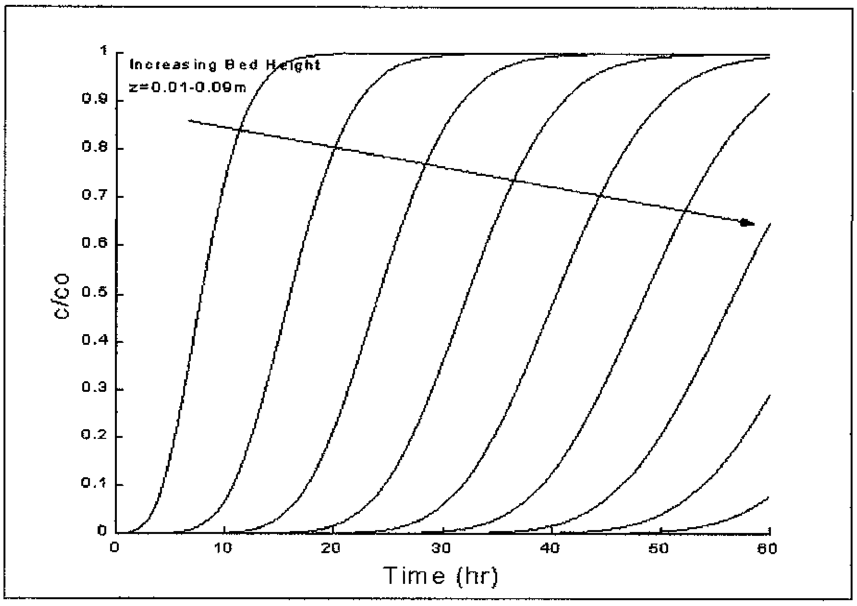


Figure 5: Example of Breakthrough Curve at Different Bed Height

**Source : Dicken et al / Gas Adsorption Group (2002)*

2.8 Scale up Approach

In order to describe the fixed-bed column behaviour and to scale it up for industrial applications, pilot-scale approach has been used by calculating the proportion of test column to the new design column (Reynolds, 1982). Pilot-scale test or bench-scale must be conducted to determine the applicability of a process for a given situation is unknown but the benefits of using the process are significant. The purpose of conducting pilot-plant studies is to establish the suitability of the process in the treatment of a specific wastewater under specific environmental conditions and to obtain the necessary data on which to base a full-scale design (Metcalf & Eddy, 2004).

To determine the new breakthrough time and volume, the design bed volume is calculated first. The design bed volume, m^3 is determined by dividing the design flow rate Q, to the adsorbent flow rate of test column, Qb.

Design Bed Volume, m^3= BV= Q/Qb

To determine the design mass of adsorbent required in the new design column, the design bed volume, BV is multiplied with the bulk density, ρs of GWTPS. The equation is given as:

Design Mass of Adsorbent, M = (BV) ρs

To determine the new breakthrough time, T, the design mass of adsorbent, M is divided by the kilograms of adsorbent exhausted per hour, Mt.

Design Breakthrough Time, T= M/Mt

Where Mt is flow rate divided by the volume treated per kilogram of adsorbent.

Mass of Adsorbent Exhauster per Hour, Mt= Q/ V

V= volume treated per kilogram of GWTPS

The new breakthrough volume, Vb is determined by multiplying the design flow rate to the new breakthrough time.

Design Breakthrough Volume, Vb = Q xT

(Reynolds, 1982)

CHAPTER 3

METHODOLOGY

This chapter presents the methodology conducted in this study besides listing out the materials, instruments and equipment used. The details of the experimental works were also discussed here. Overall the study is divided into five parts and the outline of every part is given below.

Part 1: Research plan, data and materials gathering
Part 2: Preparation and Characterization of materials
Part 3: Column study
Part 4: Analysis of effluent sample
Part 5: Data Interpretation

In order to obtain good results, the experimental works were conducted step by step as well as being cautious and focus throughout the experiments.

3.1 Research Plan, Data and Materials Gathering

A research on leachate, current leachate treatment process, adsorption concept and steps to conduct column study were done by collecting data from journals and internet search. With the guidance of supervisors, planning was made to identify the steps and methodology required to conduct the study. Parameters for the study were set based on several observations. Materials used in the study is originated from Pulau Burung Landfill Site (PBLS) for landfill leachate sample, while groundwater treatment plant sludge (GWTPS) sample were obtained from Chicha Treatment Plant, Kelantan.

3.2 Health, Safety and Environment

To avoid any accident in the laboratory, safety precautions are employed while conducting the laboratory works. Lab coat, gloves and covered shoe is a compulsory to anyone who entered the Environmental Lab. OSHA Guide of Chemical Hazard is also being referred before handling any hazardous chemical. (Refer Appendix 1).

3.3 Preparation of Materials

3.3.1 Chemicals

Most of the chemicals and reagents were obtained from the Environmental Laboratory, Civil Engineering Department while few chemicals like Nickel Chloride, Cadmium Nitrate and Zinc Nitrate were obtained from Chemical Engineering Department Laboratory.

3.3.2 Adsorbent

The GWTPS collected from Chicha Treatment Plant were stored at storage room of 6°C to maintain its characteristic. During the preparation of GWTPS for the column study, the sample was oven dried at 110°C for one day. The sample was later crushed to get smaller particles before it is being sieved. Only particles that retained on the sieve sized 300μm and 1.18mm was taken for the experimental works.

Figure 6: Oven-dried GWTPS

Figure 7: Ground GWTPS

3.3.3 Equipments

3.3.3.1 Leachate Characterization and Samples Preparation

i. pH meter- to read the current pH of the leachate samples
ii. Spectrophotometer- to read the COD and heavy metals concentration; Nickel and Zinc
iii. D.O Meter- to read BOD concentration of the leachate samples
iv. Filter machine- filter the leachate samples for column study and for TSS purposes
v. Analytical Balance- to measure TSS
vi. AAS- to read the concentration of Zinc, Cadmium, Ferum, Plumbum and Chromium

Figure 8: Spectrophotometer

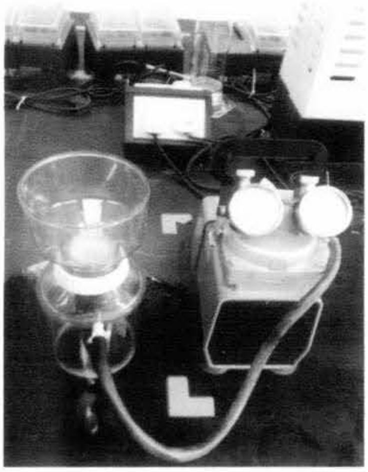


Figure 9: Filter Machine

Figure 10: Analytical Balance

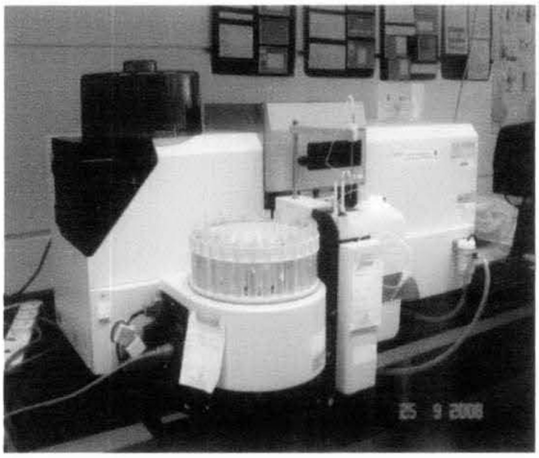


Figure 11: AAS Machine

3.3.3.2 GWTPS Preparation and Charaterization

i. XRF- to determine the composition of GWTPS
ii. SEM- to get the picture of the surface of GWTPS
iii. Oven- to dry sludge at 110^oC

Figure 11: XRF Machine

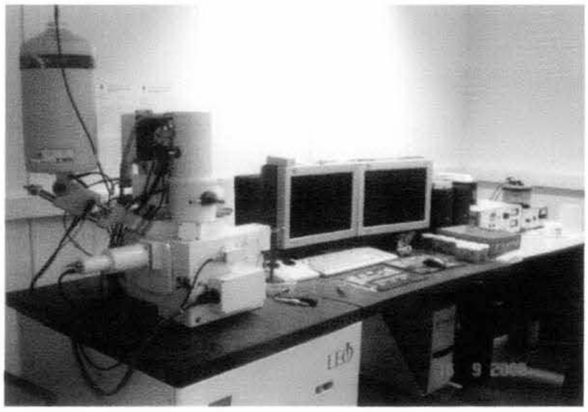


Figure 12: SEM Machine

3.3.4 Preparation of Leachate Samples

Forty litres of leachate samples were taken out from the storage room to be used in the column study. The samples were characterized first to determine the characteristic such as pH, BOD, COD, TSS and heavy metals of the leachate samples. The characterization identified that heavy metal concentration of the leachate sample is low. Hence, heavy metals (Nickel, Zinc and Cadmium) were artificially increased by adding 5.79 g of $Zn(NO_3)_2$, 4.20 g of $Cd(NO_3)_2$ and 4.46g of $NiCl_2$ into the leachate samples. However, before adding the heavy metals into the leachate sample, the pH of the leachate samples were adjusted from pH of 9 to pH 5.4 to avoid the heavy metals from precipitating. Twenty litres of the altered solution is taken out to be filtered by the filtering machine using Whatman 0.45µm filter paper. Filtered leachate (FL) sample was prepared to compare the treatment with unfiltered leachate (UL).

Figure 13: Filtered Leachate

3.4 Column Study

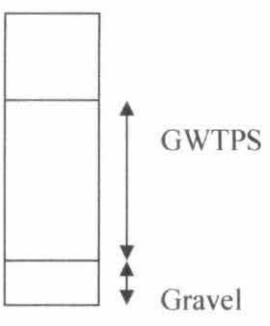
3.4.1 Column Setup

Six treatment columns at three different bed heights were prepared. Each bed height has two treatment columns where one column is for treatment of filtered leachate and the other one is for treatment of unfiltered leachate sample. Below are the details of each treatment column:

Bed height 1: 1.5 cm gravels + 5 cm GWTPS weighed 53.46 g.

Bed height 2: 1.5 cm gravels + 7.5 cm GWTPS weighed 84.52 g.

Bed height 3: 1.5cm gravels +10 cm GWTPS weighed 118.75 g.



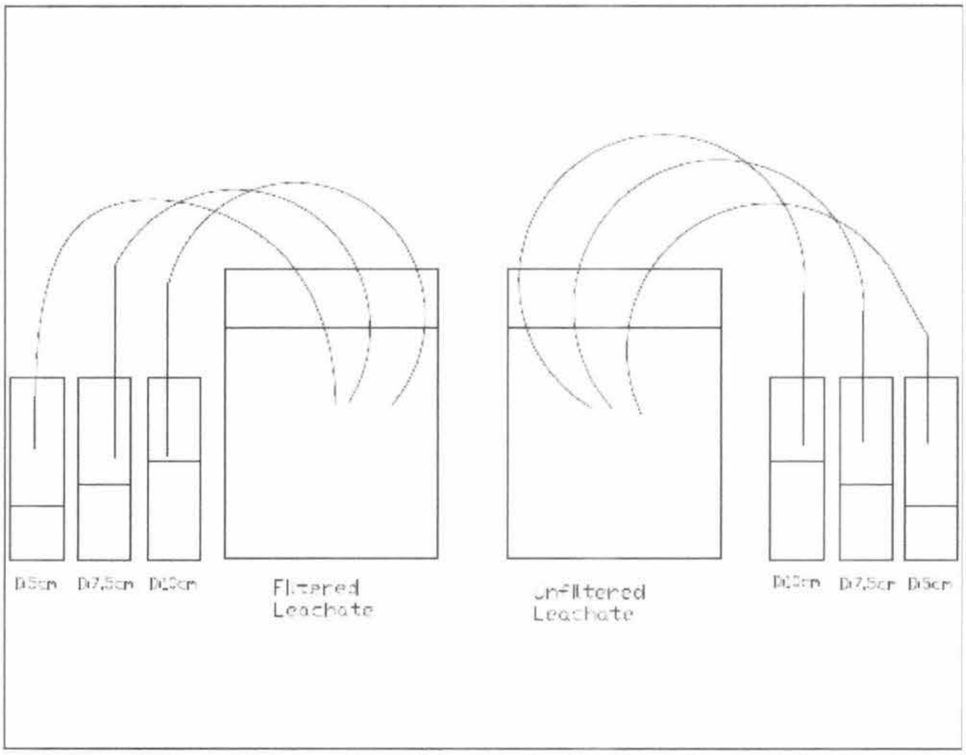
Layout of Arrangement in Column

3.4.2 Calibration of Flow Rate

Calibration of flow rate was done to determine the flow rate of each column when the pump is set to be 1.5 rev/min. Distilled water was used instead of leachate to confirm that GWTPS allows water to pass through it. Moreover, the test was also done to determine the flow rate of each column so that parameters of the study can be chosen.

3.4.3 Experimental Procedure

Column study is conducted at room temperature ($28 \pm 1^{o}C$) to test the ability of GWTPS in treating both leachate samples. Two containers of samples, where one container contains filtered leachate and the other contains unfiltered leachate were placed nearby the columns. Three columns were attached to one container using tube pipes. The samples in containers were stirred using stirrer to ensure that the concentration of COD and heavy metals are the same at every part of the sample. The effluent samples were collected for every one hour to measure the concentration of Chemical Oxygen Demand (COD) and heavy metals in each sample. Stopwatch was used to notify the time that the samples should be collected The experiment stopped at fifteen hours of operation. The experiment need to be observed every minute to avoid the influent from flowing outside the columns.



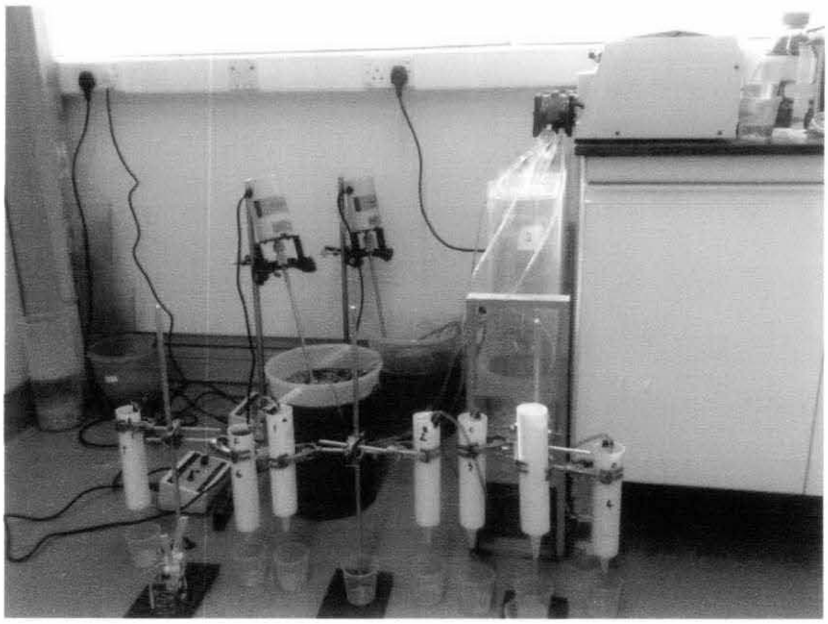


Figure 14: Column Study

Figure 15: Effluent Samples Collected

3.5 Measurement of Parameters

3.5.1 Measurement of Effluent Volume

Each volume of effluent samples was measured using measuring cylinder to determine the flow rate of each treatment column.

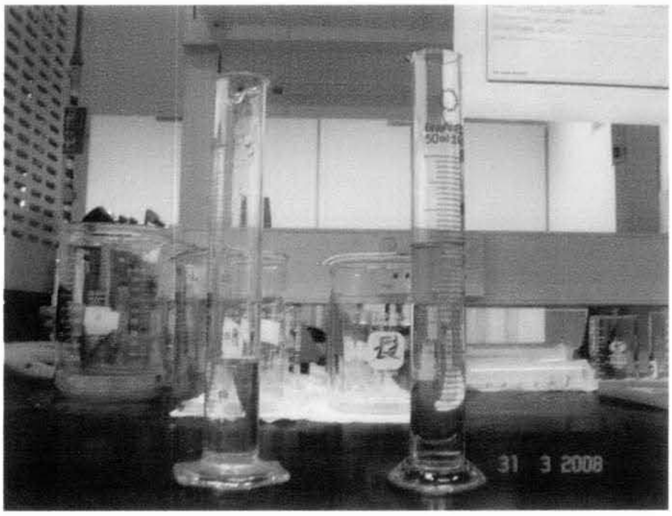


Figure 16: Measuring Cylinders

3.5.2 Measurement of Chemical Oxygen Demand (COD)

The COD measurement was conducted to determine the amount of chemical oxygen demand in the leachate samples before and after being treated. The test was conducted by adding 2 ml of supernatant of the sample into a vial. 2 vials had been prepared for each sample. The samples were digested at 150°C for 2 hours in COD Reactor DRB 200. The blank sample was prepared by pipetting the distilled water into the vial and heats it for 2 hours at 150°C. After the sample finished heated, wait for the samples to cool down after being heated, and the COD reading was taken using the spectrophotometer.

3.5.3 Measurement of Zinc (II) and Cadmium (II)

Measurement of Zinc and Cadmium were done by the AAS machine. AAS machine was chosen due to the preciseness of results obtained compared to spectrophotometer. Three concentrations of standard solutions were prepared for each heavy metal. The concentration of heavy metals in sample is read between the concentration ranges. AAS test were also done to measure other heavy metals such as Pb, Fe, and Cr during the characterization of leachate samples.

3.5.4 Measurement of Nickel

Nickel was measured using spectrophotometer due to the unavailability of Nickel standard solution for AAS Test. Blank sample was prepared by filling a square sample cell with 10 mL of deionized water while prepared sample was filled in another square sample cell. Both square sample cells were added with Phthalate Phosphate Reagent Powder Pillow and shook well to ensure that all the powder is dissolved. 0.5 mL of 0.3% PAN Indicator Solution were also added to each cell. The timer was set to be 15 minutes for the reaction period. The sample that contains Nickel varies from yellowish-orange to dark red while the blank maintains yellow. When the timer expired, EDTA Reagent Powder Pillow was added to each cell. The cell was shook before being wiped and read using the spectrophotometer.

Figure 17: Measurement of Nickel

3.5.5 Measurement of Total Suspended Solid, TSS

Characterization of leachate includes the measurement of total suspended solid (TSS) removed for every 100 mL of sample. TSS is the solid materials, including organic and inorganic, that are suspended in the water. High concentrations of suspended solids can lower water quality by absorbing light. Waters then become warmer and lessen the ability of the water to hold oxygen necessary for aquatic life.

TSS was determined by filtering the supernatant using Whatman sized 45 μm filter paper, then weight the filter paper and dried in the oven at 105°C for 30-45 minutes before weighting again the filter paper.

$$\text{The formula for TSS (mg/L) is} = \frac{\text{Final Weight} - \text{Initial Weight (mg)}}{\text{Sample Volume in L}}$$

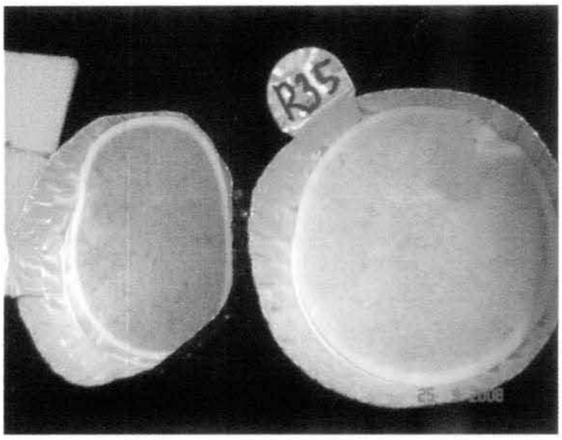


Figure 15: TSS Sample

3.5.6 Measurement of Biochemical Oxygen Demand

This test was carried out to identify the number of biochemical oxygen demand in the leachate samples. Leachate and blank samples were prepared into the BOD bottles. Initial DO was measured by the DO probe before the bottles were placed in refrigerator at 20°C temperature and left for 5 days. After 5 days of incubation, the final DO was measured using the DO Probe.

3.5.7 Measurement of Color

Measurement of color was done as one of the step to characterize the leachate sample. The test was carried out by pouring 25 ml of distilled water into a spectrophotometer bottle for the blank sample preparation. Then the spectrophotometer had been set up for the colours test. Each sample being poured into 3 bottles of samples and the reading of the sample is determined by the spectrophotometer for each sample.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Characteristic of Landfill Leachate from PBLS

The characteristic of landfill leachate was done by analyzing the total and soluble COD, colour, total organic carbon, total heavy metals; copper, zinc, nickel, lead, iron and soluble iron, chromium and cadmium.

Table 2: Chrateristic of PBLS Leachate (obtained)

Parameter	Value
Soluble COD (mg/L)	4640
Total COD (mg/L)	5750
Total Suspended Solid (mg/L)	1987
Colour (PtCo)	3771
Total Organic Carbon	2058
Total Copper (mg/L)	0
Total Chromium	0
Total Cadmium	0
Total Zinc (mg/L)	0
Total Nickel (mg/L)	0
Total Lead (mg/L)	0
Total Iron (mg/L)	7.74
Soluble Iron (mg/L)	5.54

Table above shows the results of PBLS leachate characteristic done by the author. Basically the results obtained were about the same with the characterization done by H.A. Aziz et al., 2005 except for few parameters. Since the concentration of heavy metals contain in the leachate sample is low, the leachate sample is artificially added with heavy metals for column study.

4.2 Chemical Analysis of GWTPS

XRF Test was conducted to determine the chemical composition of the groundwater treatment plant sludge. 10 grams of sample was re oven-dried at 105 C for one day to ensure that the sludge is free from moisture. Below is the characteristic of the groundwater treatment plant sludge. The chemical composition of the groundwater treatment plant sludge might influence the rate of adsorption.

Table 3: Chemical Analysis of GWTPS

Composition	**Percentage (%) by weight**
Fe_2O_3	56.4
SiO_2	16.4
CaO	16.3
Al_2O_3	6.15
P_2O_5	2.53
Rayleigh	1.47
Compton	0.74
MnO	0.310
Re	0.211
BaO	0.193
K_2O	0.0555

4.3 SEM Photograph

SEM photograph was taken on the GWTPS sample before and after the column study. The objective of conducting SEM is to obtain the surface of GWTPS. The pictures shown below are the pictures of the GWTPS before and after the column study.

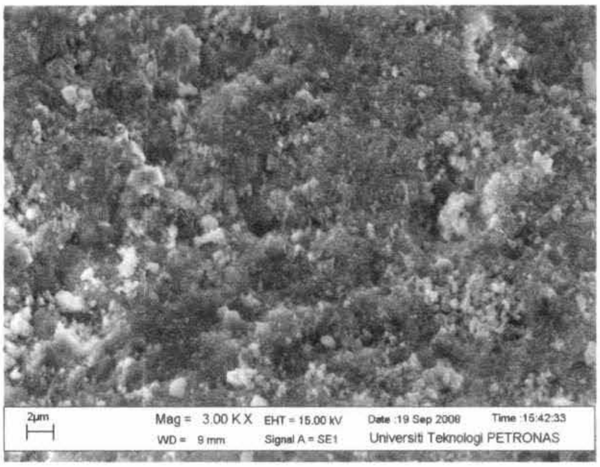


Figure 19: GWTPS before column study

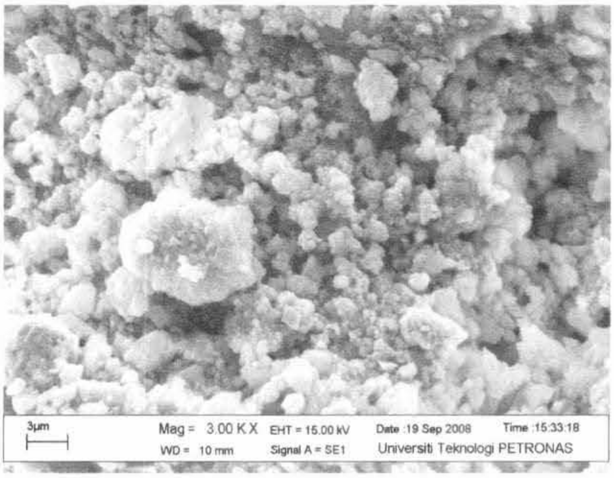


Figure 20: GWTPS after column study

Based on the comparison of Figure 19 and Figure 20, the process that occurred during the treatment process is most likely to be precipitation. Adsorption might occur, but precipitation has dominated the process. This assumption is made based on the size of GWTPS. The particle is smaller before going through the treatment process and has larger size after the treatment process. Hence, further study need to be conducted using the GWTPS to confirm the process that the GWTPS has gone through during the column study.

4.4 Calibration of Flow Rate

Calibration of flow rate was first done using distilled water as the influent to determine the estimated volume collected per hour. The speed of pump was set to be 1.5 revolution/ minute by maintaining the influent sample 2 cm above the GWTPS inside the column. Different bed height of GWTPS gave different flow rate of the influent. Below is the graph of volume collected per hour for three different bed height of treatment column.

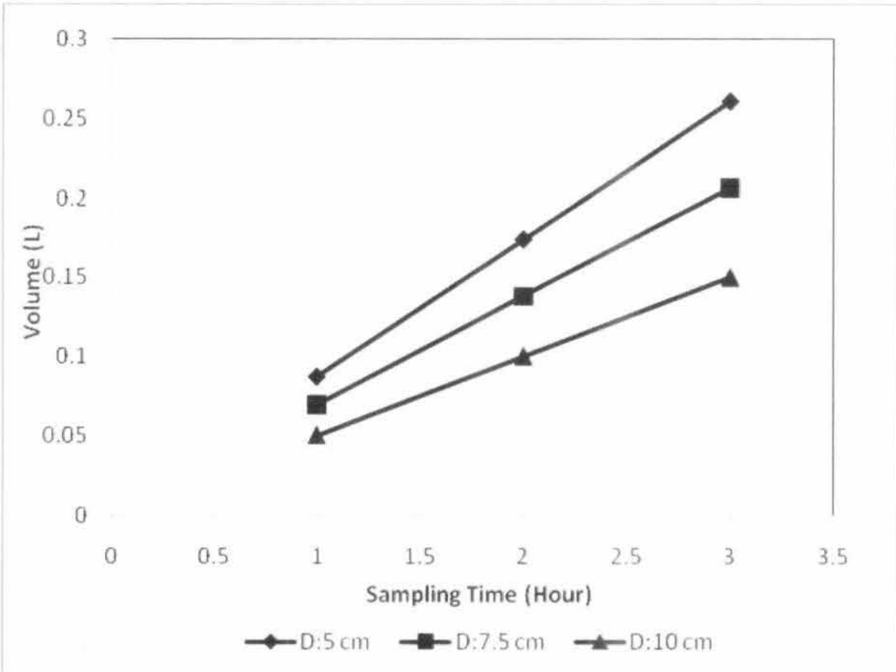


Figure 21: Volume for Calibration Test

Table 4: Calibration Flow Rate Result

Treatment Column (D)	Flow Rate (L/day)
5 cm	2.088
7.5 cm	1.664
10 cm	1.2

Based on the results obtained from the calibration of flow rate, the parameters for this study were discussed. Since the flow rate obtained for each column was low, only COD and heavy metals were chosen to be the parameter for this study.

4.5 Column Study

Observation on the effluent of leachate samples were done hourly as the samples were collected for 15 hours. Below are the pictures of leachate, from original to the effluent at hour 2, 6 and 12 of the experiment.

Figure 16: Raw Leachate

Figure 17: Changes in Effluent Colour at Hour 2, 6 and 12

The colour of the effluent samples changing from clear to the original colour of the raw leachate. The interpretation made based on the colour changes is the leachate is treated until the point where the adsorbent is exhausted.

4.6 Flow Rate for Each Treatment Column

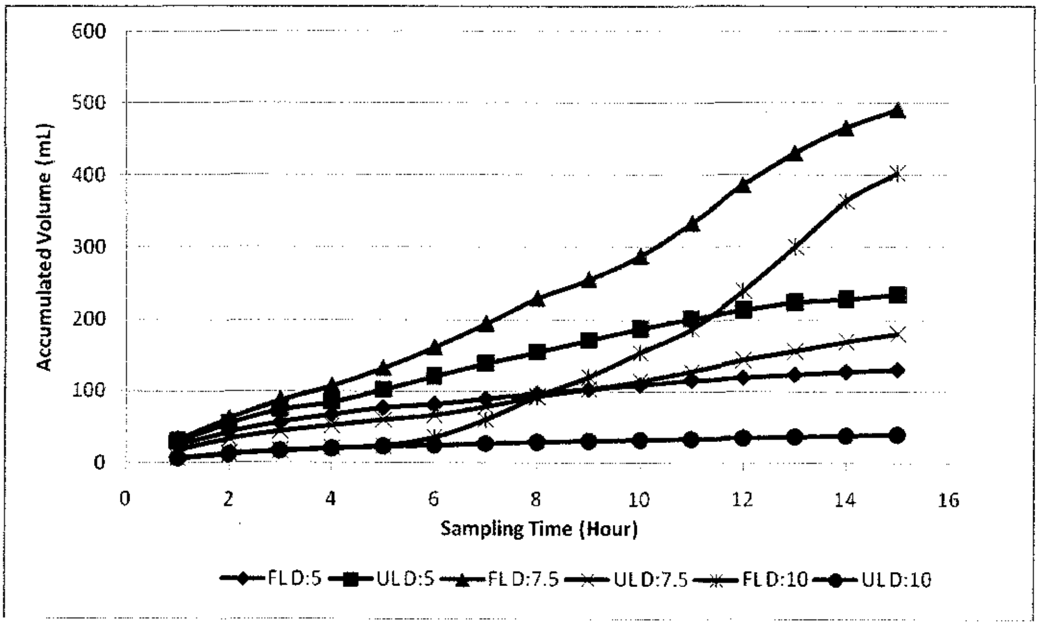


Figure 18: Accumulated Volume (mL) vs Sampling Time (Hour)

The flow rates for each treatment column were calculated by:

$$\text{Flow Rate, } Q = \frac{\text{Accumulated Volume, } m^3}{\text{Hours of Treatment (hr)}}$$

Table 5: Flow Rate for Each Treatment Column

Treatment Column	Flow Rate (L/day)
FL (D:5 cm)	0.2098
UL (D:5 cm)	0.3763
FL (D:7.5 cm)	0.7856
UL (D:7.5 cm)	0.2891
FL (D:10 cm)	0.6440
UL (D:10 cm)	0.0646

Measurement of volumes for each treatment column at every hour was done to determine the flow rate of the column. The flow rate indicates how much of leachate can be treated. Based on the results obtained, treatment column with bed height of 7.5 cm treating filtered leachate gave the highest flow rate. Generally, treatment column treats filtered leachate has higher flow rates compared to treatment column treating unfiltered leachate due to the ease of filtered leachate to flow through the GWTPS.

4.7 Effluent COD vs Sampling Time (Hour)

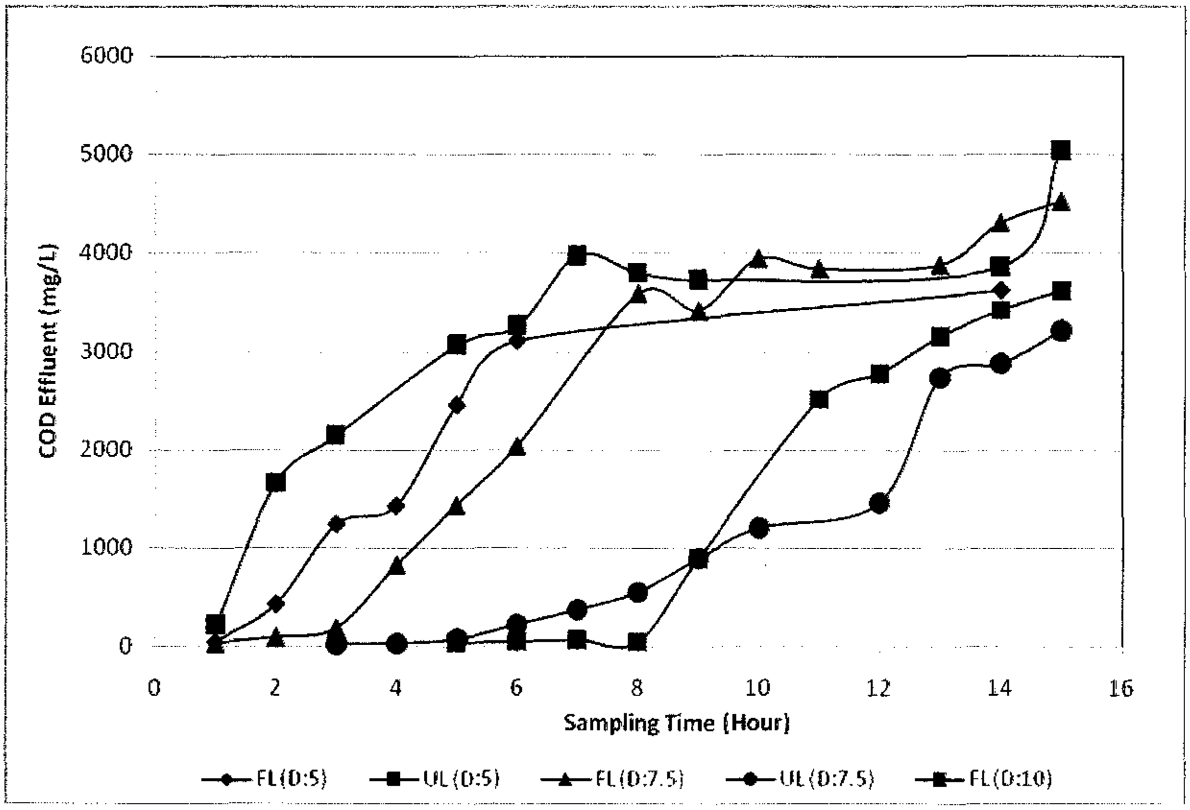


Figure 19: COD Effluent vs Sampling Time (Hour)

From the graph, it is known that at the early stage of treatment, column with bed height of 10 cm gave the lowest concentration, followed by treatment column with 7.5 cm bed height treating unfiltered leachate, treatment column with 7.5 cm bed height treating filtered leachate, treatment column with 5 cm bed height treating filtered leachate and finally treatment column with 5 cm bed height treating unfiltered leachate. Theoretically, effluent from filtered leachate sample should give lower concentration since all the suspended solid are already filtered during the filtration process. Treatment column with bed height of 5 cm conform this theory. However, for the treatment column with bed height of 7.5 cm, unfiltered leachate effluent gave lower concentration compared to filtered leachate. To explain this, comparison on the volume treated between filtered leachate and unfiltered leachate for bed height of 7.5 cm is done. Based on the Figure 26, it is shown that for the bed height of 7.5 cm, the volume of effluent from treatment column for filtered leachate is higher than unfiltered leachate. This is happened because the suspended solid from unfiltered leachate sample has clogged up above the adsorbent. The suspended solid retained above the adsorbent and has blocked the leachate from flowing through the adsorbent. As the result, the volume collected per hour is lower than the effluent for filtered leachate samples. At the same hour of point taken, the volume of filtered leachate treated is more than unfiltered leachate sample. Hence, the adsorbent for the filtered leachate column exhausted earlier than unfiltered leachate column. This justify why lower concentration of COD is given by unfiltered leachate compared to filtered leachate.

4.7.1 Comparison on treatment at different bed height for filtered leachate sample

The efficiency of adsorbent on different bed height is also tested. The graph for comparison on percentage removal of COD at different bed height is given below. Treatment column with bed height of 10 cm gave better removal, followed by bed height of 7.5 cm and finally bed height of 5 cm. This shows that the breakthrough point for bed height of 10 cm is longer than bed height of 7.5 cm and 5 cm.

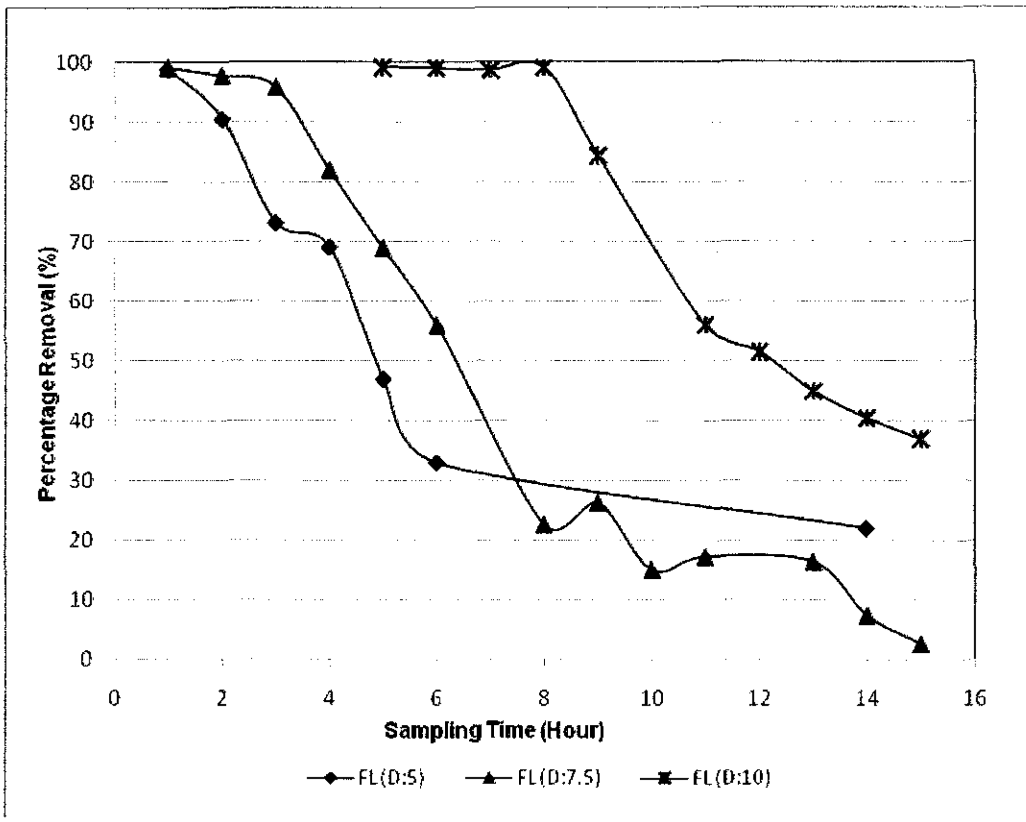


Figure 20: Percentage Removal of Filtered Leachate vs Time

The initial concentration of COD for filtered leachate sample is 4640 mg/L. The breakthrough or the allowable effluent concentration of filtered leachate sample (0.05 Co) is at 232 mg/L. The estimated breakthrough time for treatment column with bed height of 5 cm, 7.5 cm and 10 cm were at 1.5 hour, 3.5 hour and 8.5 hour of treatment.

4.7.2 Comparison on treatment at different bed height for unfiltered leachate sample

The comparison is also made on unfiltered leachate sample effluent. The treatment column with bed height of 7.5 cm gave better percentage removal compared to treatment column with bed height of 5 cm. No comparison is made on the effluent of treatment column with bed height of 10 cm since the volume is too small.

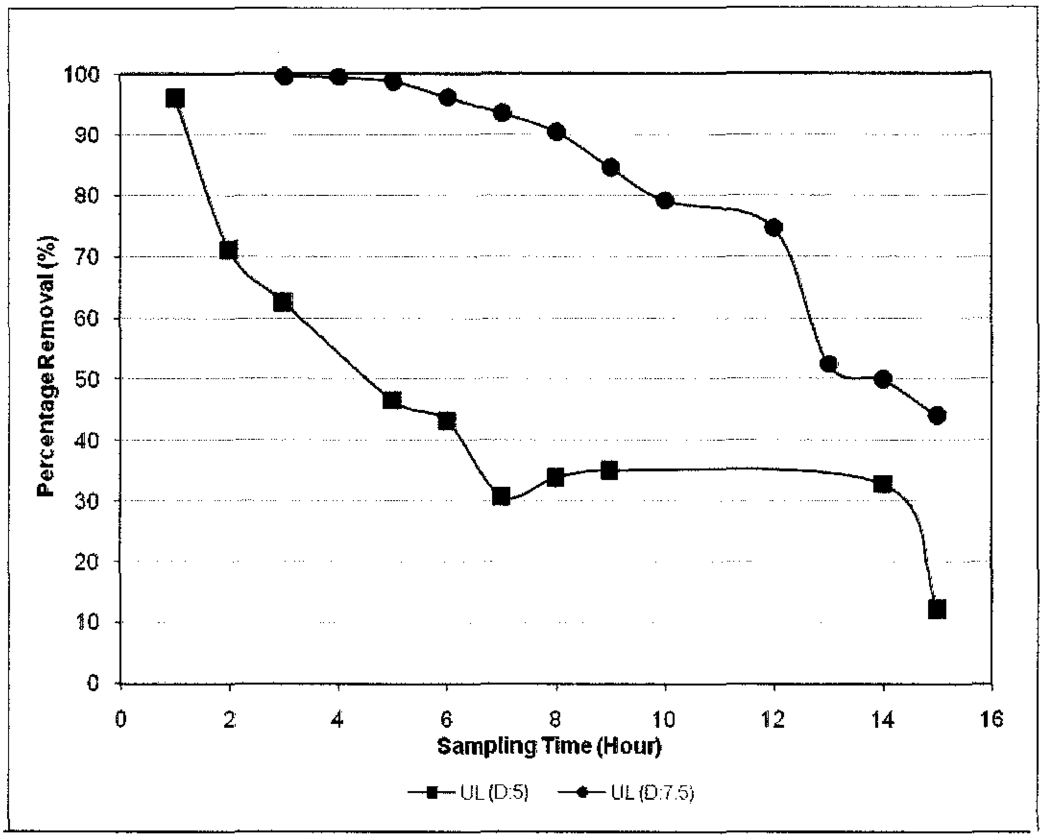


Figure 21: Percentage Removal of Unfiltered Leachate

The initial concentration of COD for unfiltered leachate sample is 5750 mg/L. The breakthrough or the allowable effluent concentration of unfiltered leachate sample is at 287.5 mg/L. The estimated breakthrough time for treatment column with bed height of 5 cm and 7.5 cm were at 1.5 hour and 6.5 hour of treatment.

4.8 Effluent Heavy Metals vs Sampling Time (Hours)

4.8.1 Comparison on treatment of heavy metals at different bed height

The effects of different bed height of adsorbent were also investigated on removal of heavy metal. The tests for heavy metals were only conducted on treatment column with bed height of 7.5 cm and 10 cm treating filtered leachate sample. This is because column with bed height of 5 cm is too short and is expected to remove only small numbers of heavy metals. Meanwhile, the test is not conducted on unfiltered leachate sample since heavy metals are in dissolved solution at low pH.

4.8.1.1 Nickel removal results

The comparison on the effect of bed height for treatment of Nickel is given in the graph below. The concentration on the effluent sample for bed height of 10 cm is lower at the early stage of treatment compared to bed height of 7.5 cm.

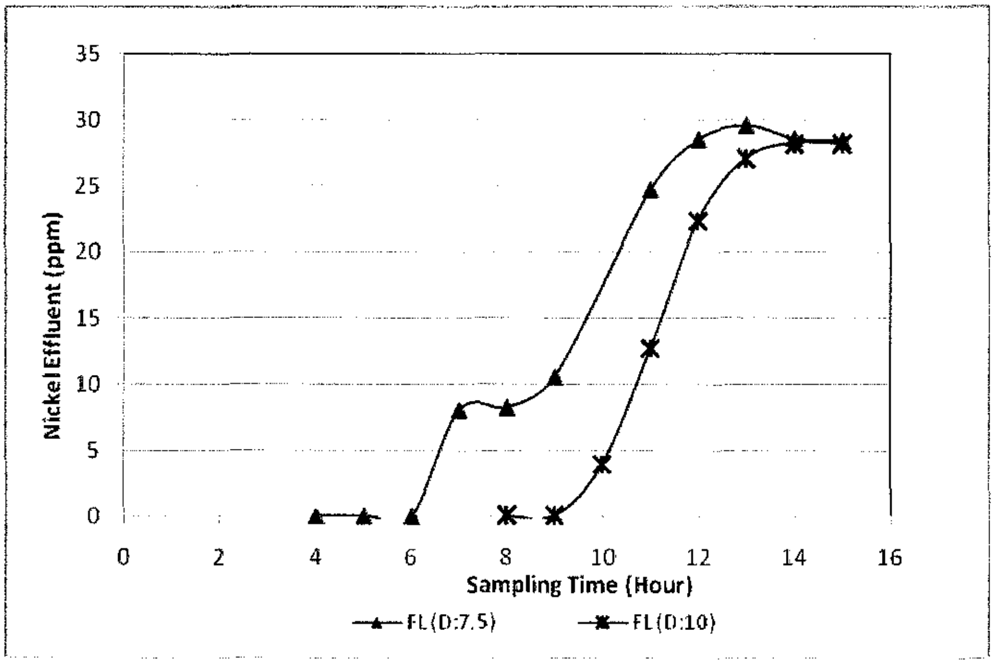


Figure 22: Effluent Nickel vs Sampling Time (Hour)

The initial concentration of Nickel in the leachate sample is 50.575 ppm. The breakthrough or the allowable effluent concentration of Nickel is at 2.53 ppm. The estimated breakthrough time for treatment column with bed height of 7.5 cm and 10 cm were at 6.5 hour and 9.5 hour.

4.8.1.2 Zinc removal results

Figure below shows the comparison on treatment of zinc for two different bed heights, 7.5 cm and 10 cm. treatment column for bed height of 10 cm gave lower concentration and the pattern of removal is more stable compared to treatment column with bed height of 7.5 cm.

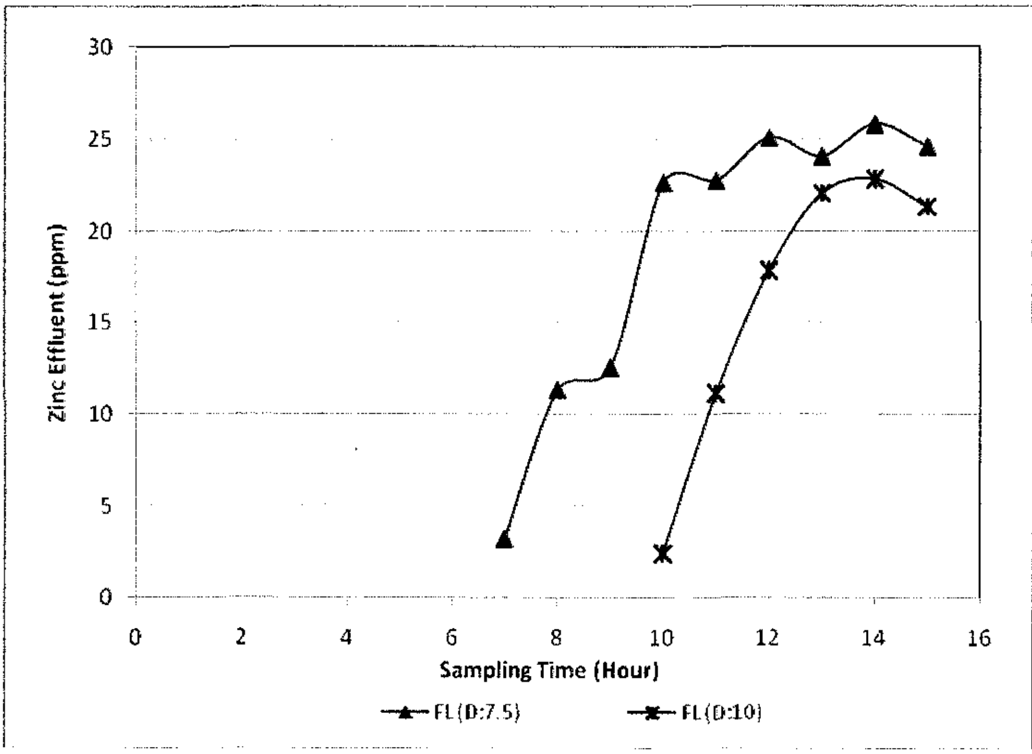


Figure 23: Effluent Zinc vs Sampling Time (Hour)

The initial concentration of Zinc in the leachate sample is 50.575 ppm. The breakthrough or the allowable effluent concentration of Zinc is at 2.96 ppm. The estimated breakthrough time for treatment column with bed height of 5 cm, 7.5 cm and 10 cm were at 6.5 hour and 9.5 hour.

4.8.1.3 Cadmium removal results

For removal of Cadmium from leachate, the effects of different bed heights of treatment column was also investigated. Treatment column with bed height of 10 cm gave lower concentration compared to treatment column with bed height of 7.5 cm at every hour of sample taken.

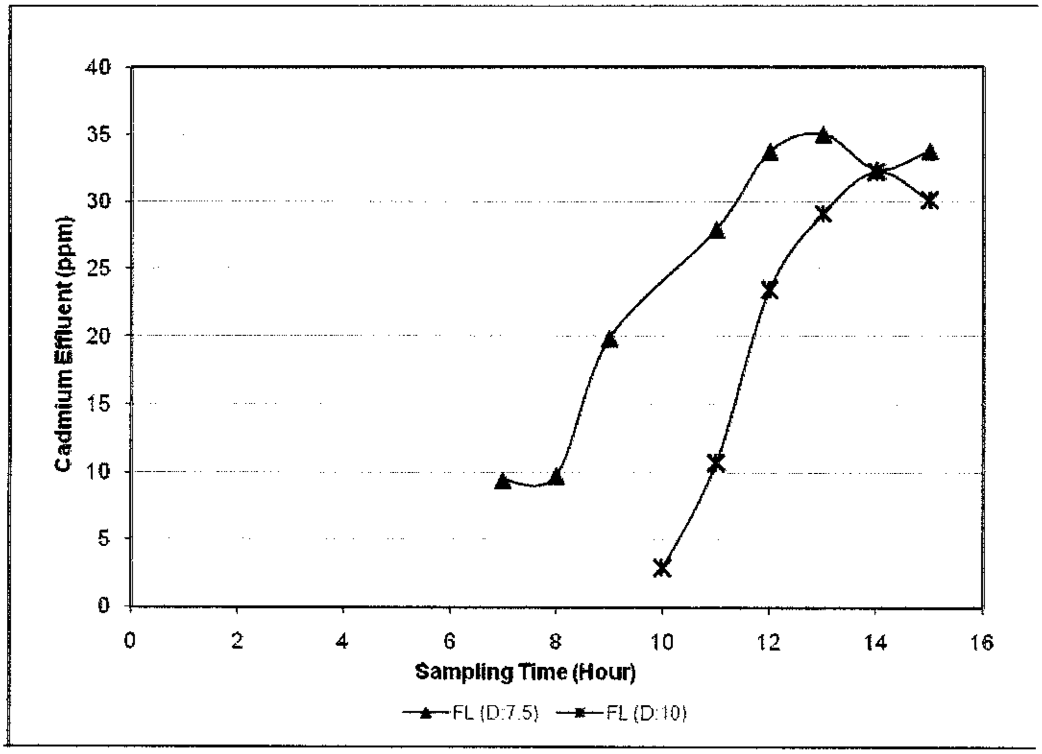


Figure 24: Effluent Cadmium vs Sampling Time (Hour)

4.8.2 Comparison on percentage removal for heavy metals at bed height of 7.5 cm and 10 cm.

The effectiveness of the adsorbent on removing three different kinds of heavy metals was also investigated. Below is the graph of comparison on percentage removal of Nickel, Zinc and Cadmium at bed height of 7.5 cm and 10 cm.

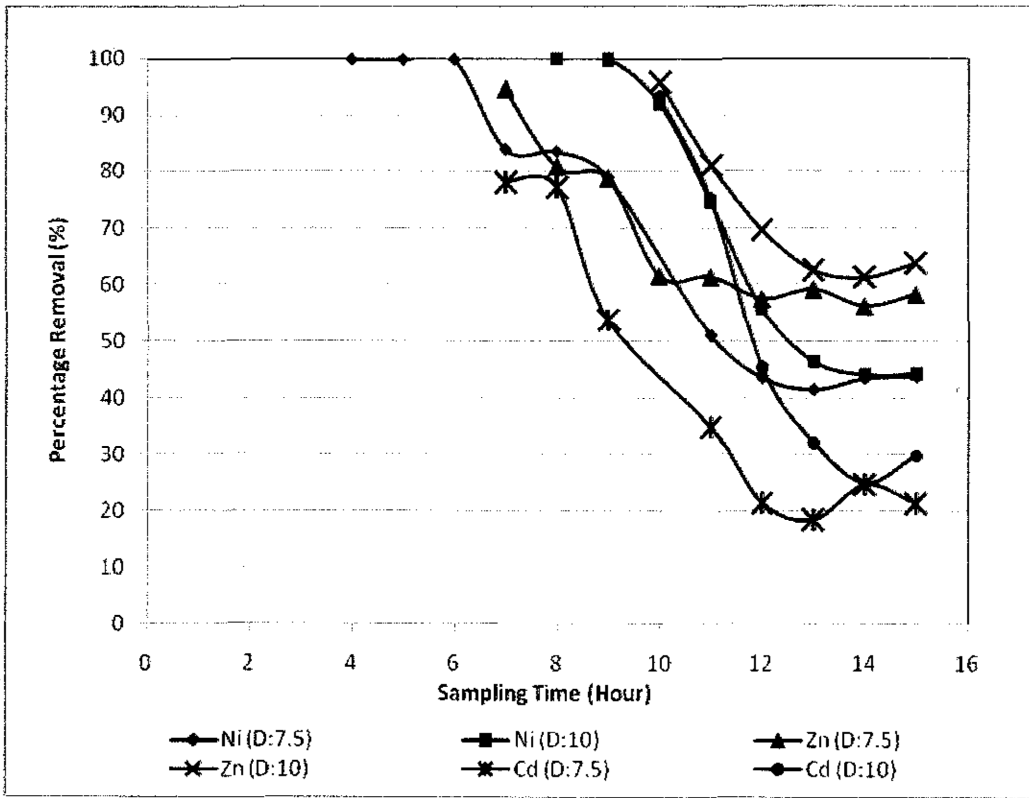


Figure 25: Percentage Removal of Heavy Metals vs Sampling Time (Hour)

From the graph, it is known that treatment column of 10 cm perform better than treatment column of 7.5 cm. In addition, nickel gave almost 100% removal at the first few hours of treatment. However, throughout the experiment, the percentage removal of Zinc is higher than Zinc. In conclusion, GWTPS removes Zinc the best, followed by Nickel and finally Cadmium.

4.9 Scale-up Approach

Scale-up approach was done to determine the new breakthrough time and volume of the design column with respect to test column.

4.9.1 Scale-up for COD

Table 6: Scale-up for New Design Column (COD)

Parameter	Pilot Scale	New Design Column

BV Design (m³)	2×10^{-4}	208.333
Initial Co (mg/L)	4640	4640
Allowable Ce (mg/L)	232	232
Mass (kg)	0.11875	237287.87
Breakthrough Time (hr)	8.5	5131
Breakthrough Volume (m³)		213.8

4.9.2 Scale-up for Heavy Metals

4.9.2.1 Scale-up for Nickel

Table 7: Scale-up for New Design Column (Nickel)

Parameter	Pilot Scale	New Design Column
BV Design (m³)	2×10^{-4}	208.333
Initial Co (mg/L)	50.575	50.575
Allowable Ce (mg/L)	2.957	2.957
Mass (kg)	0.11875	237287.87
Breakthrough Time (hr)	8.5	6595
Breakthrough Volume (m³)		274.79

4.9.2.2 Scale-up for Zinc

Table 8: Scale-up for New Design Column (Zinc)

Parameter	Pilot Scale	New Design Column
BV Design (m³)	2×10^{-4}	208.333
Initial Co (mg/L)	59.132	59.132
Allowable Ce (mg/L)	2.956	2.956
Mass (kg)	0.11875	237287.87
Breakthrough Time (hr)	10.5	8199
Breakthrough Volume (m³)		341.63

4.9.2.3 Scale-up for Cadmium

Table 9: Scale-up for New Design Column (Cadmium)

Parameter	Pilot Scale	New Design Column
BV Design (m^3)	2×10^{-4}	208.333
Initial Co (mg/L)	43.01	43.01
Allowable Ce (mg/L)	2.15	2.15
Mass (kg)	0.11875	237287.87
Breakthrough Time (hr)	9.5	6595
Breakthrough Volume (m^3)		274.8

Table 6 to Table 9 gave the new breakthrough time and volume for the new design column. The calculation is done by scaling up the value obtained from the test done in laboratory to the value of new design column. The example to calculate new breakthrough time and volume to treat COD of leachate sample is attached in Appendix IV.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Research Conclusion

This study concludes that GWTPS has the capabilities to be an adsorbent to treat leachate. Almost all treatment columns gave almost 100% removals of COD and heavy metals at the early stage of treatment. However, the removal decreases as the flow rate increases. The adsorption sites of the adsorbent are filled and stop when there are no longer space to accommodate the solid concentration of the COD and heavy metals. At this point, the adsorbent is said to reach the limit of adsorption or exhausted. Effluent for treatment column of both leachate samples were about the same despite higher percentage removal is given by treatment column for unfiltered leachate samples. Better removal is observed on treatment column with thicker bed height. Thicker bed height gave longer contact time between leachate sample and adsorbent. More solid concentration is filled in the adsorption sites. Based on the study, GWTPS is also known best to remove Zinc, followed by Nickel and finally Cadmium.

5.2 Recommendation for Future Studies

Several recommendations to improve the study are given below together with the reason for recommendation.

1) Recommendation : Conduct Column Study at outside temperature ±32°C
   Reason : Current treatment is done at outside temperature.

2) Recommendation : Conduct batch study prior to column study
   Reason : To determine the optimum temperature and pH in removing COD and heavy metals
3) Recommendation : Conduct study on larger test column
   Reason : To get better estimation on new design column
4) Recommendation : Collect effluent samples at shorter duration
   Reason : To observe the breakthrough point

5.3 Recommendation Based on Findings

1) If GWTPS is proposed to be an adsorbent, the inlet concentration shall be reduced first. Based on the column study, there are removals of COD and heavy metals during the treatment process. However, the breakthrough time (effluent concentration meet Standard A or B) occurred too fast. Hence, pre-treatment is needed prior to this treatment. The suggested treatment is by having a pretreatment by flocculation and coagulation to reduce the number of COD and heavy metals in the leachate samples. The treated leachate is later sent to adsorption tank for further treatment.

REFERENCE

1) Ahmed El-Gendy, 2003. Leachate Treatment using Natural System

2) Aksu and Gonen, (2004). Biosorption of phenol by immobilized activated sludge in a continuous packed bed: Prediction of breakthrough curves, Process Biochem. 39, pp. 599–613.

3) Hamidi Abdul Aziz, Salina Alias, Mohd Nordin Adlan, Faridah, A.H. Asaari, Mohd Shahrir Zahari, 2005. Colour removal from landfill leachage by coagulation and flocculation processes. Bioresource Technology 98 (2007) p 218-220.

4) Jilang Pan and Nickolaos Voulvoulis, 2007. The role of mechanical and biological treatment in reducing methane emissions from landfill disposal of municipal solid waste in the United Kingdom; Env. Eng 2007, 57, 155-163.

5) Keyno John Shellenbarger, 1985. Adsorption of Phenols and Endrin from a Hazardous Waste Landfill Leachate.

6) Metcalf and Eddy, 2004. Wastewater Engineering; Treatment and Reuse 4th Edition, Mc Graw Hill.

7) Michael Mavros, Nikolaos P. Xekoukoulotakis, Dionissios Mantzavinos, Evan Diamadopoulos, 2007. Complete treatment of olive pomace leachate by coagulatuion, activated-carbon adsorption and electrochemical oxidation.

8) N.Calace, A.Liberatori, B.M Petronio, 2000. Characteristic of Different Molecular Weight Fractions of Organic Matter in Landfill Leachate and their Role of Soil Sorption of Heavy Metals.

9) Noor Ida Amalina, 2006. Leachate Treatment using Constructed Wetland with Magnetic Field.

10) R.P Han, D.D Ding, Y.F Xu, W.H Zou, Y.F Wang, Y.F Li and Lina Zou, 2007. Use of rice husk for the adsorption of congo red from aqueous solution in column mode. Bioresource Technology 99 (2008), 2938-2946.

11) Rasool B. Mahar, Jianguo Liu, Dongbei Yue, and Yongfeng Nie, 2007. Biodegradation of organic matters from mixed unshredded municipal solid waste through air convection before landfilling; J. Env. Eng 2007, 57, 39-46.

12) Tom D. Reynolds, 1982. Unit Operations and Processes in Environmental Engineering, PWS Kent.

13) Weber, W.J (1972). Physiochemical Process for Water Quality Control. Wiley-Interscience, Inc., Canada. p 199-211.

APPENDICES

APPENDIX I

OSHA Guide of Chemical Hazard

1.0 CADMIUM

1.1 Cadmium (II) Compounds

Personal Protection & Sanitation	First Aid
Skin: Prevent skin contact Eyes: Prevent eye contact Wash skin: When contaminated Remove: When wet or contaminated	Eye: Irrigate immediately Skin: Water flush promptly Breathing: Respiratory support Swallow: Medical attention immediately

1.2 First Aid Procedures

Code	Definition
Eye: Irrigate immediately	If this chemical gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.
Skin exposure	If this chemical gets on the skin, wash the contaminated skin using soap or mild detergent and water. Be sure to wash the hands well before eating or smoking and at the close of work.
Breathing	If a person breathes in large amounts of cadmium dust, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.
Swallowing	When cadmium dust or liquids containing cadmium dust have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious

	person vomit. Get medical attention immediately.
Rescue	Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

1.3 Toxicity

Short-term	Long-term
Can cause irritation of the nose and throat. If enough has been inhaled, after a delay of several hours, a person may also develop cough, chest pain, sweating, chills, shortness of breath and weakness. Death may occur. Ingestion of cadmium dust may cause nausea, vomiting, diarrhea, and abdominal cramps.	Repeated or prolonged exposure to cadmium may cause loss of sense of smell, ulceration of the nose, shortness of breath (emphysema), kidney damage, and mild anemia. Exposure to cadmium had also been reported to cause an increased incidence of cancer of prostate in man.

2.0 Zinc

2.1 Zinc (II) Compounds

Personal Protection & Sanitation	First Aid
Skin: Prevent skin contact	Eye: Irrigate immediately
Eyes: Prevent eye contact	Skin: Water flush promptly
Wash skin: When contaminated	Breathing: Respiratory support
Remove: When wet or contaminated	Swallow: Medical attention immediately

2.2 First Aid Procedures

Code	Definition
Eye: Irrigate immediately	If this chemical gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If

	irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.
Skin exposure	If this chemical gets on the skin, wash the contaminated skin using soap or mild detergent and water. Be sure to wash the hands well before eating or smoking and at the close of work.
Breathing	If a person breathes in large amounts of cadmium dust, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.
Swallowing	When cadmium dust or liquids containing cadmium dust have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.
Rescue	Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

2.3 Toxicity – Effects to humans

Inhalation or ingestion of inorganic lead has caused peripheral neuropathy with paralysis of the muscles of the wrists and ankles, encephalopathy, anemia (due to decreased red blood cell life and impaired herne synthesis), proximal kidney tubule damage, decreased kidney function, and chronic kidney disease. Zinc can accumulate in the soft tissues and bones, with the highest accumulation in the liver and kidneys, and elimination is low. Zinc can penetrate the placental barrier, resulting in neurologic disorders of infants.

2.3.1 Signs and symptoms of exposure

Short-term	Long-term
Cause decreased appetite, insomnia, headache, muscle and joint pain, colic and constipation.	Weakness, weight loss, nausea, vomiting, constipation, blue or blue-black dot-like pigmentation on the gums, severe headache and abdominal cramps, delirium, convulsions and coma.

3.0 Nickel

3.1 Nickel (II) Compounds

Personal Protection & Sanitation	First Aid
Skin: Prevent skin contact	Eye: Irrigate immediately
Eyes: Prevent eye contact	Skin: Water flush promptly
Wash skin: When contaminated	Breathing: Respiratory support
Remove: When wet or contaminated	Swallow: Medical attention immediately

3.2 First Aid Procedures

Code	Definition
Eye: Irrigate immediately	If this chemical gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.
Skin exposure	If this chemical gets on the skin, wash the contaminated skin using soap or mild detergent and water. Be sure to wash the hands well before eating or smoking and at the close of work.
Breathing	If a person breathes in large amounts of cadmium dust, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

Swallowing	When cadmium dust or liquids containing cadmium dust have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.
Rescue	Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

3.3 Toxicity – Effects to humans

Inhalation or ingestion of inorganic lead has caused peripheral neuropathy with paralysis of the muscles of the wrists and ankles, encephalopathy, anemia (due to decreased red blood cell life and impaired herne synthesis), proximal kidney tubule damage, decreased kidney function, and chronic kidney disease. Nickel can accumulate in the soft tissues and bones, with the highest accumulation in the liver and kidneys, and elimination is low. Nickel can penetrate the placental barrier, resulting in neurologic disorders of infants.

3.3.1 Signs and symptoms of exposure

Short-term	Long-term
Cause decreased appetite, insomnia, headache, muscle and joint pain, colic and constipation.	Weakness, weight loss, nausea, vomiting, constipation, blue or blue-black dot-like pigmentation on the gums, severe headache and abdominal cramps, delirium, convulsions and coma.

APPENDIX II

Preparation of Heavy Metals into Leachate Sample

After pH adjustment, chemicals (Zn, Cd and Ni) were added into both filtered and unfiltered leachate sample. The chemicals were designed to be added at 20 L of leachate samples at concentration of 100 mg/L.

- Zinc preparation into leachate samples [Zn(NO3)2]

Atomic Weight, Zn = 65.39
Atomic Weight, N = 14.0067
Atomic Weight, O = 15.9994

Molecular Weight, Zn(NO3)2 = 65.39 + [14.0067 + 2(15.9994)]2
= 189.3998

Mass of Zn(NO3)2, g to be added = 100 mg/L x $\frac{189.3998}{65.39}$ x 20 L
= 5.7929 g

- Cadmium preparation into leachate samples [Cd(NO3)2]

Atomic Weight, Cd = 112.411
Atomic Weight, N = 14.0067
Atomic Weight, O = 15.9994

Molecular Weight, Zn(NO3)2 = 112.411 + [14.0067 + 2(15.9994)]2
= 236.42

Mass of Cd(NO3)2, g to be added = 100 mg/L x $\frac{236.42}{112.411}$ x 20 L
= 4.2064 g

- Nickel preparation into leachate samples [NiCl2]

Atomic Weight, Ni = 58.69

Atomic Weight, Cl = 35.453

Molecular Weight, NiCl2 = 58.69 + 2(35.453)

= 129.596

Mass of NiCl2, g to be added = $100 \text{ mg/L} \times \frac{129.596}{58.69} \times 20 \text{ L}$

= 4.4619 g

APPENDIX III

Experimental Data

1) Accumulated Volume for Each Treatment Column

Table 10: Total Effluent Volume for Each Treatment Column

Hour	FL (D:5)	UL (D:5)	FL (D:7.5)	UL (D:7.5)	FL (D:10)	UL (D:10)
1	25	30	33	19	7	7
2	43.5	56	63	34	13.5	12.8
3	57.5	75	88	44.5	18	17.3
4	68	85.5	108	52.7	21.5	20.8
5	77.5	102.5	133	60.7	24.2	23.6
6	82.5	121.5	162	67.2	36	24.9
7	90	139.5	195	79.2	61	27.4
8	97.5	155	230	93.2	93.5	29.9
9	103.5	172	256	103.2	120.5	31.4
10	109.8	188	289	114.7	154.5	32.9
11	116.3	202	335	128.7	187.5	34.4
12	120.1	213.7	387	144.7	240	35.9
13	124.1	224.2	431	156.7	301	37.4
14	128.1	228.7	466	169.7	364	38.9
15	131.1	235.2	491	180.7	402.5	40.4

2) COD Concentrations for Each Treatment Column

Initial Concentration:

Filtered Leachate, FL = 4640 mg/L

Unfiltered Leachate, UL = 5650 mg/L

Table 11: COD Concentrations per Hour

Hour	FL (D:5)	UL (D:5)	FL (D:7.5)	UL (D:7.5)	FL (D:10)
1	49.5	220	38.5		
2	430	1660	100		
3	1240	2150	190	20	
4	1430	3650	830	30	
5	2460	3070	1440	70	40
6	3110	3260	2040	220	50
7		3975		370	70
8		3800	3590	550	50
9		3730	3420	890	890
10			3940	1200	
11			3840		2520
12				1460	2780
13			3880	2740	3160
14	3620	3860	4300	2880	3420
15		5040	4520	3220	3620

3) Nickel Concentrations for Each Treatment Column

Initial Concentration:

Filtered Leachate= 50.575 ppm

Table 12: Nickel Concentration per Hour

	FL (D:7.5)	FL (D:10)
1		
2		
3		
4	0.054	
5	0.054	

6	0.072	
7	8.136	
8	8.322	0.024
9	10.638	0.042
10		3.978
11	24.72	12.8
12	28.54	22.38
13	29.58	27.06
14	28.58	28.22
15	28.42	28.18

4) Zinc Concentrations for Each Treatment Column

Initial Concentration:

Filtered Leachate= 59.13 ppm

Table 13: Zinc Concentration per Hour

14 15	FL (D 7.5) 25.905 24.671	FL (D 10) 22.856 21.398
1		
2		
3		
4		
5		
6		
7	3.203	
8	11.348	
9	12.564	
10	22.664	2.396
11	22.793	11.137
12	25.137	17.897
13	24.137	22.091

5) Cadmium Concetrations for Each Treatment Column

Initial Concentration:

Filtered Leachate= 43.01 ppm

Table 14: Cadmium Concetrations per Hour

	FL (D:7.5)	UL (D:10)
1		
2		
3		
4		
5		
6		
7	9.435842	
8	9.792945	
9	19.89082	
10		2.898385
11	27.97606	10.71609
12	33.77457	23.50933
13	35.07098	29.16641
14	32.40155	32.28369
15	33.81582	30.15639

APPENDIX IV

Scale-up Approach

Scale up approach is done to determine the breakthrough volume and time on the new design column based on the test column. From the results of COD and heavy metals, the scale up approach is given below:

1) Scale-up for COD

BV = volume occupied by adsorbent bed including adsorbent volume and pore volume.

BV Design:

Volume = $\pi D^2/4$ x bed height

= π (0.05 m)^2 / 4 x 0.1 m

= 2 x 10^-4 mα

Initial concentration of COD= 4640 mg/L

Allowable effluent concentration, Cα= 232 mg/L

1) Design Bed Volume, m^3=

   BV= Q/Qb = 1 m^3/24 hr x 1hr/ 2 x 10^-4

   = 208.333 m^3

2) Design mass of adsorbent required=

   M = (BV)ρs

   = 208.33 m^3 x 1139 kg/m^3

   = 237287.87 kg

3) The breakthrough time, T in hours and days

   From the breakthrough curve, the volume treated at the allowable breakthrough, Cα of 232 mg/L is at 8.5 hours where the volume collected is 107 mL

   The solution treated per kg GWTPS, Vb is=

   = 0.107 mL/ 0.11875 kg

   = 0.901 L/kg

Mt = the kilograms of adsorbent exhausted per hour

= flow rate divided by the volume treated per kilogram of GWTPS

= 1 m3/24 hr x kg/0.901 L x 1000 L/1 m3

= 46.245 kg/hr

The breakthrough time is

T =M/Mt

= (237287.87 kg)(h/46.245 kg)

= 5131 hrs

4) The breakthrough volume, Vb for the design column is=

Vb = Q xT

= 1 m3/d x 5131 hr x 1 d/24 hr

= 213.8 m3

2) Scale-up for Nickel

BV Design:

Volume = $\pi D^2/4$ x bed height

= π (0.05 m)^2 / 4 x 0.1 m

= 2 x 10^-4 m^3

Initial concentration of COD= 50.575 ppm

Allowable effluent concentration, $C\alpha$= 2.95658 ppm

1) Design Bed Volume, m^3=

BV= Q/Qb = 1 m^3/24 hr x 1hr/ 2 x 10^-4

= 208.333 m^3

2) Design mass of adsorbent required=

M = (BV)ρs

= 208.33 m^3 x 1139 kg/m^3

= 533.33 kg

3) The breakthrough time, T in hours and days

From the breakthrough curve, the volume treated at the allowable breakthrough, $C\alpha$ of 2.528 ppm is at 9.5 hours where the volume collected is 137.5 mL

The solution treated per kg GWTPS, Vb is=

Vb = 0.1375 mL/ 0.11875 kg

= 1.158 L/kg

Mt = the kilograms of adsorbent exhausted per hour

= flow rate divided by the volume treated per kilogram of GWTPS

= 1 m3/24 hr x kg/1.158 L x 1000 L/1 m3

= 35.98 kg/hr

The breakthrough time is

T =M/Mt

= (533.33 kg)(h/35.98 kg)

= 14.823 hr

4) The breakthrough volume, Vb for the design column is=

Vb = Q xT

= 1 m3/d x 14.823 hr x 1 d/24 hr

= 0.6176 m^3

3) Scale-up for Zinc

BV Design:

Volume = $\pi D^2/4$ x bed height

= π (0.05 m)^2 / 4 x 0.1 m

= 2 x 10^-4 m^3

Initial concentration of COD= 59.1316 ppm

Allowable effluent concentration, $C\alpha$= 2.956 ppm

1) Design Bed Volume, m^3=

BV= Q/Qb = 1 m^3/24 hr x 1hr/ 2 x 10^-4

= 208.333 m^3

2) Design mass of adsorbent required=

M = (BV)ρs

= 208.33 m^3 x 1139 kg/m^3

= 237287.87 kg

3) The breakthrough time, T in hours and days

From the breakthrough curve, the volume treated at the allowable breakthrough, Cα of 2.956 ppm is at 10.5 hours where the volume collected is 171 mL

The solution treated per kg GWTPS, Vb is=

Vb = 0.171 mL/ 0.11875 kg

= 1.44 L/kg

Mt = the kilograms of adsorbent exhausted per hour

= flow rate divided by the volume treated per kilogram of GWTPS

= 1 m3/24 hr x kg/1.44 L x 1000 L/1 m3

= 28.94 kg/hr

The breakthrough time is

T =M/Mt

= (237287.87 kg)(h/28.94 kg)

= 8199 hr

4) The breakthrough volume, Vb for the design column is=

Vb = Q xT

= 1 m3/d x 8199 hr x 1 d/24 hr

= 341.63 m3

4) Scale-up for Cadmium

BV Design:

Volume = $\pi D^2/4$ x bed height

= π (0.05 m)^2 / 4 x 0.1 m

= 2 x 10^-4

Initial concentration of Cadmium= 43.0102 ppm

Allowable effluent concentration, $C\alpha$= 2.1505 ppm

1) Design Bed Volume, m^3=

   BV= Q/Qb = 1 m^3/24 hr x 1hr/ 2 x 10^-4

   = 208.333 m^3

2) Design mass of adsorbent required=

   M = (BV)ρs

   = 208.33 m^3 x 1139kg/m^3

   = 237287.87 kg

3) The breakthrough time, T in hours and days

   From the breakthrough curve, the volume treated at the allowable breakthrough, $C\alpha$ of 2.1505 ppm is estimated at 9.5 hours where the volume collected is 137.5 mL

   The solution treated per kg GWTPS, Vb is=

   Vb = 0.1375 mL/ 0.11875 kg

   = 1.158 L/kg

   Mt = the kilograms of adsorbent exhausted per hour

   = flow rate divided by the volume treated per kilogram of GWTPS

   = 1 m3/24 hr x kg/1.158 L x 1000 L/1 m3

   = 35.98 kg/hr

   The breakthrough time is

   T =M/Mt

   = (237287.87 kg)(h/35.98 kg)

   = 6595 hr

4) The breakthrough volume, Vb for the design column is=

   Vb = Q xT

   = 1 m3/d x 6595 hr x 1 d/24 hr

   = 274.8 m3