ASSESSMENT OF HEAVY METAL CONTAMINATION IN SOIL DUE TO LANDFILL LEACHATE AND INDUSTRIAL WASTEWATER

AZZIATUL KHADIJAH BINTI IBRAHIM

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : Azziatul Khadijah Binti Ibrahim

Date of Birth : 30 September 1994

Title : Assessment of Heavy Metal Contamination in Soil Due to Landfill Leachate and Wastewater

Academic Session : 2016/2017

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

____
(Student's Signature)

____
(Supervisor's Signature)

____
New IC/Passport Number
Date:

____
Name of Supervisor
Date:

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor (Hons.) in Civil Engineering.

____

(Supervisor's Signature)

Full Name :

Position :

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : AZZIATUL KHADIJAH BINTI IBRAHIM

ID Number : AA13077

Date : 16 June 2017

ASSESSMENT OF HEAVY METAL CONTAMINATION IN SOIL DUE TO LANDFILL LEACHATE AND INDUSTRIAL WASTEWATER

AZZIATUL KHADIJAH BINTI IBRAHIM

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2017

ACKNOWLEDGEMENTS

Alhamdulillah

Thank you to all my supporters.

ABSTRAK

Larut resapan ialah cecair yang disalirkan melalui sisa pepejal dan menghasilkan cecair berbahaya. Selain itu, air kumbahan daripada semua industri ini boleh mengandungi banyak logam berat, minyak, kimia organik dan asid. Semua bahan pencemar boleh menjejaskan kesihatan dan alam sekitar insan berkualiti. Di samping itu, bahan pencemar ini juga boleh memberi kesan kepada kualiti air bawah tanah dan tanaman pertanian. Terdapat 12 sampel telah diperiksa untuk mengetahui kepekatan logam berat yang datang dari Kuantan Jabor-Jerangau bersepadu tapak pelupusan dan kereta bengkel berhampiran Gambang dengan menggunakan spektroskopi penyerapan atom (AAS). logam berat yang telah diuji Cu, Cd, Zn dan Pb. Kaedah yang digunakan untuk mengetahui tahap pencemaran dan pencemaran di dalam tanah kerana kepekatan logam berat adalah indeks geoaccumulation (I_{geo}) dan indeks beban pencemaran (PLI). Untuk mengetahui faktor yang mempengaruhi partition larutan pepejal logam berat dalam tanah, beberapa ujian telah dijalankan yang pH, kandungan bahan organik, kekonduksian elektrik dan analisis ayak. Nilai min pH di kawasan tapak pelupusan dan kawasan industri masing-masing 6.38 dan 6.29. Dan, untuk nilai min bahan organik di kawasan tapak pelupusan adalah 9,039% dan kawasan industri adalah 6,396%. Min kepekatan logam berat dalam sampel tanah adalah dalam tertib menurun seperti berikut: Zn> Pb> Cu> Cd. Tanah bengkel kereta dicirikan oleh kepekatan yang lebih tinggi Cu, Pb dan Zn daripada tanah di kawasan tapak pelupusan. Nilai I_{geo} untuk Zn menunjukkan tahap pencemaran di kawasan industri dan kawasan tapak pelupusan lebat dan sederhana tercemar masing-masing. Plus, PLI untuk semua kawasan persampelan tidak tercemar kerana nilai julat adalah lebih rendah daripada 1.

ABSTRACT

Leachate is the liquid that drained through the solid waste and produce the hazardous liquid. Besides, the wastewater from all these industries can contain a lot of heavy metals, oil, organic chemical and acids. All the pollutants can affect the human health and environment quality. In addition, these pollutant also can affect the quality of groundwater and agricultural crops. There are 12 samples were examined in order to know the concentration of heavy metal that came from Kuantan Jabor-Jerangau integrated landfill and car workshop near Gambang by using the atomic absorption spectroscopy (AAS). Heavy metals that have been tested were Cu, Cd, Zn and Pb. The method used to know the level of pollution and contamination in soil due to the heavy metal concentration were geoaccumulation index (I_{geo}) and pollution load index (PLI). In order to know the factor that affecting the solid solution partition of heavy metal in soil, several test were conducted that are pH, organic matter content, electrical conductivity and sieve analysis. The mean value of pH at landfill area and industrial area are 6.38 and 6.29 respectively. And, for mean value of organic matter in landfill area is 9.039 % and industrial area is 6.396 %. The mean concentrations of heavy metals in the soil samples are in decreasing order as follows: Zn>Pb>Cu>Cd. The car workshop soil characterized by higher mean concentration of Cu, Pb and Zn than the soil at landfill area. I_{geo} result for Zn shows the contamination level in industrial area and landfill area are heavily and moderately contaminated respectively. Plus, PLI for all sampling area are not polluted because the range value is lower than 1.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS

As	Arsenic
Ba	Barium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Hg	Mercury
Ni	Nickel
Pb	Lead
Zn	Zinc

LIST OF ABBREVIATIONS

AAS	Atomic absorption spectroscopy
EC	Electrical conductivity
FM	Fineness modulus
$Igeo$	Geoaccumulation index
MSW	Municipal solid waste
OM	Organic matter
pH	Potential of hydrogen
PLI	Pollution load index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Due to increase of population and modernization, there are a lot of ideas has been generated to reduce the economic gap and to accumulate the productivity in a country. Thus, there are considerable industries and development that have their own function and purpose to improve the quality of life. However, because owing to lack of awareness and knowledge, most of these industries are not managed properly and systematically their industrial wastewater (UN WWAP, 2017). Consequently, all the industrial effluents and wastes were discharged without following the rules by the authorities.

In Malaysia, the economic growth is influenced by the industries like manufacturing, pharmaceutical, oil and gas producing, rubber processing, agricultural processing, tin mining and smelting and agricultural processing. The wastewater from all these industries can contain a lot of heavy metals, oil, organic chemical and acids. All the pollutants can affect the human health and environment quality. Besides, the soil contamination problem seems like become worsen caused by solid waste production every day and everywhere in our country. There are approximately 30,000 tone of solid waste produced every day in Malaysia (Johari *et al.*, 2014). And, 56 percent of the total solid waste need to be dumped. Consequently, there are a lot of municipal solid waste (MSW) landfills that has been built all around the country as one of the initiative to solve the solid waste issues.

However, inadequacy of cost and prowess may result for ineffective and disorganized of MSW landfill owing to tones of solid wastes every day. The environment can be affected not just the unpleasant odour, diseases spread through bird and insects but also the soil properties also changed caused by the leachate (Lee and Anne Jones-

Lee, 2005). Leachate is the liquid that drained through the solid waste and produce the hazardous liquid. As a conclusion, both of industrial wastewater and leachate can cause for heavy metal contamination in soil. The high concentration of heavy metal can be classified as toxic and can harm the human health and environment in many ways. The toxic heavy metal are copper, zinc, cadmium, mercury, arsenic, lead, barium, nickel and chromium.

1.2 Problem Statement of Study

There are several possibilities can occur due to heavy metal contamination in soil that are vulnerable to human health and environment. Human can expose to the heavy metal via the dermal contact that means there is a high potential for the heavy metal in the contaminated soil entered to the human's body just through the skin (touch) (Singh *et al.*, 2011). As a consequence, when a human is exposed towards too much of heavy metal content, it may rise the risk of suffering skin cancer (Singh *et al.*, 2011). Furthermore, these heavy metal can affect the ground water quality that flow within the soil particles. In detail, when the soil particles can no longer sustain the sufficient amount of heavy metal caused by persistent of pollutants or changes in pH, then the heavy metal will penetrate to the ground water under the affected area (Taghipour *et al.*, 2012). Moreover, the present of heavy metal also can give an impact to the quality of agricultural crops. Subsequently, the end product in this chain is humans' food sources.

1.3 Objectives

The goals of this study are:

1) To analyse the contamination level of heavy metal in studied soils at landfill and industrial area.

2) To classify the level of contamination in soil based on pollution load index (PLI) and geoaccumulation index (I_{geo}).

1.4 Scope of Study

1.4.1 Area

In this study, the sample used come from Kuantan Jabor-Jerangau Integrated Landfill (Figure 1.1) and car wash center near Gambang (Figure 1.2) to collect the affected soil caused by leachate and wastewater respectively.

1.4.2 Layer of soil sample

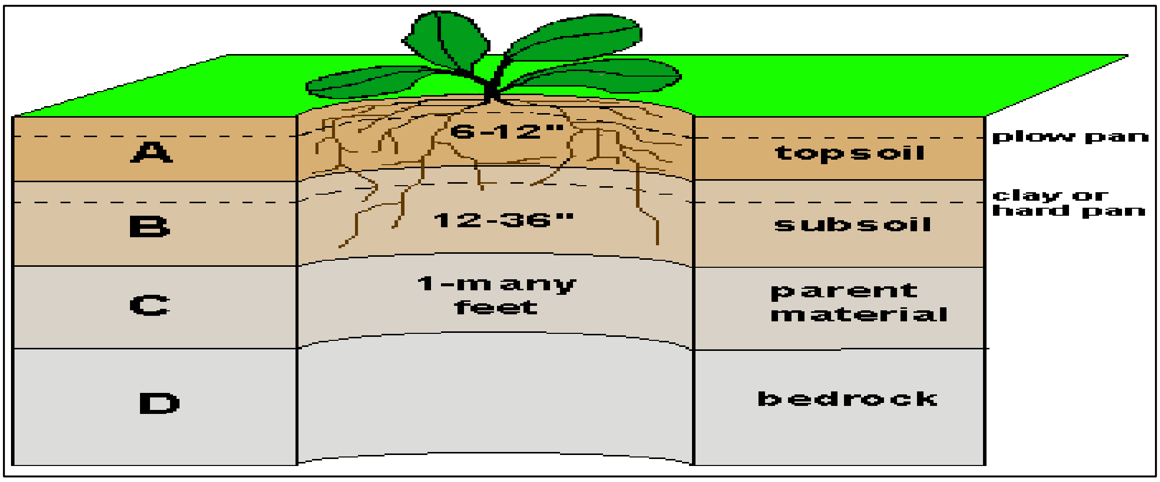


Figure 1.3 Layer of soil

Referred to Figure 1.3 above, the soil sample are taken out from surface layer and the region A that is 6 to 12 inches depth that categorized as topsoil.

1.4.3 Type of heavy metal

1) Cadmium (Cd) is a soft and bluish-white metal in the Group 12 of the periodic table. This element can be used as corrosion-resistant plating for steel and can be a compound that give the yellow, red and orange color for the glass production. Plus, cadmium compound can act as the plastic stabilizer and be used in batteries manufacturing.

2) Zinc (Zn) is one of the other metal that placed in the Group 12 of the periodic table has five stable isotopes. Zinc is one of the metal that can be produced to become alloy and very popular in the manufacturing industries. Some of the industries that used this element as zinc oxide are paint, rubber, cosmetics and plastics.

3) Copper (Cu) has the physical properties that are soft and workable with the colour of reddish-orange. This element is very good to use as heat and electric conductor. So that, copper is mostly use as electrical equipment such as wires.

4) Ambient background air concentrations of zinc are generally $<1\ \mu g/m^3$ (Roney *et al.*, 2005). Zinc is found in soils and surficial materials of the contiguous United States at concentrations between <5 and 2,900 mg/kg, with a mean of 60 mg/kg. The zinc background concentrations in surface waters are usually <0.05 mg/L, but can range from 0.002 to 50 mg/L (Roney *et al.*, 2005).

1.5 Significant of Study

This study is very significant to collect all the data related to the heavy metal contamination in the soil samples. The after-effect of this study can help the parties involved to know about the contamination and take the first step of precaution so the issues regarding to the heavy metal contamination in our country will be reduce. Besides, this study also can give early exposure to the about the risk by having the toxic heavy metal in the environment. So, the public can have the awareness to reduce the usage of heavy metal or the right ways to dispose the material that contained the compound. In addition, this study important to make sure the parties involved applied all the specification by the authorities as written in the Environmental Quality Act 1974. And, appropriate action can be levied on the parties that refused to follow all the specifications. Plus, from the outcome of the experiment, the contamination level in the soil can be specified based on the standard throughout this study.

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

This chapter was reviewing the parameters of the contaminated soil and disturbed because of heavy metal in leachate and wastewater. Apart from the parameters of land was inspected and tested briefly to get the result of the soil characteristics.

This test is very important and had been done to see the effects and the changes in soil parameters as influenced by the leachate and wastewater. Information and data are based on references books and internet journals or articles. Source of leachate and wastewater were collected from the selected landfill and also from industry. Test like examining the rate of soil strength, soil moisture content, impermeable rates also done to ensure that the system of soil and soil under water is was not polluted.

This chapter was reviewing the parameters of the contaminated soil that disturbed by the leachate and wastewater. Apart from the parameters of land had been inspected and tested briefly to get the results of the soil characteristics. From the result of the parameter, the soil was labelled as contaminated or not.

2.2 Soil Contamination

Human activities is the main factor that can cause to the soil contamination by affecting the quality and texture of the soil. Soil can be a black or dark brown material as the upper layer of earth that consist of mixture of organic remains, clay and rock particles. While, contamination is a contaminating act or make something impure and not suitable by contact with the unclean, bad and etc. Therefore, soil contamination is a part of land deterioration caused by the presence of chemical from human activities or any material that can harm the environment. The contaminants in soil able to move from a place to another place due to several factors. As an example, the chemical element such as metal can be easier or not taken up by plant or animal because of metal cannot break down but can has the changes of characteristic (Shayler, McBride and Harrison, 2009). Plus, the contaminants in soil have the liability to penetrate into the groundwater, evaporate into the air and attached tightly to the soil particles. There are several main characteristics that may be affected in soil because of the contamination content. The characteristics are soil texture, acidity of soil based on the value of pH, portion of organic matter, temperature and existence of other chemicals.

Figure 2.2.1 Contaminated soil.

2.3 Sources of the soil contamination.

There are a lot of sources that can cause the soil contamination such as lead paint, pesticides, industrial or commercial use and etc. obviously, and all these sources come from anthropogenic (man-made) activities that gets out of control lately.

2.3.1 Lead paint.

There are some types of paint that contain high amount of lead, for example white lead paint, red lead, colored lead paint and lead drying agent. This type of paint mostly used as coloring agent and drying agent for bricks and tiles.

2.3.2 Pesticides.

Pesticide is any substances or mixture of substances done for purpose of averting, disrupting, repelling or mitigating any pest or weed (Salako, Sholeye and Dairo, 2012). Fungicide, herbicide, insecticide, acaricide and molluscicide are few example for type of pesticide.

2.3.3 Industrial or commercial site use.

In every different type of industrial site, there will be several of chemical used in order to make the manufacturing process or any other process. Because of that issue, all of the industrial site must be placed within the allowable distance from public area or property area in order to secure the safety and health of publics. The presence of heavy metals and residues from town and industrial wastes has been found to be the causes of pollution in soil (Sonawane *et al.*, 2010).

2.3.4 Fertilizers.

Any substances that can help the soil fertility and the plant growth by giving the nutrient is called as fertilizer. Sewage bio solids or fly ash are example of waste material that can be used as fertilizer, and this type of material can be the contaminant to soil by increasing the concentration of heavy metal such as cadmium, copper, zinc and lead (Shayler, McBride and Harrison, 2009).

2.3.5 Automobile and machine repair.

The problem arises when there are accidental spills and chemical dumps in public area and this workshop area. Presence of metals and any other material in the chemical used can give the bad effects to the quality of soil. As an example, the used batteries may contain of lead and mercury and engine oil can have nickel and chromium.

2.3.6 Landfill or garbage dump.

The garbage dump can contain a lot of chemical that come from various type of places or location. Landfill leachate usually contains four groups of contaminants, including dissolved organic matters, inorganic compounds (e.g., ammonium, calcium, magnesium, sodium, potassium, iron, sulfates, chlorides), heavy metals (e.g., cadmium, chromium, copper, lead, zinc, nickel…), and xenophobic organic substances, the discharge of which causes serious environmental threats to the surrounding soil, groundwater, and even surface water (Tiwari, 2015). The type of chemical can be determined based on the material that being disposed at the site. Moreover, this issue not just can affect the soil but also can give the very bad smell and odor.

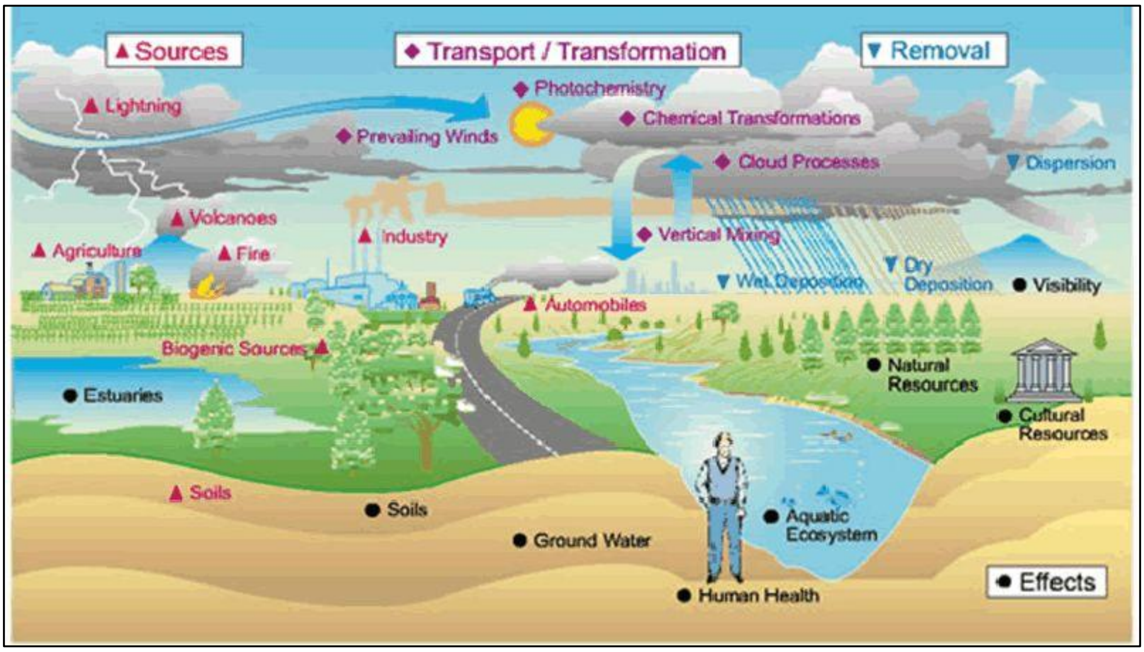


Figure 2.3.6.1 Sources of soil contamination. (Ashraf M.A, Maah, and Yusoff 2014)

2.4 Effect of being exposed to the soil contamination.

The soil contamination can affect the human, animal and environmental health. The harmful effects of soil contamination can come from direct contact with contaminated soil or of relations with other resources, such as water or food that has been grown on or come in direct contact with contaminated soil (European Commission, 2013).

2.4.1 Effect to human health

The severity of the effect to a person depends on the level of exposure to the certain contaminant. Based on Shayler. H et al., (2009) at the age group of a young children are most risky to be attack by the effect and danger of the contaminant because children are more vulnerable to the soil. Individuals who are commonly exposed or make a direct contact with the contaminated soil have the high possibilities to develop the cancer cells in their body (Tchounwou *et al.*, 2012). Besides, soil contamination can cause the organ damage such as the contaminants can damage the developing brain process for young children and able to harm the liver and kidney (Geiger and Cooper, 2010).

Furthermore, for the humans who are consuming the plant or animal that already being affected by the contaminants may be poisoned (Singh *et al.*, 2011).

2.4.2 Effect to animal.

Soil contamination can disturb the food chain by destroying some layer of primary chain and giving a destructive effect to the predator species because of contaminants are negatively giving effect to the microorganisms' and arthropods' metabolism (Kaur and Garg, 2014). Logically, if small life like arthropod consumes the food that already being affected by contaminant, then it can be passed up to larger animal in the food chain and possibilities for mortality will increase.

2.4.3 Effect to plant.

The contaminants in soil are able to evolve the plant metabolism and the consequence is the crop yields will reduce (Ashraf M.A, Maah, and Yusoff , 2014). As a result, it may lead to the soil erosion by reducing the quantity of plant and crop every day. Soil contaminated by acid rain affects plants by interfering with the chemical properties of the soil and reduce the plant's ability to take up nutrients and undergo photosynthesis (Ashraf M.A, Maah, and Yusoff, 2014). Soil pollution also leads to loss of land and natural nutrients present in it, preventing the plant's ability to thrive in the soil which will upset the balance of flora and fauna that live in the soil.

2.5 Toxic heavy metal in soil

Metal toxicity or metal poisoning is the toxic effect of certain metals in certain forms and doses on life. Some metals are toxic when they form poisonous soluble compounds. Examples of heavy metals are lead, cadmium, copper and zinc.

2.5.1 Lead

Lead, Pb is one of the metal in Group IV and period 6 in the periodic table. In addition, lead occur in bluish-gray metal and commonly found as a mineral that combined with other element such as sulfur and oxygen. And lead placed on the fifth rank in the industrial production of metal after Fe, Cu, Al and (Wuana and Okieimen, 2011). Typical mean Pb concentration for surface soils worldwide averages 32 mg kg^{-1} and ranges from 10 to 67 mg kg^{-1} (Wuana and Okieimen, 2011).

2.5.1.1 Environmental Occurrence, Industrial Production and Use

Lead is occurring naturally in the earth however the concentration of lead increase due to anthropogenic activities such as fossil fuel, mining and manufacturing (Tchounwou *et al.*, 2012). Lead has contribute in different type of industries that are agriculture and domestic application and most of this metal used in production of lead-acid batteries, ammunitions, metal products (solder and pipes), and devices to protect X-rays (Tchounwou *et al.*, 2012). Based on Kropschot and Doebrich (2011) at the early 2000s, 88 percent of US apparent consumption of lead is in lead-acid batteries, which is a huge difference from 1960 when just 30 percent of global use of lead in lead-acid batteries.

2.5.1.2 Effects to Human Health.

Lead is able to affect several organs in the body including kidney, liver, central nervous system, hematopoietic system, the endocrine system and the reproductive system (Tchounwou *et al.*, 2012). Furthermore, referred to Wuana R.A. and Okieimen F.E. (2011), Children are exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity and mental decline, with children under age of six are at greater risk. Besides, an adult is possible to experience slower reaction time, memory loss, nausea, insomnia, anorexia, and weakness of the joints when exposed to lead (Wuana and Okieimen, 2011).

2.5.2 Copper

In the periodic table, copper is in Group 11 and period 4 as one of the transition metal element. In addition, copper has atomic number 29, atomic weight 63.5, density 8.96gcm^{-3}, melting point 1083°C and boiling point 2595°C. The metal's average density and concentrations in crustal rocks are 8.1 × 103 kgm^{-3} and 55 $mg\ kg^{-1}$respectively (Wuana and Okieimen, 2011). Copper has a lot of advantages related to its properties such as excellent thermal conductor, corrosion resistant, antibacterial, easily joined, ductile, tough, non-magnetic, attractive colour, easy to alloy, recyclable and catalytic.

2.5.2.1 Environmental Occurrence, Industrial Production and Uses

Copper is a metal that exist naturally in soil, rocks, water and air. Plus, copper also an essential element needed by the plant, animal and human to stay alive (Nagajyoti, Lee, and Sreekanth. 2010). This is because, in human copper can help in the blood haemoglobin production, while in plant copper improves the seed production , for disease resistance and water regulation in cell (Leifert and Group, 2007). Globally, copper is widely used in the production of electrical wiring, printed circuit boards, in generators, electric motors and transformer (Eisentraut and Brown, 2013). Besides, copper also can be use as additives to control the algae growth.

2.5.2.2 Effects to Human Health

Copper consumption is very important in our daily lives, but the uncontrolled use and the usage that exceed the allowable quantities can harm the human health. As a result, copper can cause the anaemia, liver and kidney damage, and stomach and intestinal irritation (Wuana and Okieimen, 2011). Moreover, based on Flemming and Trevors (1989) high doses of copper can cause hypotension, heart disease, premenstrual tension, postpartum depression, paranoid and hallucinatory schizophrenias, and last not least is childhood hyperactivity and autism.

2.5.3 Cadmium

"Cadmium is located at the end of the second row of transition elements with atomic number 48, atomic weight 112.4, density 8.65 gcm^{-3}, melting point 320.9 $^{\circ}$C, and boiling point 765 $^{\circ}$C" (Wuana and Okieimen, 2011). "Cadmium is a lustrous, silver-white, ductile, very malleable metal. Its surface has a bluish tinge and the metal is soft enough to be cut with a knife, but it tarnishes in air" (Wuana and Okieimen, 2011).

2.5.3.1 Environmental Occurrence, Industrial Production and Uses

In the environment, cadmium can mainly be found in the earth's crust and the presence of cadmium come up by the combination with zinc all the time (ECHA, 2012). In the same article, after the application of cadmium, it seems to be able to enter the ground because it is found in the manures and pesticides and surprisingly, there are 25000 tons a year of the cadmium that being released to environment. Moreover, approximately 80% of production associated with cadmium zinc production, while the other 20% is associated with the production of lead and copper by product and cadmium recapture of the finished product (Moscow, cited in ATSDR 2012). There are a lot of industries that are using the cadmium such as batteries, alloys, coatings (electroplating), solar cells, plastic stabilizers, and pigments (Wuana and Okieimen, 2011; Tchounwou *et al.*, 2012). Cadmium is also contained in certain foods such as leafy vegetables, potatoes, grains and seeds, liver and kidneys, and crustaceans and molluscs (Tchounwou *et al.*, 2012).

2.5.3.2 Effects to Human Health

Cadmium is believed to affect the enzymes in the human body. One of the effect is the kidney damage as a result of the destructive effect by cadmium to the enzyme that responsible for reabsorption of proteins in kidney tubules (Wuana and Okieimen, 2011). *"Cadmium also reduces the activity of delta-aminolevulinic acid synthetase, arylsulfatase, alcohol dehydrogenase, and lipoamide dehydrogenase, whereas it enhances the activity of deltaaminolevulinic acid dehydratase, pyruvate dehydrogenase, and pyruvate decarboxylase"* (S.E. Manahan, cited in Wuana and Okieimen 2011).

2.5.4 Zinc

Zinc is released into the environment as the result of mining, smelting of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes. Ambient background air concentrations of zinc are generally <1 μg/m^3 (Roney *et al.*, 2005). Zinc is found in soils and surficial materials of the contiguous United States at concentrations between <5 and 2,900 mg/kg, with a mean of 60 mg/kg. The zinc background concentrations in surface waters are usually <0.05 mg/L, but can range from 0.002 to 50 mg/L (Roney *et al.*, 2005).

2.5.4.1 Environmental Occurrence, Industrial Production and Uses

Human or animal can expose to the zinc toxicity by two ways that are dermally and inhalation. Zinc enters the air, water, and soil as a result of both natural processes and human activities. Most zinc enters the environment as the result of mining, purifying of zinc, lead, and cadmium ores, steel production, coal burning, and burning of wastes (Roney *et al.*, 2005).

2.5.4.1 Effects to Human Health

Actually, zinc can be considered as nontoxic metal, particularly if taken orally. However, if there are extremely high zinc intakes, this can make manifestations of overt toxicity symptoms like nausea, vomiting, epigastria pain, lethargy and fatigue can happen (Fosmire, 1990).

2.6 Factor That Affecting the Solid Solution Partition of Heavy Metal In Soil

Several soil process such as cation exchange, specific absorption, and complexion can influence the transfer of metal from the solid to the solution phase of soil (Rieuwerts *et al.*, 1998). There are several parameter that can relate to these process in soil that are pH, clay fraction, redox potential and organic matter content.

2.6.1 pH

pH stands for power of hydrogen and acts as a measurement to know the concentration of hydrogen ion in the body. Solution is consider as neutral if the pH value is 7, lower than that is acidic and more than 7 is the alkaline solution. The higher pH tends to decrease the metal solubility in soil, while the lower pH can increase the metal solubility (Tills and Alloway; Garcia-Miragaya; Ram and Verloo; Sanchez-Camazano et al.; Chuan et al.; Thornton, cited in Rieuwerts et al. 1998). This is because, the high concentration of hydroxide ion (OH^-) in the soil can increase the reaction with the heavy metal to form the metal hydroxide in form of precipitation.

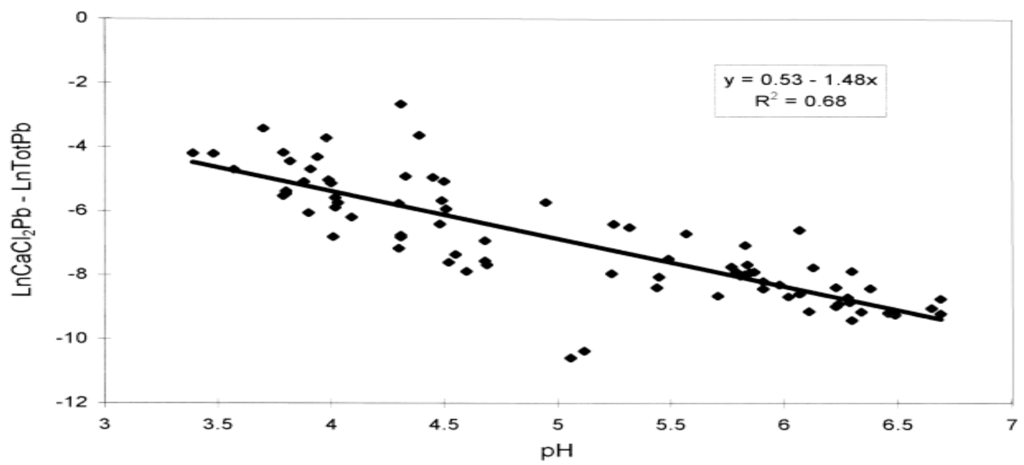


Figure 2.6.1.1 Example of decreasing metal solubility with increase in pH. (Rieuwerts *et al.*, 1998)

2.6.2 Organic matter content

Organic matter is the matter composed of organic compounds that has come from the remains of organisms such as plants and animals and their waste products in the environment. Though soil organic matter content are often small compared the clay, the organic fraction have a great influence the metal binding (Zimdahl and Skogerboe, cited in Rieuwerts et al. 1998). The absorption of heavy metals in sediment increased with increasing organic matter content (Lin and Chen, 1998).

2.6.3 Redox potential

Redox is a process in which one substance or molecule is reduced and another oxidized; oxidation and reduction considered together as complimentary processes. In addition, redox reaction is about electron transfer. Redox reactions in soils are controlled by the aqueous free electron activity, pE, which can also be expressed in terms of Eh, the redox potential (Sposito, cited in Rieuwerts et al. 1998). The higher the organic matter content, the lower the Eh value in soil. So, the metal solubility will increase due to lower of Eh value. The solubility of Pb, Cd and Zn in soils increased when redox potential decreased (Chuan et al., cited in Rieuwerts et al. 1998).

2.6.4 Soil texture

The influence of soil texture on metal solubility in soils is best expressed in terms of the division of soils into clay, silt and sand fractions that are <2 µm, 2–50 µm and >50 µm in sizes respectively. The strong affinity of Pb and other metals to the clay fraction is demonstrated by the ranking, in terms of adsorption, of clay > silt > sand (Andersson, cited in Rieuwerts et al. 1998). A high degree of extractability was also observed in sand fractions of the soil and this was attributed to the low binding strength of these fractions (Rieuwerts *et al.*, 1998).

2.7 Geoaccumulation Index (I_{geo})

The I_{geo} indexes allow the evaluation of contamination by correlating the obtained current concentration of metals with their pre-industrial concentrations (Muller, cited in Hossain et al., 2014). I_{geo} for the metals is determined using the following equation;

$$I_{geo} = Log_2 \frac{C_n}{1.5B_n} \qquad 2.7.1$$

Here, C_n is the measured concentration in the sediment for metal n, B_n is the background value for the metal n (Hasan *et al.*, 2013; Hossain *et al.*, 2014) and the factor 1.5 is used because of possible variations of the background data due to lithological variations.

I_{geo} class	I_{geo} value	Contamination level
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated/moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately/strongly contaminated
4	$3 < I_{geo} < 4$	Strongly contaminated
5	$4 < I_{geo} < 5$	Strongly/extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

Figure 2.7.1 Geoaccumulation Index (I_{geo}) for contamination level. (Muller, cited in Hasan et al. 2013; Hossain et al. 2014)

2.8 Pollution Load Index (PLI)

The PLI is an empirical index that provides a simple and comparative way to evaluate the level of heavy metal pollution (Tomlinson et al.; Usero et al.; Bhuiyan et al.; Bentum et al., cited in Hossain et al. 2014). In order to know the PLI value in soil, the CF ratio must be determine based on the related metals (Muller, cited in Hossain et al. 2014). The CF ratio was estimated by dividing the concentration of each metal in the soil by the baseline/background value (Bhuiyan et al., cited in Hossain et al., 2014).

$$CF = \frac{C_{metal}}{C_{background\ value}} \qquad 2.8.1$$

Then,

$$PLI = \sqrt{(n)}(CF_1 x\ CF_2 x\ CF_3 x \ldots x\ CF_n) \qquad 2.8.2$$

Where, C_{metal} = metal concentration obtained from sample, $C_{background\ value}$ = geochemical background/baseline value of the metal and n = number of metals. The PLI>1indicates heavy metal pollution and PLI<1 indicates no pollution (Tomlinson et al.; Harikumar et al., cited in Hossain et al., 2014).

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, all the tests will be explained briefly in term of procedure, apparatus and data analysis. For this research, there are 5 different tests must be conducted in order to collect all the related parameter data. In addition, 4 out of 5 will be conducted in environmental laboratory and another one in geotechnical laboratory.

3.2 Sample Collection

- Collect the sample from 3 different point for the landfill and industrial area using hand auger.

- For every point, take 2 sample of soil, then total of sample are 12.

Figure 3.2.1 Sample collection using hand auger

3.3 Acid Digestion Method and Atomic Absorption Spectroscopy (AAS) test

Stage 1 (Sampling and pre-treatment)

- Sample stored and left to dry out.
- Wet sample dried using drying oven.
- Sample pulverized & sieve with 2mm sieve.
-

Stage 2 (Acid Digestion Method)

1.00-4.00 gram of dried soil sample needed to be digested in a mixture of 9 mL of concentrated hydrochloric acid and 3mL of concentrated acid at ambient air in a 50 mL digestion vessel. Make sure to prepare all the mixture in a fume hood due to the volatility of the acids. Then, the mixture will be slowly heated until 95 degree Celsius to avoid any vigorous reaction happened. The digestion until the reddish brown fume disappear that represent the NO_2. The sample must be brought to near dryness. The digestate being filtered using AAS grade filter paper and collected in a 100 mL volumetric flask.

Stage 3 (AAS spike method)

- Spike method procedure
- Mix 1 mL of the sample with 250 micro L of 1000 ppm stock solution (Cd,Cu,Pb) in 50mL volumetric flask.
- Shake well the mixture
- Analyze sample using AAS
- Spike 5 ppm calculation

$$M1V1=m2v2 \quad (3.3.1)$$

The value get from AAS analysis then must be subtract with 5 ppm to get the sample actual concentration value.

3.4 pH

1) Take small amount of soil sample and put it in the beaker.
2) Dilute the soil sample with same amount of distilled water.
3) Stir or shake the sample vigorously and let it sit for 5 minutes
4) Turn on your pH meter and remove the cap to expose the sensor completely in the solution.

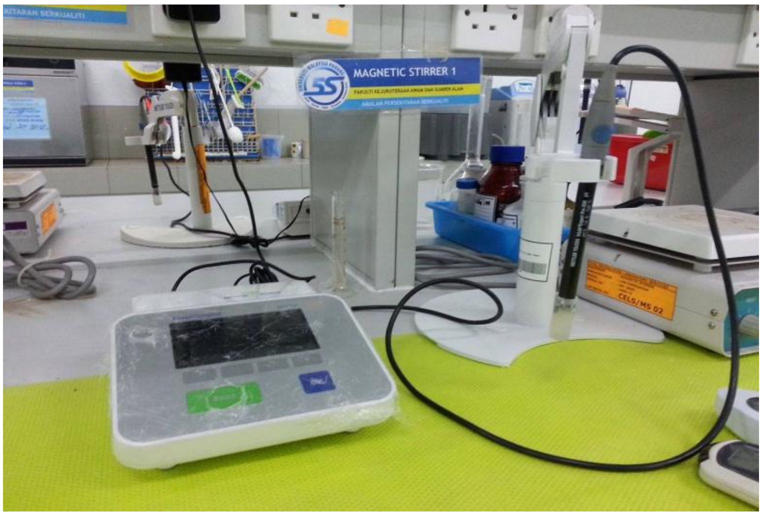


Figure 3.4.1 pH meter

3.5 Organic Matter content.

Equipment:

- Muffle furnace,
- Balance,
- Porcelain dish,
- Spatula,
- Tongs

Procedure:

1) Determine and record the mass of an empty, clean, and dry porcelain dish (M_P).
2) Place a part of or the entire oven-dried test specimen from the moisture content experiment in the porcelain dish and determine and record the mass of the dish and soil specimen (M_{PDS}).
3) Place the dish in a muffle furnace. Gradually increase the temperature in the furnace to 440°C. Leave the specimen in the furnace overnight.
4) Remove carefully the porcelain dish using the tongs (the dish is very hot), and allow it to cool to room temperature. Determine and record the mass of the dish containing the ash (burned soil) (M_{PA}).
5) Empty the dish and clean it.

Data Analysis:

1) Determine the mass of the dry soil.

$$M_D = M_{PDS} - M_P \quad 3.5.1$$

2) Determine the mass of the ashed (burned) soil.

$$M_A = M_{PA} - M_P \quad 3.5.2$$

3) Determine the mass of organic matter.

$$M_o = M_D - M_A \quad 3.5.3$$

4) Determine the organic matter (content).

$$OM = \left(\frac{M_O}{M_D}\right) x100 \quad 3.5.4$$

3.6 Electric Conductivity Test.

1) Take small amount of soil sample and put it in the beaker.
2) Dilute the soil sample with same amount of distilled water.
3) Stir or shake the sample vigorously and let it sit for 5 minutes.
4) Turn on your EC meter and remove the cap to expose the sensor completely in the solution.

Figure 3.6.1   Electrical Conductivity meter

3.7 Sieve analysis

1) Soil sample will be dried;

2) Particles greater than 2 mm, such as gravel and stones, will be removed;

3) The remaining part of the sample, the fine earth, will be finely ground to free all the separate particles;

4) The total weight of the fine earth will be accurately measured;

5) The fine earth will be passed through a series of sieves with mesh of different sizes, down to about 0.1 mm in diameter;

6) The weight of the contents of each sieve will be calculated separately and expressed as a percent of the total initial weight of the fine earth.

Table 3.7.1 Sieve number and diameter

Sieve Number	Diameter (mm)
#4	4.75
#10	2.00
#16	1.18
#30	0.60
#40	0.425
#50	0.30
#100	0.15
#230	0.063
Pan	-

3.8 Method use to analyse data

In order to now the level of contamination and pollution in soil sample at study area, there two method used to analyse all the data get from experiments. The methods are finding geoaccumulation index and pollution load index.

3.8.1 Geoaccumulation Index (I_{geo})

$$I_{geo} = Log_2 \frac{C_n}{1.5B_n} \qquad 2.7.1$$

Here, C_n is the measured concentration in the sediment for metal n, B_n is the background value for the metal n (Hasan *et al.*, 2013; Hossain *et al.*, 2014) and the factor 1.5 is used because of possible variations of the background data due to lithological variations.

3.8.2 Pollution Load Index (PLI)

$$CF = \frac{C_{metal}}{C_{background\ value}} \qquad 2.8.1$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

All the results obtained after several tests have been conducted on soil sample from the sampling area. The laboratory tests that have been carried out are AAS, pH, OM, EC and sieve analysis. Results and data expressed in form of table and chart to illustrate the condition of soil samples in both sampling area, landfill and industrial area. Every sub-point for landfill area labelled as L1.1, L1.2, L2.1, L2.2, L3.1 and L3.2. Then, the sub-point in industrial area named as I1.1, I1.2, I2.1, I2.2, I3.1 and I3.2.

4.2 Data assessment

Data was gathered from all tests conducted in both geotechnical and environmental laboratory. All the data for concentration of heavy metal in (ppm), electrical conductivity in (µS/cm) and organic matter in (%). Plus, sieve analysis result analysed by the value of fineness modulus (FM).

4.2.1 Atomic adsorption spectroscopy (AAS) – concentration

Table 4.2.1.1 Concentration of heavy metal in industrial area

Sample	Cd (ppm)	Zn (ppm)	Cu (ppm)	Pb (ppm)
I1.1	b.d.l	0.1922	0.0174	0.0142
I1.2	b.d.l	0.2168	0.0182	0.0131
I2.1	b.d.l	0.3044	0.0155	0.0245
I2.2	0.0002	0.1562	0.0087	0.0203
I3.1	b.d.l	0.1560	0.0262	0.0222
I3.2	0.0005	0.0694	0.0077	0.0213
mean	0.0004	0.1825	0.0156	0.0193

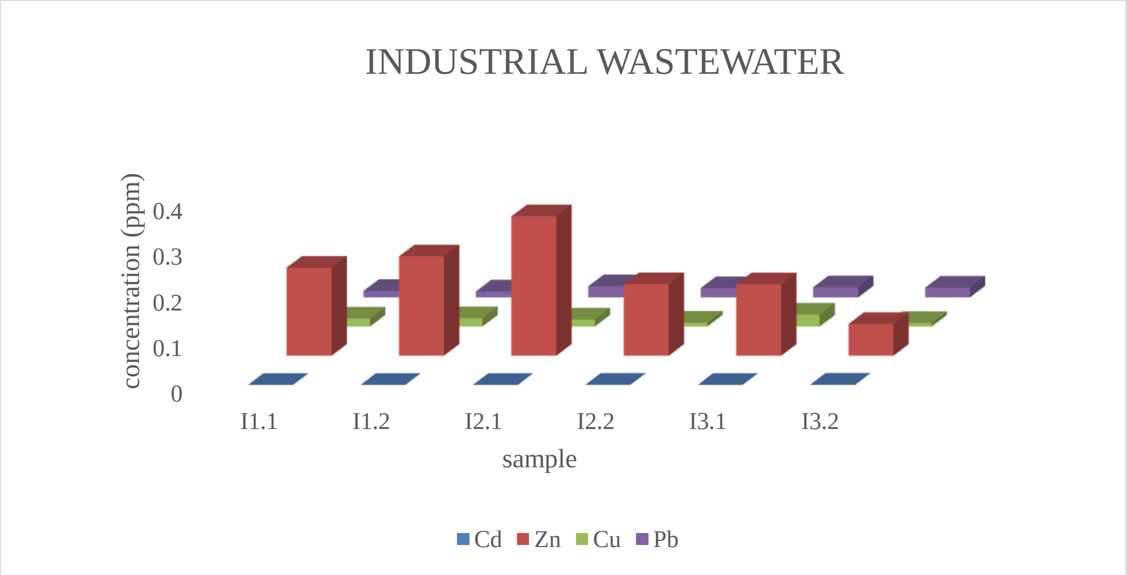


Figure 4.2.1.1 Graph of heavy metal concentration in industrial area

Based on Table 4.2.1.1, zinc has the highest mean value and followed by lead for the concentration in soil. In the same table, the lowest concentration with 0.0002 ppm goes to cadmium in sample I2.2 and most of the concentration in this area for cadmium is below detect limit that mean there is no or just a small portion(<0.00002 ppm) presence of respective heavy metal in the soil. Plus, range for heavy metal concentration in this area is between 0.0002 ppm until 0.3044 ppm. Through Figure 4.2.1.1, the reading for concentration of zinc shows a very big difference compared to the other heavy metal.

Table 4.2.1.2 Concentration of heavy metal in landfill area

Sample	Cd (ppm)	Zn (ppm)	Cu (ppm)	Pb (ppm)
L1.1	0.0002	0.0289	0.0100	0.0062
L1.2	0.0002	0.0379	0.0080	0.0164
L2.1	0.0007	0.0836	0.0098	0.0182
L2.2	0.0002	0.1587	0.0084	0.0211
L3.1	0.0014	0.0147	0.0175	0.0182
L3.2	0.0007	0.0666	0.0147	0.0055
mean	0.000584	0.065068	0.011388	0.014272

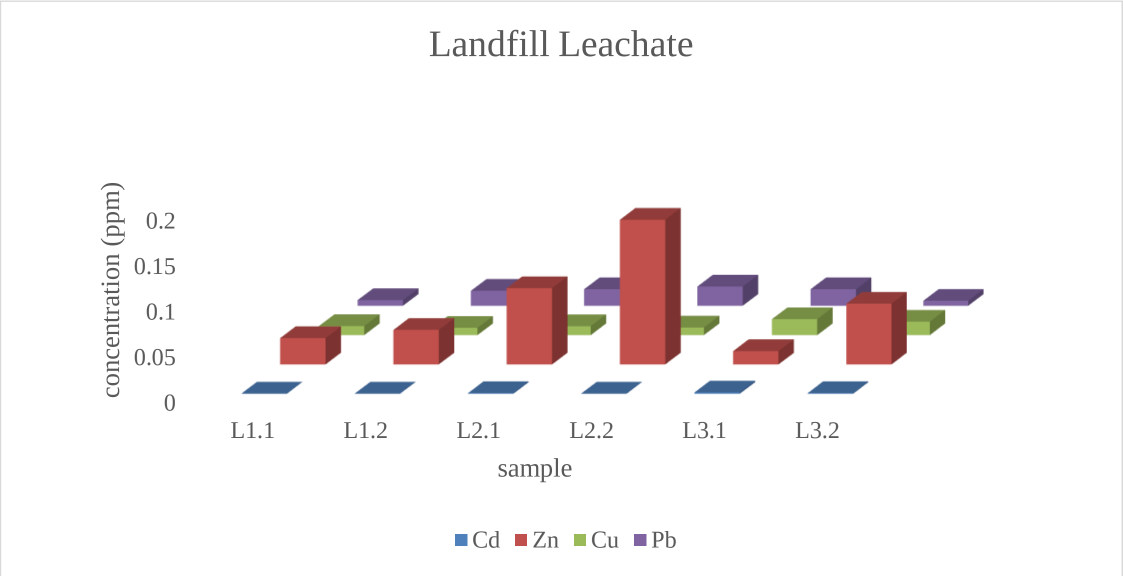


Figure 4.2.1.2 Graph of heavy metal concentration in landfill area

Based on Table 4.2.1.2, zinc has the highest mean value and followed by lead for the concentration in soil. In the same table, the lowest concentration with 0.0002 ppm goes to cadmium in sample L1.1, L1.2 and L2.2. However, there is no reading for this area that is below detect limit. Plus, range for heavy metal concentration in this area is between 0.0002 ppm until 0.1587 ppm. Referred to Figure 4.2.1.2, the concentration of zinc at L3.1 is differ than other points and having the lowest reading. Obviously, the reading for cadmium contrast from other heavy metal in the landfill area.

4.2.2 Electrical conductivity (EC)

Table 4.2.2.1 Electrical conductivity (EC) for both sampling area

Sample	EC (µS/cm)
I1.1	26900
I1.2	23300
I2.1	10430
I2.2	11090
I3.1	251
I3.2	243
mean	12036
L1.1	1652
L1.2	1298
L2.1	1254
L2.2	1140
L3.1	5850
L3.2	1393
mean	2098

Based on Table 4.2.2.1, mean reading for industrial area is much higher than landfill area for electrical conductivity in soil with a difference of 9938 µS/cm. Moreover, both sampling area have shown the characteristic of low quality topsoil in term of electrical conductivity value when the means are exceeding the good range that is 100-1500 µS/cm. However, two samples from sub-point 3 have lower electrical conductivity value than the other sample and the value are in the good range for high quality of topsoil.

4.2.3 Organic matter (OM)

Table 4.2.3.1 Organic matter (OM) content for both both sampling area

Sample	OM(%)
I1.1	5.941
I1.2	6.243
I2.1	6.977
I2.2	6.082
I3.1	6.016
I3.2	7.116
mean	6.396
L1.1	6.796
L1.2	9.049
L2.1	13.994
L2.2	8.984
L3.1	9.381
L3.2	6.027
mean	9.039

From Table 4.2.3.1, the mean organic matter percentage for landfill area is higher than industrial area. The content of organic material in leachate can be higher because all the garbage came from varies of area and sources. Besides, the sources for industrial area mostly came from accidental spill and intentional dumping of chemical, so there is not much of organic material decomposed.

4.2.4 pH

Table 4.2.4.1 pH value for both sampling area

Sample	pH
I1.1	6.87
I1.2	6.47
I2.1	6.16
I2.2	6.88
I3.1	5.37
I3.2	5.91
mean	6.28
L1.1	7.31
L1.2	7.30
L2.1	6.79
L2.2	6.23
L3.1	5.50
L3.2	5.19
mean	6.39

Mean value for both sampling area in the Table 4.2.4.1 indicate the acidic condition of soil because of the pH is lower than 7. In detail, all the samples in industrial area can be categorize as acidic soil while in landfill area, there are 4 out of 6 sample are acidic soil and another two are alkaline soil. There is not much difference of pH value between those sampling areas.

4.2.5 Sieve analysis

Table 4.2.5.1 Sieve analysis (Fineness Modulus) for both sampling area

Sample	Fineness Modulus
I1.1	5.74
I1.2	5.42
I2.1	5.34
I2.2	5.46
I3.1	5.54
I3.2	5.87
mean	5.56
L1.1	6.31
L1.2	6.32
L2.1	6.89
L2.2	6.85
L3.1	6.00
L3.2	5.93
mean	6.38

Based on Table 4.2.5.1 above, all the fineness modulus value show that the samples are containing coarser aggregates because of all the values are larger than 3.5. However, the mean value for industrial area indicate that the soil sample there is finer than in landfill area. The result for fineness modulus can be affected by the other small size material in soil that presence in top soil.

4.3 Data analysis

Based on concentration of heavy metal at sampling area in Table 4.2.1.1 and Table 4.2.1.2, the geoaccumulation index and pollution load index can be generate using related formula. These values from both geoaccumulation index and pollution load index can be analyse and classify into several class in order to know the level contamination in soil.

Table 4.3.1 Geoaccumulation index (I_{geo}) for industrial area

Sample	Cd	Zn	Cu	Pb
I1.1	b.d.l	2.647	-3.106	-3.173
I1.2	b.d.l	2.821	-3.044	-3.293
I2.1	b.d.l	3.311	-3.276	-2.387
I2.2	-15.419	2.348	-4.110	-2.658
I3.1	b.d.l	2.346	-2.518	-2.532
I3.2	-14.301	1.177	-4.286	-2.589
mean	-14.860	2.442	-3.390	-2.772

Referred to Table 4.3.1 above, all three heavy metal (cadmium, copper and lead) have the mean value for I_{geo} below zero value that means there are no contamination of soil in industrial area related to these heavy metal. Different goes to zinc, the mean value shows 2.442 and this can be classify as Grade 4 (heavily contaminated).

Table 4.3.2 Pollution load index (PLI) for industrial area

Sample	CF				PLI
	Cd	Zn	Cu	Pb	
I1.1	b.d.l	0.0039	0.0017	0.0012	
I1.2	b.d.l	0.0044	0.0018	0.0011	
I2.1	b.d.l	0.0062	0.0015	0.0021	
I2.2	0.0015	0.0032	0.0009	0.0017	0.0022
I3.1	b.d.l	0.0032	0.0026	0.0019	
I3.2	0.0033	0.0014	0.0008	0.0018	
mean	0.0024	0.0037	0.0016	0.0016	

Placed on Table 4.3.2 the contamination factor was listed in order to calculate the PLI value for industrial area and range value for CF is from 0.0008-0.0062. Still, the mean value of CF for zinc is highest among all heavy metal. And, PLI value in the table above is 0.0022 and this value is lower than 1 that mean there is no heavy metal contamination in industrial area.

Table 4.3.3 Geoaccumulation index (I_{geo}) for landfill area

Sample	Cd	Zn	Cu	Pb
L1.1	-15.294	-0.087	-3.912	-4.365
L1.2	-15.418	0.306	-4.228	-2.963
L2.1	-13.801	1.447	-3.933	-2.815
L2.2	-15.395	2.371	-4.165	-2.602
L3.1	-12.824	-1.060	-3.100	-2.820
L3.2	-13.775	1.119	-3.345	-4.551
mean	-14.418	0.682	-3.781	-3.353

Same goes to landfill area, all three heavy metal (cadmium, copper and lead) were not found to be the cause of contamination in soil related to heavy metal when all the I_{geo} value is below than zero as stated in Table 4.3.3. Based on the same table, zinc still shows the highest mean value for I_{geo} with 0.682 and this can be classify in Grade 2 as moderately contaminated. In detail, there are two sample with negative result for zinc that can be categorized as uncontaminated soil.

Table 4.3.4 Pollution load index (PLI) for landfill area

Sample	CF				PLI
	Cd	Zn	Cu	Pb	
L1.1	0.0017	0.0006	0.0010	0.0005	
L1.2	0.0015	0.0008	0.0008	0.0014	
					0.001
L2.1	0.0047	0.0017	0.0010	0.0016	6
L2.2	0.0015	0.0032	0.0008	0.0018	
L3.1	0.0092	0.0003	0.0017	0.0016	
L3.2	0.0048	0.0014	0.0015	0.0005	
mean	0.0039	0.0013	0.0011	0.0012	

Based on Table 4.3.4, the highest mean value for contamination factor goes to cadmium and the lowest value come from copper. The range value for CF is 0.0003 to 0.0048. PLI for landfill area is 0.0016, so there is no pollution in soil related to those heavy metal.

CHAPTER 5

CONCLUSION

5.1 Introduction

There are 12 samples were examined in order to know the concentration of heavy metal that came from Kuantan Jabor-Jerangau integrated landfill and car workshop near Gambang. Both study area have the higher concentration of zinc than the other heavy metal. And, the mean concentrations of heavy metals in the soil samples are in decreasing order as follows: Zn>Pb>Cu>Cd. The car workshop soil characterized by higher mean concentration of Cu, Pb and Zn than the soil at landfill area. Highest $Igeo$ value shown in industrial area for the concentration of Zn that is 2.44 and can be classified into heavily contaminated soil. Besides, the $Igeo$ value for landfill area is 0.682 and can be catagorized as moderately contaminated. PLI value shows that both sampling area are not polluted when the value is lower than 1.

For factor that affecting the solid solution partition of heavy metal in soil, electrical conductivity in sample at industrial area has higher mean value than landfill area. Besides, organic matter content for industrial area is 6.396 % and it is lower than organic matter content at landfill area. In addition, based on mean value of pH in both study area, it shows the soil is acidic soil because pH lower than 7. For sieve analysis result, the fineness modulus value for industrial area and landfill area are 5.56 and 6.38 respectively. That means soil sample in both area are coarser aggregates.

5.2 Recommendation

1) Increase the number of sub-point and sample for every study area. The more data collected, the more precise the result to be analyze.

2) Increase the number of heavy metal that need to be test in laboratory. This can make the pollution load index (PLI) be more accurate. Besides, the contamination related to other heavy metal can be identified.

3) Conduct hydrometer test to know clay fraction precisely in soil. And this test very suitable to analyze the disturb sample.

REFERENCES

ATSDR (2012) 'Toxicological Profile for Cadmium', *Agency for Toxic Substances and Disease Registry, Public Health Service- U.S. Department of Health and Human Services*, (September), pp. 1–487. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp5.pdf%5Cnhttp://www.ncbi.nlm.nih.gov/books/NBK158845/.

ECHA (2012) 'Cadmium and cadmium compounds in plastics', *European Chemicals Agency*, 1993, p. 13 pp. doi: 10.1002/14356007.a04.

Eisentraut, A. and Brown, A. (2013) 'The essential chemical industry', *University of York*, (2), pp. 1–41.

European Commission (2013) 'Soil Contamination : Impacts on Human Health', *Science for Environmental Policy*, (5), pp. 1–29.

Flemming, C. A. and Trevors, J. T. (1989) 'Copper toxicity and chemistry in the environment: a review', *Water, Air, and Soil Pollution*, 44(1–2), pp. 143–158. doi: 10.1007/BF00228784.

Fosmire, G. J. (1990) 'Zinc toxicity', *American Journal of Clinical Nutrition*, 51(2), pp. 225–227.

Geiger, A. and Cooper, J. (2010) 'Overview of airborne metal regulations, exposure limits, health effects and contemporary research', pp. 1–61.

Hasan, A. B. *et al.* (2013) 'Enrichment factor and geo-accumulation index of trace metals in sediments of the ship breaking area of Sitakund Upazilla (Bhatiary-Kumira), Chittagong, Bangladesh', *Journal of Geochemical Exploration*. Elsevier B.V., 125, pp. 130–137. doi: 10.1016/j.gexplo.2012.12.002.

Hossain, M. A. *et al.* (2014) 'Spatial distribution and source apportionment of heavy metals in soils of Gebeng industrial city, Malaysia', *Environmental Earth Sciences*, 73(1), pp. 115–126. doi: 10.1007/s12665-014-3398-z.

Johari, A. *et al.* (2014) 'Municipal solid waste management and potential revenue from recycling in Malaysia', *Modern Applied Science*, 8(4), pp. 37–49. doi: 10.5539/mas.v8n4p37.

Kaur, H. and Garg, H. (2014) 'Pesticides: Environmental Impacts and Management Strategies', *Pesticides - Toxic Aspects*. doi: 10.5772/57399.

Kropschot, S. J. and Doebrich, J. L. (2011) 'Lead — Soft and Easy to Cast'.

Lee, G. F. and Anne Jones-Lee (2005) 'Municipal Solid Waste Landfills – Water Quality Issues', *Water Encyclopedia*, 169, pp. 163–169. doi: 10.1002/047147844X.wq1504.

Leifert, C. and Group, N. E. F. (2007) *Handbook of Organic Food Safety and Quality, International Journal of Food Microbiology*. doi: 10.1016/j.ijfoodmicro.2008.04.017.

Lin, J. G. and Chen, S. Y. (1998) 'The Relationship Between Adsorption of Heavy Metal and Organic Matter in River Sediments', *Environment International*, 24(3), pp. 345–352. Available at: isi:000072816200011.

Muhammad Aqeel Ashraf, Maah, M. J. and Yusoff, I. (2014) 'Soil Contamination, Risk Assessment and Remediation', in *Environmental Risk Assessment of Soil Contamination sional*, pp. 4–55. doi: 10.5772/57287.

Nagajyoti, P. C., Lee, K. D. and Sreekanth, T. V. M. (2010) 'Heavy metals, ocurrence and toxicity for plants: a review', *Environmental Chemistry Letters*, 8(3), pp. 199–216. doi: 10.1007/s10311-010-0297-8.

Rieuwerts, J. S. *et al.* (1998) 'Factors influencing metal bioavailability in soils: Preliminary investigations for the development of a critical loads approach for metals', *Chemical Speciation and Bioavailability*, 10(2), pp. 61–75. doi: 10.3184/095422998782775835.

Roney, N. *et al.* (2005) 'Toxicological Profile for Zinc', *Agency for Toxic Substances and Disease Registry*, (August), p. 352. doi: http://dx.doi.org/10.1155/2013/286524.

Salako, A. A., Sholeye, O. O. and Dairo, O. O. (2012) 'Beyond pest control : A closer look at the health implication of pesticides usage', 4(February), pp. 37–42. doi: 10.5897/JTEHS11.059.

Shayler, H., McBride, M. and Harrison, E. (2009) 'Sources and Impacts of Contaminants in Soils', *Soil Sciences*, (CornelL Waste Management Institute), pp. 1–6.

Singh, R. *et al.* (2011) 'Heavy metals and living systems: An overview', *Indian Journal of Pharmacology*, 43(3), p. 246. doi: 10.4103/0253-7613.81505.

Sonawane, D. V *et al.* (2010) 'Impact of Industrial Waste Water on Soil Quality and Organic Matter Around Kurkumbh Industrial Area Daund , Pune District (Ms)', 8(1), pp. 97–102.

Taghipour, H. *et al.* (2012) 'Heavy Metals Concentrations in Groundwater Used for Irrigation', *Health Promotion Perspectives*, 2(2), pp. 205–210.

Tchounwou, P. B. *et al.* (2012) 'Molecular, Clinical and Environmental Toxicology', 101, pp. 1–30. doi: 10.1007/978-3-7643-8340-4.

Tiwari, M. K. (2015) ‘An Analytical Study of Heavy Metal Concentration in Soil of an Industrial Region of Chhattisgarh , central’, *International Journal of Scientificc and Research Publications*, 5(7), pp. 1–8.

UN WWAP (2017) *WWAP (United Nations World Water Assessment Programme)*. Available at: http://unesdoc.unesco.org/images/0024/002471/247153e.pdf.

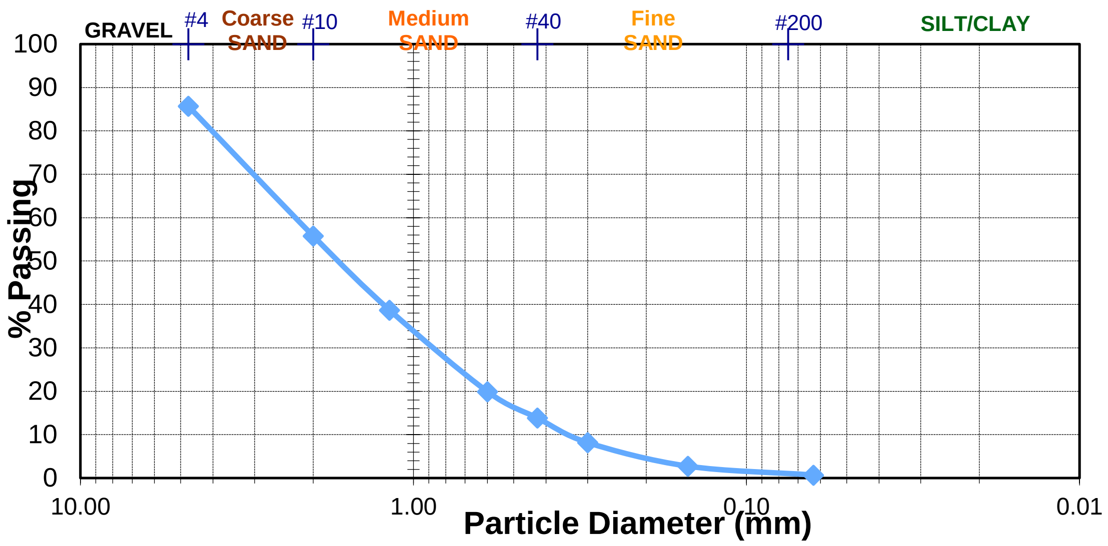
Wuana, R. A. and Okieimen, F. E. (2011) ‘Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation’, *ISRN Ecology*, 2011, pp. 1–20. doi: 10.5402/2011/402647.

APPENDIX A

DATA FOR SIEVE ANALYSIS AT I1.1

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	475.2	71.4	14.3	14.3	85.7
#10	2.00	376.47	526.24	149.8	30.0	44.2	55.8
#16	1.18	485.34	570.68	85.3	17.1	61.3	38.7
#30	0.60	391.23	485.1	93.9	18.8	80.1	19.9
#40	0.425	297.16	327.56	30.4	6.1	86.2	13.8
#50	0.30	431.42	459.8	28.4	5.7	91.8	8.2
#100	0.15	426.26	453.49	27.2	5.4	97.3	2.7
#230	0.063	257.5	267.68	10.2	2.0	99.3	0.7
Pan		372.22	375.46	3.2	0.6	100.0	0.0
			TOTAL:	**499.79**	**100.0**		

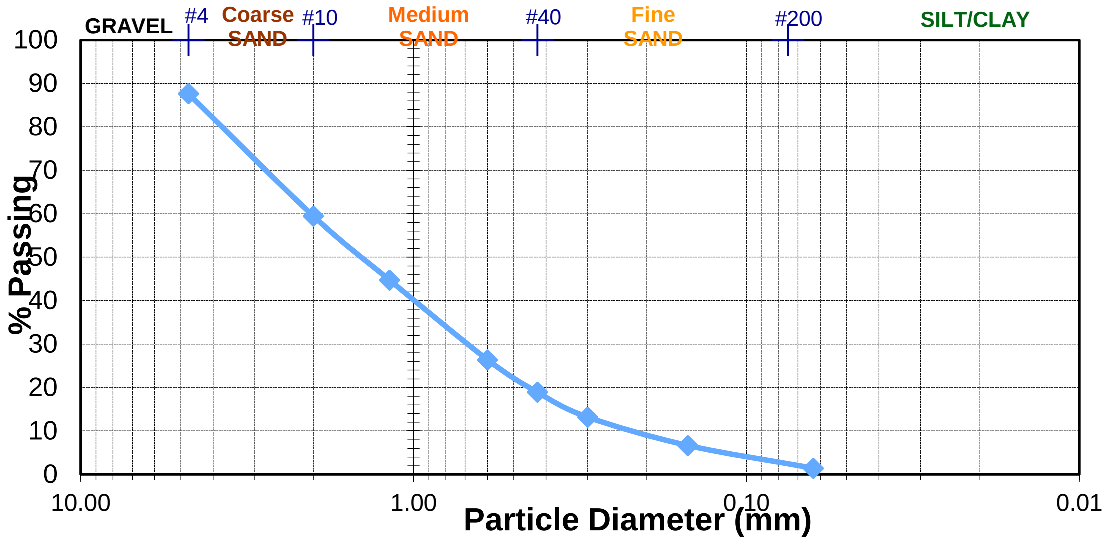
SEMI LOG GRAPH FOR I1.1



DATA FOR SIEVE ANALYSIS AT I1.2

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	465.56	61.7	12.3	12.3	87.7
#10	2.00	376.47	517.36	140.9	28.2	40.5	59.5
#16	1.18	485.34	559.14	73.8	14.8	55.3	44.7
#30	0.60	391.23	482.78	91.6	18.3	73.6	26.4
#40	0.425	297.16	334.59	37.4	7.5	81.1	18.9
#50	0.30	431.42	460.12	28.7	5.7	86.8	13.2
#100	0.15	426.26	458.96	32.7	6.5	93.4	6.6
#230	0.063	257.5	283.59	26.1	5.2	98.6	1.4
Pan		372.22	379.2	7.0	1.4	100.0	0.0
			TOTAL:	499.88	100.0		

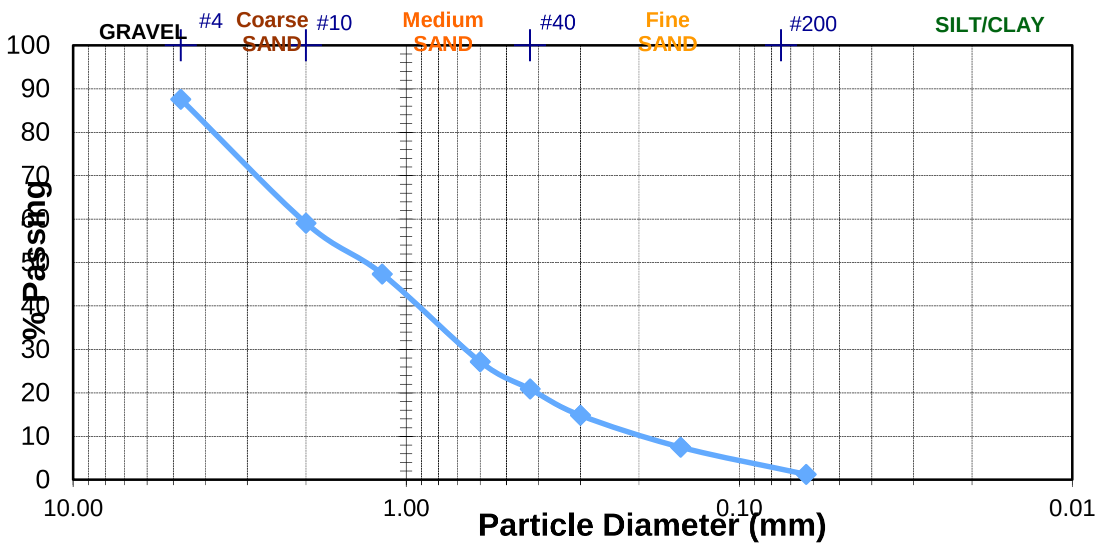
SEMI LOG GRAPH FOR I1.2



DATA FOR SIEVE ANALYSIS AT I2.1

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	465.98	62.2	12.4	12.4	87.6
#10	2.00	376.47	518.93	142.5	28.5	40.9	59.1
#16	1.18	485.34	543.98	58.6	11.7	52.7	47.3
#30	0.60	391.23	492.15	100.9	20.2	72.8	27.2
#40	0.425	297.16	328.65	31.5	6.3	79.1	20.9
#50	0.30	431.42	461.68	30.3	6.1	85.2	14.8
#100	0.15	426.26	462.98	36.7	7.3	92.5	7.5
#230	0.063	257.5	288.78	31.3	6.3	98.8	1.2
Pan		372.22	377.68	5.5	1.1	99.9	0.1
			TOTAL:	499.39	99.9		

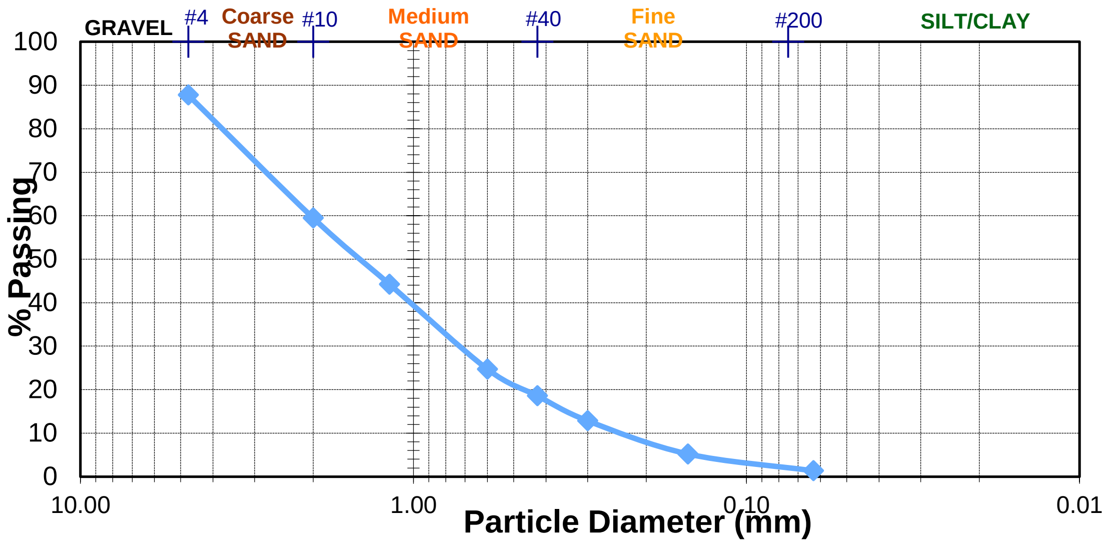
SEMI LOG GRAPH FOR I2.1



DATA FOR SIEVE ANALYSIS AT I2.2

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	464.89	61.1	12.2	12.2	87.8
#10	2.00	376.47	517.99	141.5	28.3	40.5	59.5
#16	1.18	485.34	561.54	76.2	15.2	55.8	44.2
#30	0.60	391.23	488.79	97.6	19.5	75.3	24.7
#40	0.425	297.16	327.8	30.6	6.1	81.4	18.6
#50	0.30	431.42	460.19	28.8	5.8	87.2	12.8
#100	0.15	426.26	464.4	38.1	7.6	94.8	5.2
#230	0.063	257.5	276.89	19.4	3.9	98.7	1.3
Pan		372.22	378.66	6.4	1.3	99.9	0.1
			TOTAL:	**499.73**	**99.9**		

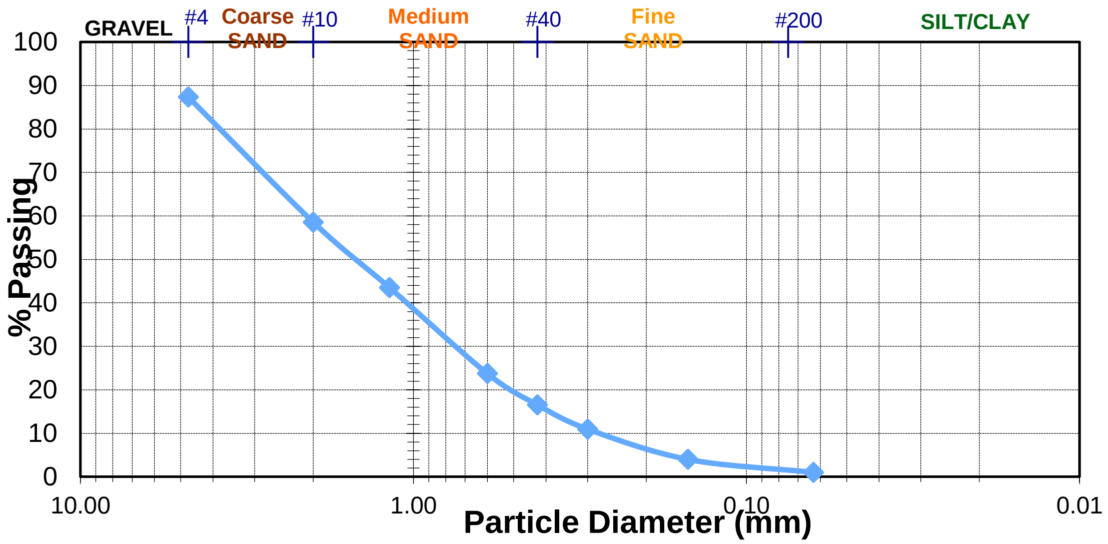
SEMI LOG GRAPH FOR I2.2



DATA FOR SIEVE ANALYSIS AT I3.1

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	467.03	63.2	12.6	12.6	87.4
#10	2.00	376.47	520.57	144.1	28.8	41.5	58.5
#16	1.18	485.34	560.54	75.2	15.0	56.5	43.5
#30	0.60	391.23	490.11	98.9	19.8	76.3	23.7
#40	0.425	297.16	333	35.8	7.2	83.4	16.6
#50	0.30	431.42	459.41	28.0	5.6	89.0	11.0
#100	0.15	426.26	461.1	34.8	7.0	96.0	4.0
#230	0.063	257.5	272.41	14.9	3.0	99.0	1.0
Pan		372.22	377.25	5.0	1.0	100.0	0.0
			TOTAL:	**500**	**100.0**		

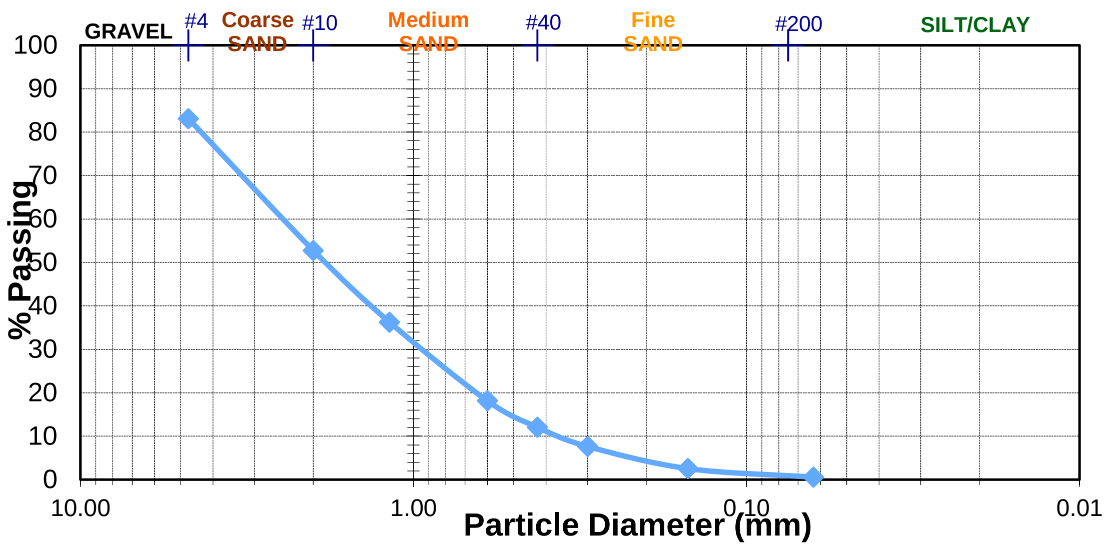
SEMI LOG GRAPH FOR I3.1



DATA FOR SIEVE ANALYSIS AT I3.2

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	488.34	84.5	16.9	16.9	83.1
#10	2.00	376.47	528.55	152.1	30.4	47.2	52.8
#16	1.18	485.34	568.03	82.7	16.5	63.7	36.3
#30	0.60	391.23	481.88	90.7	18.1	81.8	18.2
#40	0.425	297.16	327.56	30.4	6.1	87.9	12.1
#50	0.30	431.42	453.64	22.2	4.4	92.3	7.7
#100	0.15	426.26	451.79	25.5	5.1	97.4	2.6
#230	0.063	257.5	267.43	9.9	2.0	99.4	0.6
Pan		372.22	374.94	2.7	0.5	99.9	0.1
			TOTAL:	**500.74**	**99.9**		

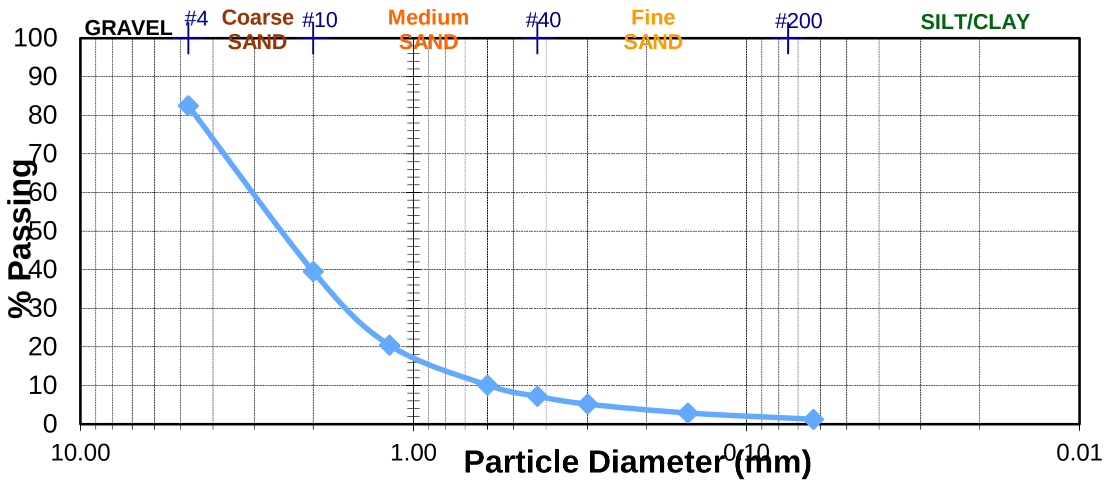
SEMI LOG GRAPH FOR I3.2



DATA FOR SIEVE ANALYSIS AT L1.1

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	488.02	84.2	17.5	17.5	82.5
#10	2.00	376.4	583.01	206.6	43.0	60.5	39.5
#16	1.18	515.34	607.09	91.8	19.1	79.6	20.4
#30	0.60	391.14	440.79	49.7	10.3	89.9	10.1
#40	0.425	451.58	465.57	14.0	2.9	92.8	7.2
#50	0.30	448.15	457.87	9.7	2.0	94.8	5.2
#100	0.15	426.32	437.36	11.0	2.3	97.1	2.9
#230	0.063	257.49	265.29	7.8	1.6	98.8	1.2
Pan		372.21	378.2	6.0	1.2	100.0	0.0
			TOTAL:	**480.75**	**100.0**		

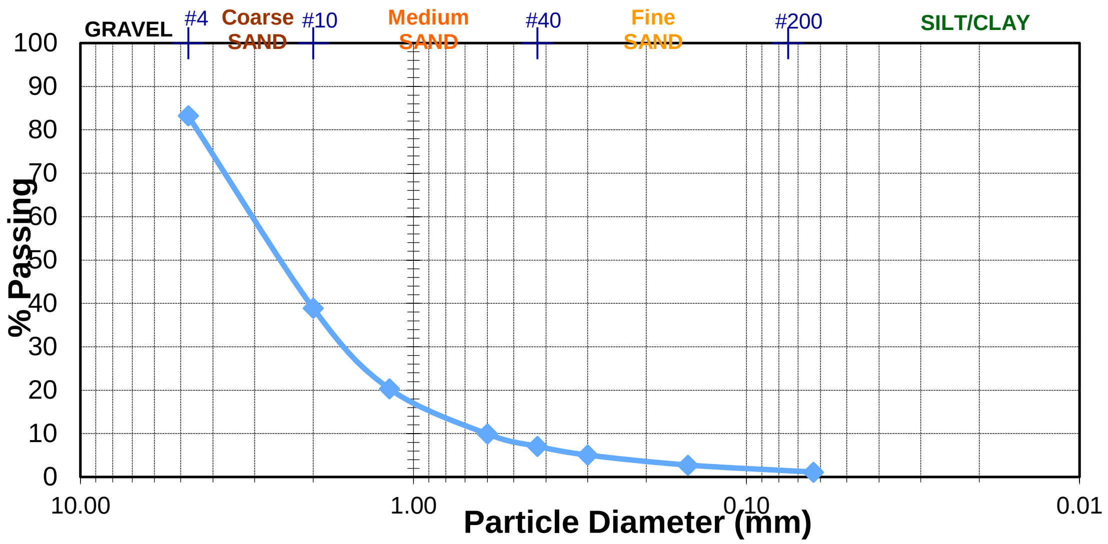
SEMI LOG GRAPH FOR L1.1



DATA FOR SIEVE ANALYSIS AT L1.2

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	487.7	83.9	16.8	16.8	83.2
#10	2.00	376.4	598.38	222.0	44.3	61.1	38.9
#16	1.18	515.34	608.33	93.0	18.6	79.7	20.3
#30	0.60	391.14	443.21	52.1	10.4	90.1	9.9
#40	0.425	451.58	465.83	14.3	2.8	92.9	7.1
#50	0.30	448.15	458.25	10.1	2.0	94.9	5.1
#100	0.15	426.32	437.82	11.5	2.3	97.2	2.8
#230	0.063	257.49	265.56	8.1	1.6	98.8	1.2
Pan		372.21	377.99	5.8	1.2	100.0	0.0
			TOTAL:	**500.62**	**100.0**		

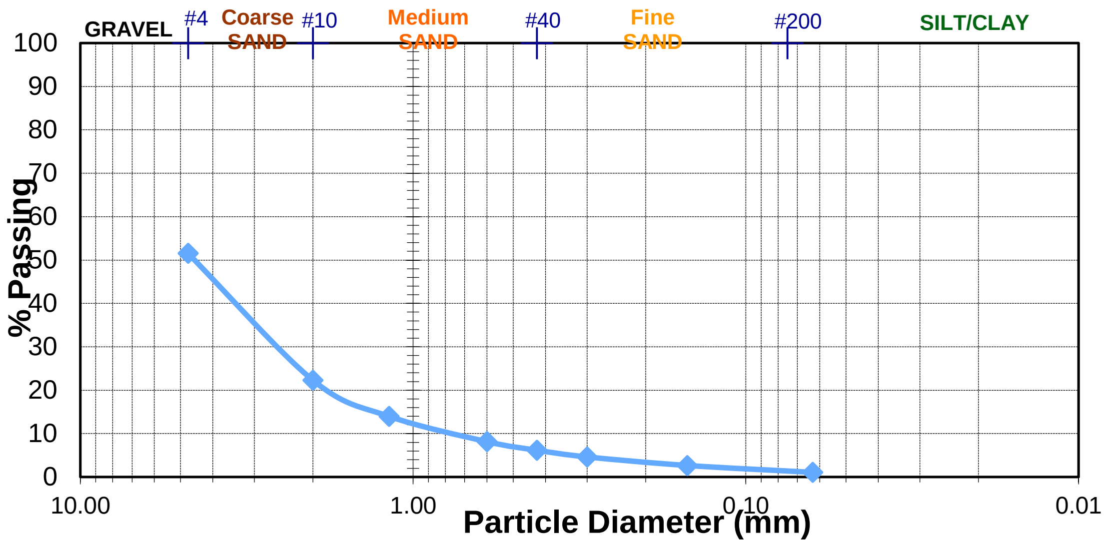
SEMI LOG GRAPH FOR L1.2



DATA FOR SIEVE ANALYSIS AT L2.1

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	646.37	242.6	48.4	48.4	51.6
#10	2.00	376.4	522.89	146.5	29.3	77.7	22.3
#16	1.18	515.34	557.04	41.7	8.3	86.0	14.0
#30	0.60	391.14	420.29	29.2	5.8	91.8	8.2
#40	0.425	451.58	461.44	9.9	2.0	93.8	6.2
#50	0.30	448.15	455.93	7.8	1.6	95.3	4.7
#100	0.15	426.32	436.16	9.8	2.0	97.3	2.7
#230	0.063	257.49	265.42	7.9	1.6	98.9	1.1
Pan		372.21	377.73	5.5	1.1	100.0	0.0
			TOTAL:	**500.82**	**100.0**		

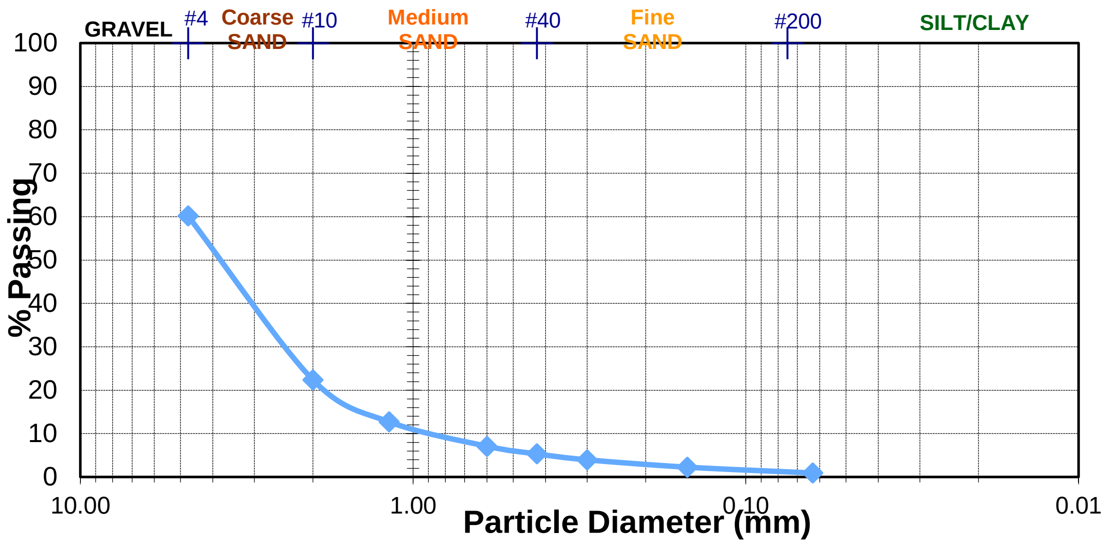
SEMI LOG GRAPH FOR L2.1



DATA FOR SIEVE ANALYSIS AT L2.2

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	603.25	199.4	39.8	39.8	60.2
#10	2.00	376.4	565.57	189.2	37.8	77.6	22.4
#16	1.18	515.34	563.74	48.4	9.7	87.3	12.7
#30	0.60	391.14	419.25	28.1	5.6	92.9	7.1
#40	0.425	451.58	460.39	8.8	1.8	94.6	5.4
#50	0.30	448.15	455	6.9	1.4	96.0	4.0
#100	0.15	426.32	434.8	8.5	1.7	97.7	2.3
#230	0.063	257.49	264.2	6.7	1.3	99.0	1.0
Pan		372.21	377.03	4.8	1.0	100.0	0.0
			TOTAL:	**500.78**	**100.0**		

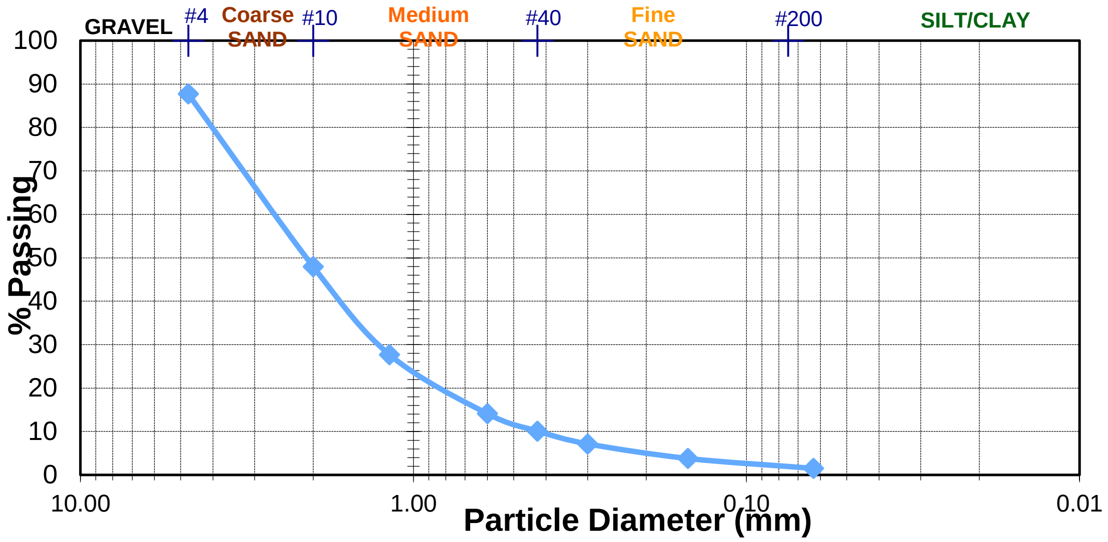
SEMI LOG GRAPH FOR L2.2



DATA FOR SIEVE ANALYSIS AT L3.1

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	465.08	61.3	12.2	12.2	87.8
#10	2.00	376.4	575.48	199.1	39.8	52.0	48.0
#16	1.18	515.34	616.74	101.4	20.3	72.3	27.7
#30	0.60	391.14	459.05	67.9	13.6	85.9	14.1
#40	0.425	451.58	471.55	20.0	4.0	89.9	10.1
#50	0.30	448.15	462.94	14.8	3.0	92.8	7.2
#100	0.15	426.32	443.15	16.8	3.4	96.2	3.8
#230	0.063	257.49	268.9	11.4	2.3	98.5	1.5
Pan		372.21	379.92	7.7	1.5	100.0	0.0
			TOTAL:	**500.36**	**100.0**		

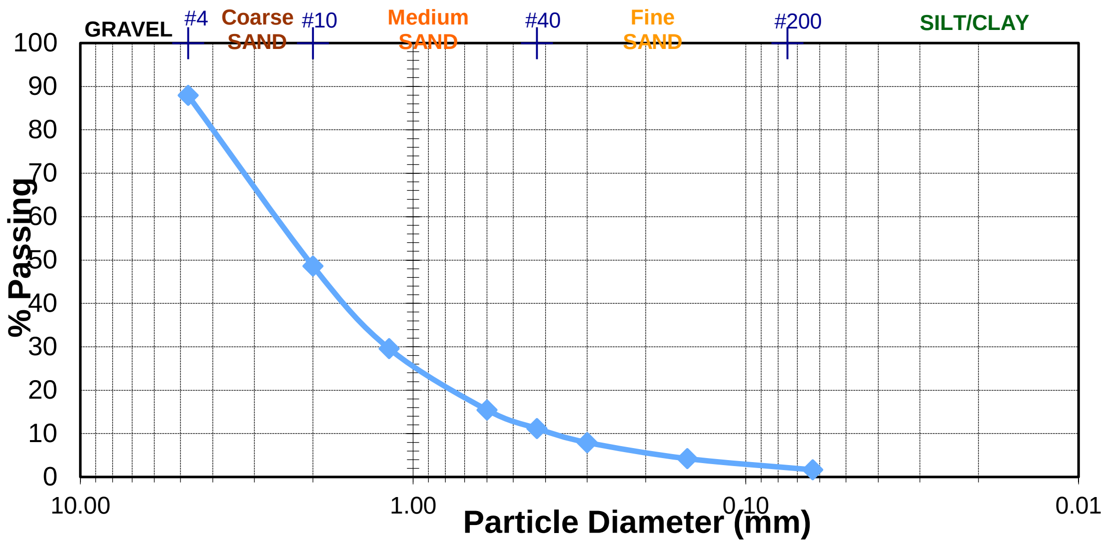
SEMI LOG GRAPH FOR L3.1



DATA FOR SIEVE ANALYSIS AT L3.2

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Cumulative retained (%)	Soil Passing (%)
#4	4.75	403.82	463.94	60.1	12.0	12.0	88.0
#10	2.00	376.4	573.27	196.9	39.4	51.4	48.6
#16	1.18	515.34	610.51	95.2	19.0	70.4	29.6
#30	0.60	391.14	461.7	70.6	14.1	84.5	15.5
#40	0.425	451.58	472.95	21.4	4.3	88.8	11.2
#50	0.30	448.15	464.36	16.2	3.2	92.0	8.0
#100	0.15	426.32	444.95	18.6	3.7	95.7	4.3
#230	0.063	257.49	270.35	12.9	2.6	98.3	1.7
Pan		372.21	380.68	8.5	1.7	100.0	0.0
			TOTAL:	**500.26**	**100.0**		

SEMI LOG GRAPH FOR L3.2



CERTIFIED VALUES OF SELECTED HEAVY METAL IN STANDARD REFERENCE MATERIAL ® 1646A ESTUARINE SEDIMENT

Element	Certified Value (µg/g)
As	6.23
Ba	210
Cd	0.15
Co	5
Cr	40.9
Cu	10.01
Hg	0.04
Ni	23
Pb	11.7
Zn	48.9

APPENDIX B

SAMPLE COLLECTION AT LANDFILL AREA

DATA COLLECTION AT INDUSTRIAL AREA

LOCATION OF LANDFILL AREA

CAR WORKSHOP NEAR GAMBANG (INDUSTRIAL AREA)