ENHANCEMENT OF LANDFILL DAILY COVER PERFORMANCE BY USING MIXTURE OF LOCAL SOIL, PRESSMUD AND EMPTY FRUIT BUNCH IN MINIMIZING THE MIGRATION OF HEAVY METALS IN LANDFILL

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by

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BDL	Below Detection Limit
BET	Batch Equilibrium Test
BOD	Biochemical Oxygen Demand
BS	British Standard
CCD	Central Composite Design
CEC	Cation Exchange Capacity
CIRIA	Construction Industry Research & Information Association
COD	Chemical Oxygen Demand
CV	Coefficient of Variance
DOE	Department of Environment
EDTA	Ethylenediaminetetraacetic acid
EFB	Empty Fruit Bunch
EP	Extraction Procedure
EPA	Environmental Protection Agency

EQA	Environmental Quality Act
ETPI	Environmental Technology Program for Industry
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
FESEM-EDX	Field Scanning Electron Microscopy & Energy Dispersive X-Ray
FRIM	Forest Research Institute Malaysia
FTIR	Fourier Transform Infra-Red
GAC	Granular Activated Carbon
GRC	Geotechnical Research Centre
HDPE	High Density Polyethylene
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectrometry
IOI	Industrial Oxygen Incorporated
LFG	Landfill Gas
LOF	Lack of Fit
MPC	Maximum Permissible Concentration
MPCA	Minnesota Pollution Control Agency
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Council
MSM	Malayan Sugar Manufacturing

MSW	Municipal Solid Waste
NRE	Natural Red Earth
OM	Organic Matter
PORIM	Palm Oil Research Institute of Malaysia
PV	Pore Volume
RCRA	Resource Conservation and Recovery Act
RISDA	Rubber Industry Smallholders Development Authority
RSM	Response Surface Methodology
SEPA	Scottish Environmental Protection Agency
TCLP	Toxicity Characteristics Leaching Procedure
TDS	Total Dissolved Solid
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
US	United States
USEPA	United State Environmental Protection Agency
WHO	World Health Organization
XRD	X-Ray Diffraction System

PENAMBAHBAIKAN PRESTASI PENUTUP HARIAN TAPAK PELUPUSAN SISA PEPEJAL MENGGUNAKAN CAMPURAN TANAH TEMPATAN, KEK LUMPUR DAN TANDAN SAWIT KOSONG DALAM MEMINIMAKAN PENGHIJRAHAN LOGAM BERAT DI TAPAK PELUPUSAN SISA PEPEJAL

ABSTRAK

Peningkatan kepekatan logam berat dalam larut lesap tapak pelupusan sisa pepejal adalah membimbangkan kerana ia merupakan bahan utama kepada terjejasnys kualiti kesihatan manusia dan persekitaran sekitarnya. Pengubahsuaian penutup tanah harian tapak pelupusan sisa pepejal adalah pilihan yang baik untuk mengurangkan pergerakan logam berat di dalam sel pelupusan sampah. Dalam kajian ini, sampel tanah tempatan kemudian dicampur dengan pressmud iaitu bahan buangan daripada proses pembuatan gula dan tandan kosong buah kelapa sawit (EFB) dengan peratusan berat yang berbeza. Seterusnya, eksperimen penjerapan dilakukan secara kajian kelompok untuk mengkaji keberkesanan campuran tanah-pressmud-EFB dalam menyingkirkan logam berat. Keberkesananya dibandingkan dengan penggunaan tanah, pressmud dan EFB secara individu. Pencirian bagi tanah dan juga campuran tanah-pressmud-EFB secara fizikokimia dan geoteknikal, seterusnya ujian luluhlarut dijalankan. Kaedah ujian luruhlarut termasuk ujian keseimbangan kelompok dan ujian turus tanah. Daripada kajian pencirian, terdapat beberapa penambahbaikkan sifat fizikokimia dan pencirian kejuruteraan bagi campuran berbanding dengan tanah sahaja. Campuran tanah-pressmud-EFB berkeupayaan menyingkirkan lebih daripada 59% sehingga 98.9% kandungan Cd, Cr, Cu, Fe, Mn, Ni and Zn penyingkiran logam berat daripada larutan. Sementara itu, kecekapan penyingkiran logam berat di dalam tanah adalah masing-masing daripada 1.6% sehingga 33.3% sahaja manakala pressmud pula menunjukkan daripada 78.4% sehingga 99.7% penyingkiran. EFB hanya menunjukkan 19.9% sehingga 56.2% penyingkiran. Kaedah respon balas permukaan (RSM) mengenai reka bentuk komposit pusat (CCD) telah digunakan untuk mengoptimumkan pembolehubah operasi terhadap keberkesanan setiap respon daripada segi kecekapan penyingkiran kepekatan awal dan masa tindak balas. Berdasarkan hasil ujikaji, 4.05 mg/L kepekatan awal dan 30 minit masa tindak balas diperlukan untuk penyingkiran untuk semua logam berat. Keputusan ujian turus yang berdasarkan kepada kajian pencirian, kecekapan penyingkiran dan penjerapan bahan campuran tanah-pressmud-EFB khususnya 50S:40P:10E adalah lebih sesuai dan mempunyai potensi yang baik untuk digunakan sebagai bahan penutup tanah harian untuk meminimakan penghijrahan logam berat dalam larut lesap di tapak pelupusan sisa pepejal.

ENHANCEMENT OF LANDFILL DAILY COVER PERFORMANCE BY USING MIXTURE OF LOCAL SOIL, PRESSMUD AND EMPTY FRUIT BUNCH IN MINIMIZING THE MIGRATION OF HEAVY METALS IN LANDFILL

ABSTRACT

An increase of heavy metals concentration in landfill leachate is a concern as it is a major threat to human health and surrounding environment. Landfill daily soil cover amendment is a good option to reduce the mobility of heavy metals in the landfill cell. In this study, local soil samples were mixed with waste from sugar manufacturing process, pressmud and empty fruit bunch (EFB) of palm oil at different percentage of weight ratio. Then, batch adsorption experiments were performed to evaluate the effectiveness of soil mixtures in removing the heavy metals. Their performances were compared to the individual performance of the soil, pressmud and EFB. The physicochemical and geotechnical properties of the soil, pressmud, EFB and soil-pressmud-EFB mixtures characterization as well as leaching test were carried out. The leaching test method included batch equilibrium test and soil column test. From the characterization study, there were some improvements on the physicochemical and engineering properties of mixtures compared to soil alone. Batch equilibrium test showed that the soil-pressmud-EFB mixtures have the capability to remove more than 59% to 98.9% Cd, Cr, Cu, Fe, Mn, Ni and Zn metals from solution. Meanwhile, the removal efficiency of heavy metals from solution in the soil alone was ranged from 1.6% to 33.3%. Pressmud alone, however, showed 78.4% to 99.7% heavy metals removal while EFB indicated 19.9% to 56.2% removal. The response surface methodology (RSM) concerning Central Composite Design (CCD) was used to optimize the experimental condition in the removal of

heavy metals. According to the results, initial concentration of 4.05 mg/L and 30 minutes contact time were required to effectively remove all heavy metals. Based on the characterization study, the removal efficiency and the column test, the soil-pressmud-EFB mixture particularly 50S:40P:10E was the most suitable combination and possessed great potential as daily cover to reduce heavy metals migration in landfill leachate.

CHAPTER ONE

INTRODUCTION

1.1 Background

A landfill is defined as that system designed and constructed to contain discarded waste so as to minimize releases of contaminants to the environment. Landfills are necessary because (1) other waste management technologies such as source reduction, recycling and waste minimization cannot totally eliminate the waste generated and (2) waste treatment technologies such as incineration and biological treatment produce residues (LaGrega et al, 2001). Landfills are the most widely used facilities for solid waste disposal all over the world (Aziz et al, 2016; Aljaradin, 2015; El-Salam and Abu-Zuid, 2015).

Nowadays, increasing population growth and industrial development in Malaysia have increased the generation of municipal solid waste (MSW). MSW can be defined as the wastes generated from domestic, commercial, industrial and institutional activities (Ravindra et al., 2015). Most landfills in Malaysia do not have proper covers which resulted in potential problems of groundwater and surface water contamination because of the leachate generated from solid waste in landfill (Aziz et al., 2016). Therefore, due to these arising environmental issues regarding landfilling, cover system implementation should be taken into consideration. The landfill cover system can be used to minimize exposure on the surface of the waste facility, and prevent vertical infiltration of water into wastes that would create contaminated leachate (EPA, 1991).

Landfilling practice is basically a process of dumping waste in trenches after manual sorting and followed by covering it with 0.5 m thick of soil on a daily basis.

This means that the daily cover remains within the landfill after the next lift of waste and often ends up as the final cover of the landfill. For this reason, it is vital to select the appropriate type of cover to promote drainage. In general, the thickness of waste within the landfill ranges from 6 to 20 m (Chopra, 2001; Aljaradin and Persson, 2010). The dumped waste includes solid waste and liquid waste with a high water content that can generate more leachate with more toxicity. Generation of leachate from MSW landfill has been long neglected with the assumption that minimal leachate could be formed in the absence of precipitation. Many studies, on the other hand, have identified the potential of contamination occurrence is due to uncontrolled landfilling (e.g., Teta and Hikwa, 2017; Kamaruddin et al., 2015). In addition, Aljaradin and Persson, (2015) found that the water held in the surface soils by capillary action can infiltrate through the solid waste. As a result, the leachate will eventually migrate toward the water table beneath the landfill contaminating the soil and the aquifer system.

The use of soil cover in landfills is important in protecting health and the environment, leading to less landfill volume available for compacted waste and providing good operational practice to prevent scattering of waste. As a result of these concerns, there is a great interest worldwide in ways to minimize the amount of soil cover used in landfills and to execute different cover types. For example, in some countries, less space demanding geotextiles, foams or other forms of waste (e.g., recycled tyres) have been used in place of cover soil. However, these types of daily cover alternatives are prohibitively expensive and impractical within developing countries. Using local soils or blends of them as daily cover is a much more accessible way to minimize the environmental consequences of waste disposal. Therefore, in order to have a low cost and sustainable landfilling process, it is necessary to execute the most efficient cover from the native soils (Aljaradin and Persson, 2015). In landfill technology, landfill soil needs to be amended or mixed with other materials in order to enhance the performance of soil stabilization in terms of geotechnical and physicochemical properties as well to reduce the pollutant in landfill. This is because soil cover in landfill acts as a medium for the migration of pollutant in leachate, especially heavy metals, before seeping to the surface water.

There are several materials that can be used for landfill cover system like sand, clay, silt and sludge generated from industrial wastewater treatment plants. The functions of covering systems are to promote drainage, minimize erosion of the cover, accommodate settling and have hydraulic conductivity less than or equal to that of any bottom liner system or natural soil present (Aziz et al., 2016 and Chabuk et al., 2018). There are three types of cover that can be used in a landfill which are daily cover, intermediate cover and final cover. Daily cover is placed over the entire working face at the end of each working day. Typically, daily cover uses soil, however, other daily cover alternatives may also be approved. Normally, 15 cm of soil is used as daily cover. Intermediate cover must be placed on areas with received waste but then will be inactive for a period of longer than 180 days. Intermediate cover must be at least 30 cm in thickness. Lastly, final cover is placed over areas of the landfill that have reached full capacity and final design waste grades. The final cover system typically consists of multiple layers of materials. A final layer of cover material is used when the fill reaches the final design height (Peavy et al., 1985).

One of the possible ways to reduce the migration of heavy metals in leachate is by enhancing daily soil cover material with local soil as a mixture of daily cover in landfill. Nowadays, researchers are not only focusing on the hydraulic transport of contaminants, but also on reducing the diffusion of contaminants through daily soil cover and the chemical processes. All of these cover materials are emerging to increase the sorption capacity of daily soil covers especially through the application of mixtures in the soil materials (Aljaradin, 2015; Ng and Lo, 2010). Every landfill requires a large amount of cover materials, however, it is essential to begin the transition from open dumping to sanitary landfilling since it has huge environmental benefits (Aljaradin, 2015; Aljaradin and Persson, 2010).

In Malaysia, the environmental challenge for the local sugar mills is associated with liquid waste, gaseous emission and solid waste. There are three major departments in sugar manufacturing namely mill house, process house and boiler house. Main sources of solid waste are from mill house (bagasse), process house (pressmud and molasses), and boiler house (fly ash) (ETPI, 2001). Pressmud is the compressed sugar industry waste produced from the vacuum filtration of the cane juice. It is a good source of fertilizer. Sugar mills produce millions of tons of pressmud (filter cake) as a waste from double sulphitation processes. The precipitated impurities contained in the cane juice, after removal by filtration, form a cake of varying moisture content known as pressmud or filter mud. This cake contains much of the colloidal organic matter anions that precipitate during clarification, as well as certain non-sugars occluded in these precipitates (Akhtar et al., 2017). Pressmud contains, on a dry basis, about 1 percent by weight of phosphate (P_2O_5) and about 1 percent of nitrogen. Therefore, it has been used as a fertilizer (James and Pandian 2017). It contents 50–70 % moisture, which is most favorable for soil micro-organisms, especially earth-worms (Dominguez, 1997). The composition of pressmud is also affected by variety, fertility status of soil, and also the recovery process of industries. It contains significant amounts of iron, manganese, calcium, magnesium, silicon, and phosphorus, and enhanced the suitability of pressmud as a source of nutrient (Yadav and Solomon, 2006). Pressmud, an end product of the sugar industry, is used as one of the substrates in bio-composting (Chand et al., 2011). The pressmud is also generated from the alcohol distillation originating from the fermentation of sugarcane molasses; it contains a huge volume of water and plant nutrients. Therefore, it is a necessity for treating pressmud to a valuable bio-fertilizer for agricultural crop production (Dotaniya et al., 2016 and Patil et al., 2013).

Malaysia is among the top most important oil palm producers in the world and experiencing a robust development in new plantations and palm oil mills through giant government companies (FELDA, FELCRA, and RISDA) and private estates (Guthrie, IOI Plantations, Genting Plantations, and Sime Darby) (Faizi et al., 2017). EFB supply is available and its continuous production at palm oil mills makes it a great prospect for commercial exploitation. Thus, these materials have been widely used in agriculture and industry. The fresh EFB from the mill usually contains 30.5% lignocellulose, 2.5% oil, and 67% water; and the main constituents of the lignocellulose are cellulose, hemicellulose, and lignin. Those constituents are physically hard and strong. Hence, the EFB basically possess qualities promising for further applications. In Malaysia, for an example, the EFB has been used to produce a medium density fiberboard. However, to be able to further use the EFB fiber, particularly for an engineering application, it is necessary to quantify the fiber mechanical properties (Gunawan et al., 2009). A potential use of EFB, which has received little attention, is in soil stabilization. Shredded EFB can be mixed with soil to improve their engineering properties for specific applications (Samuding, 2010). Pressmud and EFB can be mixed with soil to improve their engineering properties for specific utilizations and capability to remove heavy metals from the leachate in landfill. The spread of pollutants or contaminants in soil can be hindered by the soil stabilization technique (Edao, 2017; Onyelowe and Chibuzor, 2012).

1.2 Problem Statement

Most of the landfill in developing countries does not have any covers which results in the potential problems of ground water/surface water contamination due to the leachate generated from the solid waste landfill. Therefore, landfills must be separated away from the surrounding environment. Some environmental aspects for landfilling should be considered such as cover or capping system. The landfill capping system can be used to minimize exposure on the surface of the waste facility, and prevent vertical infiltration of water into wastes that would create contaminated leachate (Aziz et al., 2016 and EPA, 1991).

Several materials can be used for landfill cover system like sand, clay, silt and sludge generated from industrial waste water treatment plants. Cover materials should restrict surface water infiltration into the contaminated subsurface to reduce the potential for contaminants to leach from the site. Covering systems must function with minimum maintenance, promote drainage, minimize erosion of the cover, accommodate settling, and have hydraulic conductivity less than or equal to that of any bottom liner system or natural soil present (Aziz et al., 2016 and We and, 2010). In humid climates, cover and/or re-vegetation are usually required for erosion protection and infiltration control. The regulations do, however, permit alternative designs if they can achieve erosion and infiltration protection equivalent to an acceptable conventional cover system. This indicates the significance of searching different alternatives to compacted clay-based covers or barriers in arid areas and evaluates their performance under various environmental conditions (Fatta and

Loizidou, 2011). Many laboratory tests are needed to ensure that the materials being considered for each of the landfill cover components are suitable. Landfill instability can be solved by understanding the interface friction properties between all material layers, natural or synthetic (Aziz et al., 2016).

A variety of heavy metals are found in landfill leachate such as iron, zinc, copper, cadmium, lead, nickel, chromium and mercury. They are either soluble components of the refuse or are products of physical processes such as corrosion. Heavy metal concentrations in leachate increase over a period of time as they are non-biodegradable and accumulated in living tissues and finally became a threat to human health. Therefore, by introducing and amending the daily cover with other materials that have the capability of adsorbing metals, it can reduce the migration of heavy metals pollutants in landfill cells.

In this proposed study, local soil cover was enhanced by mixing soil with 2 types of wastes namely pressmud, which was obtained from sugar manufacturing waste, and empty fruit bunch (EFB) of palm oil at different ratio in order to improve the capability of daily soil cover in minimizing the migration of heavy metals in landfill. This study introduced pressmud and EFB as new admixture materials in landfill daily cover to reduce the migration of heavy metals in landfill.

1.3 Objectives

The main objectives of this study are as follows:

1. to determine physico-chemical properties and geotechnical properties of the local soil and soil-pressmud-EFB mixtures.
2. to determine the migration of heavy metals in the proposed soil mixtures.

3. to evaluate the suitability and the significance of the proposed landfill daily cover with optimal mixture of local soil, pressmud and EFB.

1.4 Scope of Study

This research investigates and evaluates the ability of pressmud and EFB mixed with soil to reduce and minimize the migration of heavy metals in landfill leachate. It involves field samples collection and laboratory experiments. The field sampling involves the collection of leachate from municipal solid waste disposal site and fresh soil from several areas in Nibong Tebal, Penang, while laboratory experiments involve physico-chemical analysis and characterization of soil and suitability of the soil implemented at the specific landfill site.

Physico-chemical, geotechnical, batch equilibrium test (BET) and column tests were conducted on the materials. BET was performed to evaluate the removal efficiency of heavy metals. In order to determine the suitability of the soil-pressmud-EFB mixtures usage from industrial waste material, column tests were carried out to investigate the removal of heavy metals such as cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) which were among the significant pollutants present in the Pulau Burung landfill leachate plume. These data (from characterization and adsorption behavior) were used to evaluate the potential use of soil-pressmud-EFB mixtures as a daily soil cover. Physico-chemical characterizations and geotechnical properties were studied in this research, focusing on the pattern and trend in removal capability of the new materials namely pressmud and EFB.

1.5 Outline of Thesis

This thesis contains 5 chapters (including this chapter) as follows;

Chapter 1: Introduction: This chapter introduces the background of the study, presents the problem statement, list of objectives, scope of the research and outline of thesis.

Chapter 2: Literature Review: This chapter discusses and elaborates on the groundwater aspects such as the groundwater status in terms of quality and quantity, groundwater pollution and the sources of groundwater pollution. It discusses about the solid waste disposal site and emphasizes more on the leachate quality and quantity. Besides, this chapter provides information on the overview of subsurface containment that contained the daily cover development, function and nature of engineered covers, as well as characterization and improvement of the cover materials. This research emphasizes more on the behavior of the heavy metals studied. This chapter also discusses about the adsorption model concept, optimization by using response surface methodology (RSM) and column study.

Chapter 3: Materials and Methods: This chapter presents the field sampling techniques, laboratory experimental programed and analytical equipment that were used in this study. Field sampling involved the collection of leachate and soil profile at the study site. The methods to characterize the samples are also presented in this chapter. Experimental procedures of the batch equilibrium test, including optimization sequence using RSM and column test were also discussed.

Chapter 4: Results and Discussion: This chapter contains analytical data obtained from the experimental work. The concentrations of leachate or contaminant species at the waste disposal site are presented. The characterization of the proposed materials as adsorbent are also investigated. The removal efficiencies of heavy metals such as Cd, Cr, Cu, Fe, Mn, Ni and Zn from the contaminant in batch tests using soil, pressmud, EFB and soil-pressmud-EFB mixtures are determined. Adsorption isotherm models, Langmuir and Freundlich isotherms, are plotted to determine the best fit models. Adsorption kinetic models i.e. Pseudo-first order and Pseudo-second order model are plotted using the results and presented. Optimum removal efficiency of heavy metals involved are also obtained from RSM. Breakthrough curves of the pollutant species from the column test data are plotted and discussed.

Chapter 5: Conclusion and recommendations: This chapter summarizes all of the findings of the research and makes conclusion based on them. Besides that, future work is also recommended.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is divided into several subtopics. The first topic discusses the general information on landfills. The second topic presents the solid waste disposal site and further focuses on the problem of landfill leachate. The third topic discusses in detail on the overview of containment landfill daily cover in order to minimize the migration of landfill leachate plume. The fourth topic explains about the selected heavy metals in more details. The fifth section discusses the adsorption concept and mechanism involved for the proposed daily cover. Finally, the sixth section extensively discusses about the statistical analysis used in this study including the principles and application of RSM and CCD approaches, accordingly. Besides, the regeneration of adsorbent is also discussed in detail.

2.2 Landfills

Prosperous lifestyles and continuing industrial and commercial growth in many countries around the world during the past decades have been accompanied by rapid increases in both municipal and industrial solid waste production (Jumaah et al., 2015). Municipal solid waste (MSW) generation continues to grow both in per capita and overall terms (Wang et al., 1982). Methods such as recycling, composting and incineration are promoted as alternatives to landfill method. However, even the most incineration method creates residue of approximately 10-20 % that must be ultimately landfilled (Johansson and Nils, 2014). Currently, modern landfills are complex engineered facilities designed to eliminate or minimize the adverse environmental impact of the waste on the surrounding areas (Jumaah et al., 2016).

In spite of the fact that many alternative methods of MSW treatment was introduced, sanitary landfilling is currently the most common municipal solid waste disposal method in many countries due to its relatively simple procedure and low cost (Norma et al., 2012; Jumaah and Othman 2015b). Up to 95 % of the total MSW collected worldwide is being disposed of in landfills (Adamcová et al., 2016). After landfilling, solid waste undergoes physico-chemical and biological changes. Consequently, the degradation of the organic fraction of the wastes in combination with percolating rainwater leads to the production of a dark colored and highly polluted liquid called “leachate”.

The Fukuoka method semi-aerobic system was developed more than 20 years ago at the Fukuoka University but it is not widely known to many countries around the world. It is a proven technology practically tested in many places in Japan, and in a few developing countries such as Malaysia, Iran and China. Generally, the Fukuoka method semi-aerobic landfill system can be explained as a system where the leachate and gas are continuously removed from the waste mass using leachate collection and gas venting systems, with proper engineering designs in which the ambient air flows into the waste body naturally through the leachate collection pipes, and subsequently improves the waste stabilization process and increases the leachate quality due to the enhancement of the micro-organisms activities in the waste body (Amiri et al., 2016).

A sanitary landfill is an engineered method in which solid wastes are disposed of by spreading them in thin layers, compacting them to the smallest practical volume and covering them with earth each day in a manner that minimizes environmental pollution. The disposal site shall: (1) be easily accessible in any kind of weather to all vehicles expected to use it; (2) safeguard against water pollution originating from the disposed solid waste; (3) safeguard against uncontrolled gas movement originating from the disposed solid waste; (4) have an adequate quantity of earth cover material that is easily workable, compactible, free of large objects that would hinder compaction, and does not contain organic matter of sufficient quantity and distribution conducive to the harborage and breeding of vectors; (5) conform with land use planning of the area (EPA, 1971).

Landfill plays the most important role in the solid waste disposal because it is economical and is usually used as the final resort. Solid waste leachate with its high organic and inorganic strength and quantities are however containing more major polluting substances compared with wastewater (Ozel et al., 2008; Ozel et al., 2012). Leachate is generated by water passing through solid wastes with biological and chemical constituents leaching into the subsoil (Tchobanoglous et al., 1993; Koerner and Soong, 2000). Leachate discharge into the subsoil causes groundwater pollution, so landfill technology needs to be implemented in preventing and controlling the leachate problems. Therefore, barrier or cover systems are used in order to mitigate the negative effects of the leachate. The technology of modern sanitary landfilling includes cover systems over the waste to control nuisances, to protect the environment, and to protect the health and safety of workers and the public. Depending on the location of the fill and the phase of the construction and operation, the cover systems employed are categorized as daily, intermediate, and final. Figure 2.1 shows the cross section of an operating of sanitary landfill.

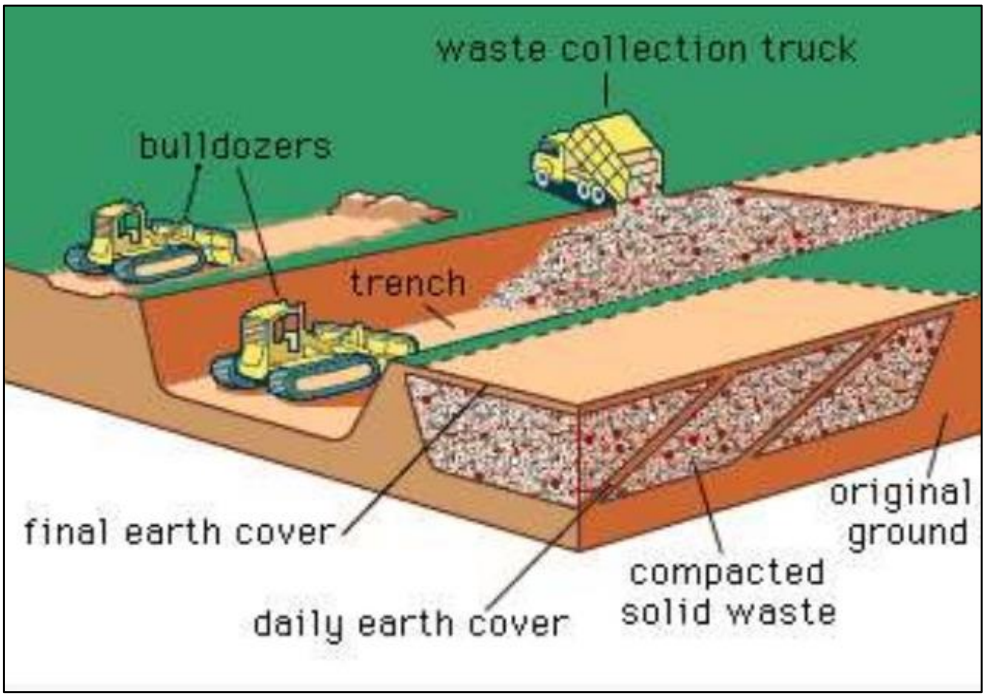

Figure 2.1: Cross section of an operating of sanitary landfill (UNEP, 2005)

The daily and intermediate covers are placed more or less continuously during the active phase of the filling operation, or in other words, they consist of compressed soil or earth which is laid on top of a day's deposition of waste on an operational landfill site. The final cover is usually applied after the landfill or a single landfill cell has reached its final capacity. First the waste needs to be covered by an intermediate cover layer, which is insensitive to settlements of the landfill surface. In the context of economically developing countries, the design and materials selection for the construction of each of the three types of cover systems are subjected to short- and long-term risks posed by the operation of the fill, the availability of suitable materials, and financial resources (ISWA, 2013).

Using daily cover on landfills helps to control odors, reduce windblown litter and inhibit fires, as well as minimizing the percolation of water through the waste which leads to the generation of leachate. Placing soil over freshly disposed waste is time consuming and requires large volume of soil. The potential saver of time and material at specific sites is the motivating force behind the consideration to the usage of alternative daily cover materials. Using local soils or blends of them as daily cover is a much more accessible way to minimize the environmental consequences of waste disposal. Therefore, in order to have a low cost and sustainable landfilling process, it is necessary to execute the most efficient cover from the native soils (Aljaradin, 2015). A growing variety of alternative materials are available to site operators in lieu of soil. These include spray applied foams and cellulose/polymer mixtures, geotextiles, modified soils, and waste-based materials (Medne et al., 2015). The decision to use an alternative daily cover material is a site-specific procedure. The benefits of using these materials can become striking from both the labor and material savings and the landfill volume saving aspects (Medne et al., 2015; Carson, 1992).

2.3 The Migration of Contaminant in Landfill

Engineered soil daily covers constitute important components of general landfill cover systems because of their ability to attenuate contaminant transport through the system when the proper choice of soil materials is made. Apart from its low cost, natural materials can retard the flow of leachates and chemically attenuate contaminant transport through various sorption processes. The most suitable types of soils are those which possess high cation exchange capacities (CEC), large specific surface areas, and high chemical buffering capacities (Yong et al., 2001 and 1999).

The use of clay soils as impermeable or attenuating barriers is becoming more popular as the material of choice in landfill liner systems. Many researchers (Ige, 2013; Griffin et al., 1976; Yanful et al., 1988; Yong et al., 1992; Yong and Phadungchewit, 1993, etc.) had discussed the different aspects and potential use of soil material not only for liners, but also as substrate material under landfills. Heavy metals such as Pb, Cu and Zn that are commonly found in leachate from landfills can be effectively attenuate by such soils. The amount of heavy metals retained depends on the pH of the soil-water (leachates) and they are retained in soils by hydroxide and carbonate when the pH of the soil solution is higher than 4 (Yong et al., 2001; Yong et al., 1999). The primary mechanism for Pb, Cu and Zn retention in clay soils is through precipitation of the metal ions with carbonates and amorphous oxides or hydroxides (Griffin et al., 1976). Yong and Phadungchewit (1993) have shown that the presence of carbonates in a soil contributes significantly to the retention capability of the soil (Yong et al., 2001).

Leachate is known as a liquid that passes through the waste refuse and water generated within the landfill site (Fard et al., 2017). The solid waste management facility regulations require that a groundwater protection system (commonly referred to as a cover and liner system) be installed at all new or expanding landfills. The purpose of cover or a liner system is to prevent leachate from reaching groundwater by collecting leachate for treatment and disposal. By preventing the movement of leachate into groundwater, the cover serves to protect groundwater and surface water from pollution. A cover of landfill is intended to be a low permeable barrier, which is laid down above wastes in engineered landfill sites (Mahmud and Alamgir, 2014).

2.3.1 Problem of Leachate in Landfill

Landfill leachate is one of the main sources of groundwater and surface water pollution if it is not properly collected, treated and safely disposed. It may percolate through soil reaching water aquifers (Bashir et al., 2009; El-Salam and Abu-Zuid, 2015). The risk of groundwater contamination by leachate is determined by many factors, including precipitation, hydrogeological conditions of the area, the toxicity, concentration and chemical composition of contaminants, solid waste composition, degree of compaction, absorptive capacity of the waste, landfill chemical and biological activities, landfill temperature, age of waste, and depth and distance from the pollution source or the direction of groundwater flow (Koda et al., 2016). In Malaysia, groundwater quality at Ampar Tenang landfill sites showed that the value for various parameters are higher than standards. This indicates that the groundwater within and surrounding the landfill is contaminated by the leachate (Yusoff et al., 2013). Heavy metals are the most dangerous pollutant group that are present in leachates and they are able to contaminate water resources (groundwater and surface water) that are close to the landfill sites, making this as one of the most serious environmental concerns. Although some of the heavy metals such as Zn, Mn, Ni and Cu act as micronutrients at lower concentrations, they become toxic at higher concentrations (Awaz, 2015).

2.3.1 (a) Factors Affecting Leachate Quantity

Several factors influencing leachate quantity are precipitation, groundwater intrusion, moisture content of the waste, refuse condition and final cover of the landfill (Mukherjee et al., 2014; Baziene et al., 2013; Aziz et al., 2004a; 2004b, El-Fadel et al., 2002). Daily cover meant to minimize leachate quantity as well to reduce the contaminant content in leachate seeping through it.

(i) Precipitation

The amount of rain and snow falling on the landfill influences leachate quantity significantly. In Malaysia, a country with high rainfall rate, the amount of leachate is very significant at all landfills. As rainwater filtrated through a waste layer by the procedure of penetration, it dissolves and leaches out a wide spectrum of organic and inorganic components (Mukherjee et al., 2014). According to Baziene et al., (2013), different quantities of leachate with different concentrations are accumulated during different seasons of the year due to an unequal amount of precipitation (less precipitation – more pollutants).

(ii) Groundwater Intrusion

Sometimes the base of a landfill is constructed below the groundwater table. In this case, the groundwater intrusion may increase the leachate quantity especially at the unlined landfills. As a part of naturally occurring process, it is common for landfill to be constructed below the groundwater table. As a result, landfills that are unlined and untreated may contribute to groundwater intrusion. In this context for instance, leachate may happen (Ibrahim et al., 2017).

(iii) Moisture Content of Waste

The waste especially organic waste will produce leachate through aerobic or anaerobic reactions. In Malaysia, the moisture content of the waste is high. So, leachate quantity will increase if the waste releases pore water during the compaction activity when it is squeezed. Gaps between soils and waste contain both water and air in the unsaturated zone. Regardless of considerable amount of water exist in this zone, the water is unable to be compacted through landfill cell as they are hold tightly by the capillary forces (Matsin, 2017). Unsaturated waste continues to absorb water until it reaches field capacity. Thereby dry waste will reduce leachate formation. Co-disposal of sludge or liquid waste will increase the leachate quantity in a landfill (Samuding, 2010).

Landfill moisture can be influenced by many factors such as rainfall, groundwater intrusion, initial moisture content, irrigation, recirculation, liquid waste co-disposal and also refuse decomposition (El-Fadel, 1997). Most Asian countries have biodegradable and moisture content solid waste composition such as food waste, paper, plastic/foam and agriculture waste (Tarmudi et al., 2012). Those are the factors that affect the leachate or moisture distribution within the landfill. Generally, as more water flows through the solid wastes, more pollutants are leached. Therefore, it is important to know methods that can be used to estimate the amount of leachate generation at a landfill site (Ibrahim et al., 2017; Qasim and Chiang 1994).

(iv) Final Cover/Daily Cover

To prevent leachate generation or infiltration, the surface and stormwater flows should be managed by using suitable cover materials, as well as saving the material with high liquid content away from the waste management facility (Chabuk et al., 2018). Leachate volume is reduced significantly after the landfill is covered. Application of soil as a final or daily cover will reduce infiltration. Low permeability of the final or daily covered material can also cause reduction in percolation. Basically, good design of the final or daily cover will reduce leachate quantity significantly. However, sometimes cracks appear on the surface of cover materials due to several factors such as waste settlement and wet and dry processes (Aziz et al., 2016; Samuding, 2010 and Albright et al., 2004). Addition of fibers has been found to improve toughness, reduce cracking from plastic shrinkage and decrease crack width and transfer stress across cracks. The potential benefit gained by adding fibers is that the fibers can reduce small crack width in shrink-swell soils. While fibers do not stop the formation of cracks, they can reduce the extent of cracking by decreasing crack width and growth, thereby improving the overall performance of the grout (Saradar et al., 2018 and Allan et al., 1995).

2.3.1 (b) Factors Affecting Leachate Quality

The extent of variation in leachate quality can be attributed to many interacting factors such as waste composition, depth of waste, availability of moisture, availability of oxygen, temperature and age of landfill. Scientists and researchers have mentioned the following factors for variation in leachate quality in general (Adhikari et al., 2014; Aziz et al. 2004a, 2004b, El-Fadel et al., 2002).

(i) Waste Composition

In general, the composition of waste determines the extent of biological activity within the landfill sites (Adhikari et al., 2014; Wimalasuriya et al., 2011; Zouboulis et al., 2004). The waste such as food and garden wastes, and crop and animal residues contribute to the organic material in leachate in most of the cases and, inorganic constituents in leachate are often derived from ash wastes and construction and demolition debris derived from different sources (Adhikari et al., 2014; Christensen et al., 2001). Bagchi, (1994) noted that the leachate quality variation is higher for putrescible waste (food, paper and textile) than that for non-putrescible waste (glass, metal and plastic).

(ii) Depth of Waste

Some researchers (Adhikari et al., 2014; Tatsi and Zouboulis, 2002; Kang et al., 2002; and WHO, 2004; Qasim and Chiang, 1994) found that the concentrations of the pollutants are higher in leachate sample from deeper landfills under similar conditions of precipitation and percolation. Deeper fills require more water to reach saturation, require longer time to decompose and distribute the leached material over a longer period of time (Qasim and Chiang, 1994; Lu et al., 1985). Deep landfills give greater contact time between the liquid and solid phases which increase the leachate concentration (Trankler et al., 2005; McBean et al., 1995).

(iii) Availability of Moisture

Water is the most significant factor influencing waste biodegradability and leachate quality. Moisture within the landfill serves as reactant in the hydrolysis reactions, transports the nutrients and enzymes, dissolves metabolites and dilutes inhibitory compounds (Adhikari et al., 2014; Shuokr et al., 2010; Noble and Arnold, 1991). The quantity of the moisture is important because it directly affects stabilization rate within the landfill (Mor et al., 2006; Silva et al., 2004). High moisture flow rates can flush soluble organic and inorganic out of the landfill (Tatsi and Zouboulis, 2002; WHO, 2004 and Shuokr et al., 2010). The optimum amount of moisture content reported ranges from 40 to 70 percent (Trankler et al., 2005; Barlaz et al., 1990).

(iv) Availability of Oxygen

The quantity of oxygen in landfill dictates the type of decomposition (aerobic or anaerobic). Aerobic decomposition occurs during the initial placement of waste, when oxygen is available. Aerobic degradation may continue to occur in the upper layers of the waste (Adhikari et al., 2014; Amokrane et al., 1997; McBean et al., 1995). Chemical release as a result of aerobic decomposition differs greatly from those produced during anaerobic degradation (Kiliç et al., 2007 and Bagchi, 2004). During the process of aerobic decomposition, microorganisms degrade organic matter to CO_2, H_2O, and produce considerable amount of heat. Generally, high concentrations of organic acids, ammonia, hydrogen, carbon dioxide, methane, and water are produced during anaerobic degradation (Bagchi, 1990). During bio-degradation, different phases occur in the landfills as a result of reductions in the quantity of oxygen. As for example, a transitional change takes place when oxygen is depleted and an anaerobic environment develops in the bio-degradation of landfills (Adhikari et al., 2014).

(v) Temperature

Landfill temperature is considered as an uncontrolled factor that influences leachate quality. Temperature affects bacterial growth and chemical reactions within the landfill. Each microorganism has an optimum growth temperature and any deviation from the temperature will decrease its growth due to enzyme deactivation and cell wall rupture. Solubility of compounds in leachate such as $CaCO_3$ and $CaSO_4$ decreases with increasing of temperature (Adhikari et al., 2014; Christensen et al., 1996; Lu et al., 1985).

(vi) Age of Landfill

Leachate quality is greatly influenced by the length of time which has elapsed since waste placement. The quantity of chemicals in the waste is finite and therefore, leachate quality reaches a peak after approximately two or three years followed by a gradual decline in the following years (Adhikari et al., 2014; Asadi, 2008; McBean et al., 1995). All contaminants do not peak at the same time (Tchobanoglous et al., 1993). Organic compounds decrease more rapidly than inorganics with increasing age of the landfill (Chiang et al., 2001 and Adhikari et al., 2013).

2.3.1 (c) Impact on Groundwater and Surface Water

Landfill leachate is one of the main sources of groundwater and surface water pollution if it is not properly collected and treated and safely disposed as it may percolate through soil reaching water aquifers (Bashir et al., 2009). Contamination of groundwater by landfill leachate is considered being a major environmental concern. The landfill leachate generally contains hundreds of different inorganic and organic chemicals at some finite concentration beside a large microbial population and may be heavily contaminated with pathogenic organisms (Kumari et al., 2017; Samuding, 2010).

Leachate generation continues in a cyclic pattern in active and closed landfill as precipitation groundwater may enter the cell in landfill then finally will directly correspond to the net infiltration rates, modified by runoff evapotranspiration patterns (Oweis and Khera, 1988). Mostly, high concentration of heavy metals, organic matters and suspended solids are present in landfill leachate (Jokela et al., 2002). A lot of cases of leachate contaminated groundwater and surface water have been documented (Maiti et al., 2016; Murray and Beck, 1990; Nasir and Chong, 1999).

Documentation of the movement of leachate plumes originally at waste dumps moreover landfills is becoming increasingly abundant. Under certain hydrologic conditions, leachate plumes can shift considerable distances and degrade groundwater throughout wide areas.

Pollution of water bodies and natural streams by leachate can causes serious problem to humans and environment including animals and plants. High concentration of heavy metals such as zinc, lead, copper, cadmium and chromium can cause serious water pollution and threaten the environment (Kamaruddin et al., 2017; Aziz et al., 2004). Therefore it is very important to remove the contaminants from the leachate in order to minimize the contaminants movement towards the surface water and groundwater.

Leachate must be treated prior to discharge and it must meet the discharge limits of treated effluents. Generally, these limits vary from country to country, depending on the various factors such as treatment cost and economic situation of the country.

Leachate treatment is costly and requires multiple processes (Ozturk and Bektas, 2004). Numerous factors need to be considered when designing the leachate treatment system. Leachate treatment is required during the landfill operation and after the landfill closure. During life cycle of the landfill, leachate characteristics will change, thus an improvement in treatment system may be required. One of the possible landfill leachate treatment systems is the use of landfill daily soil cover system. The details of landfill soil cover system are discussed in the subsequent topic.

2.4 Overview of Daily Cover

The use of cover material is an essential element of landfilling operations and performs a number of important functions to minimize the impact on the environment of the landfill. The type, quantity and method of application of the cover material used at each landfill must be appropriate to achieve the overall objective of controlling potential nuisances that may arise (Medne et al., 2015). Operational landfills represent a very dynamic and changing work environment that must be managed on a continuous basis to achieve good overall environmental