ENHANCEMENT OF LANDFILL DAILY COVER IN MINIMIZING THE MIGRATION OF HEAVY METALS USING MIXTURE OF LATERITE, PEAT SOILS AND RICE HUSK

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by

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LIST OF ABBREVIATIONS

ASTM	American Standard Method
BDL	Below Detection Limit
BS	British Standard
CCD	Central Composite Design
CEC	Cation Exchange Capacity
CIRIA	Construction Industry Research & Information Association
DOE	Department of Environment
EPA	Environmental Protection Agency
FESEM	Field Scanning Electron Microscope
FTIR	Fourier Transform Infra- Red
ICP-OES	Inductively Couple Plasma Optical Emission Spectrometry
JICA	Japan International Cooperation Agency
LS	Laterite soil
MHLG	Ministry of Housing and Local Government
MSW	Municipal solid waste
PS	Peat soil
PV	Pore Volume
RH	Rice husk

RSM	Response Surface Methodology
SEPA	Scottish Environmental Protection Agency
USEPA	United State Environmental Protection Agency
WHO	World Health Organization
XRD	X-ray Diffraction

PENAMBAHBAIKAN PENUTUP HARIAN TAPAK PELUPUSAN SISA PEPEJAL DALAM MENGURANGKAN PENGHIJRAHAN LOGAM BERAT MENGGUNAKAN CAMPURAN TANAH MERAH, GAMBUT DAN SEKAM PADI

ABSTRAK

Tapak pelupusan sisa pepejal adalah fasiliti yang direka sebagai platform pelupusan sampah yang selamat. Penutup tanah harian tapak pelupusan dianggap sebagai komponen yang paling kritikal untuk mencegah dan mengurangkan kemasukan larut lesap ke dalam air bawah tanah. Pergerakan bahan pencemar dari kawasan pelupusan sisa pepejal berpotensi untuk menyebabkan pencemaran air bawah tanah. Logam berat di dalam sumber air adalah salah satu masalah alam sekitar yang paling utama di Malaysia. Oleh itu, kajian ini dijalankan untuk mengkaji keberkesanan campuran tanah merah (LS), tanah gambut (PS) dan sekam padi (RH) sebagai penutup tanah harian dalam mengurangkan pergerakan logam berat di tapak pelupusan. Lima jenis logam iaitu kadmium (Cd), kromium (Cr), tembaga (Cu), nikel (Ni) dan zink (Zn) digunakan sebagai bahan cemar. Kaedah kajian yang digunakan adalah ujian pemadatan, ketelapan, ujian tegasan mampatan, kadar pertukaran kation (CEC), mikroskopi pengimbasan elektron (SEM) dan permukaan kumpulan berfungsi bahan. Kapasiti penjerapan oleh campuran tanah merah, tanah gambut dan sekam padi ke arah ion logam telah dikaji. Kapasiti penjerapan ditentukan dalam kajian kelompok sebagai fungsi parameter proses (kepekatan awal dan tindak balas masa). Kemudian, data yang diperoleh daripada kajian kelompok disuaipadankan pada model isoterma penjerapan Langmuir dan Freundlich bagi menentukan model isoterma yang terbaik. Seterusnya, kajian pengoptimaan bagi campuran tanah merah, tanah gambut dan sekam padi telah dijalankan dengan menggunakan *Central*

Composite Design. Keputusan CEC bagi campuran tanah merah, tanah gambut dan sekam padi adalah 8.7 hingga 17.9 meq/100g di mana lebih tinggi berbanding LS. Keputusan keseluruhan kajian kelompok menunjukkan campuran tanah merah, tanah gambut dan sekam padi berkeupayaan menyingkirkan lebih dari 90% Cd, 99% Cu dan Cr, 85% Ni dan 83% Zn. Sementara itu, kecekapan penyingkiran logam berat di dalam LS adalah kurang daripada 61%. Berdasarkan, kajian isoterma penyingkiran bahan pencemar Cr, Cu, Ni dan Zn adalah dikawal oleh penjerapan ke permukaan homogen melalui perkongsian antara bahan atau pertukaran ion kecuali Cd. Keputusan kajian pengoptimuman campuran tanah merah, tanah gambut dan sekam padi adalah pada kepekatan awal 5.76 ppm dan 15 minit tindak balas masa. Berdasarkan pada keputusan pencirian, kecekapan penyingkiran dan penjerapan, campuran 50LS:40PS:10RH adalah gabungan yang lebih sesuai dan mempunyai potensi yang baik untuk digunakan sebagai penutup tanah harian. Dari analisis ujian turus, ia menunjukkan pergerakan bandingan bagi logam berat ialah Ni>Zn>Cu>Cd>Cr untuk 50LS:40PS:10RH.

ENHANCEMENT OF LANDFILL DAILY COVER IN MINIMIZING THE MIGRATION OF HEAVY METALS USING MIXTURE OF LATERITE, PEAT SOILS AND RICE HUSK

ABSTRACT

An engineered landfill is a facility designed for the safe disposal of solid wastes. The daily soil cover of a landfill is considered as the most critical components to prevent and minimize leachate generation that finally will infiltrate into the groundwater. Migration of contaminants has the potential to increase groundwater pollution. Heavy metals in water are one of the most significant environmental problems in Malaysia. Therefore, this study examines the effectiveness of admixture of laterite soil (LS), peat soil (PS) and rice husk (RH) as daily soil cover in minimizing the migration of heavy metals in landfill. Five types of metals namely cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni) and zinc (Zn) were utilized as metal contaminants. Some laboratory tests were employed in studying the compaction behavior, permeability, unconfined compression strength, cation exchange capacity (CEC), scanning electron microscopy (SEM) and surface functional groups. The adsorption capacity of laterite soil-peat soil-rice husk mixtures towards metal ions was also being studied. The adsorption capacity study was performed by batch experiments as a function of process parameters (initial concentration and contact time) was observed. Furthermore, the batch experimental data were fitted to Langmuir and Freundlich isotherms to determine the best-fit model. Next, optimization study of the laterite soil-peat soil-rice husk mixture was conducted by using Central Composite Design then followed by column studies. The CEC value of laterite soil-peat soil-rice husk mixtures was indicated in the range of 8.7 to 17.9 meq/100g which was higher than LS alone. Results from the batch study had shown that laterite soil-peat soil-rice husk mixture was found effective in removing over 90% of Cd, 99% of Cu and Cr, 85% of Ni and 83% of Zn. Meanwhile, the removal efficiency of heavy metals from the solution in the LS was less than 61%. According to the equilibrium study, the removals of Cr, Cu, Ni and Zn were controlled by monolayer adsorption onto homogeneous surface of mixtures except for Cd. The optimization study of laterite soil-peat soil-rice husk mixture revealed that 5.76 ppm initial concentration and 15 minutes of contact time were required for optimum heavy metals removal. Based on the characterization, removal efficiency and adsorption results, 50LS:40PS:10RH mixture was found to be the most suitable combination and had a good potential to be used as landfill daily soil cover. From the column test analysis, it was indicated that the relative mobility of the heavy metals was in the sequence of Ni>Zn>Cu>Cd>Cr for 50LS:40PS:10RH.

CHAPTER ONE

INTRODUCTION

1.1 Background

It is estimated that 17,000 tonnes of solid waste are produced in Peninsular Malaysia daily, which by 2020 is expected to be more than 30,000 tonnes per day. This is in fact due to the rapid growth of population and increment in per capita generation (UNDP, 2008). Evaluation by Malaysia Department of Statistics (2017) provided that the estimation number of population in Malaysia was at 32.0 million with a population growth rate at 1.3% resulted in a tremendous increase in the quantities and types of solid wastes generated. Data from previous studies suggested that without a proper municipal solid waste management and sustainable practice in the landfill sites, groundwater pollution would become crucial and actions should be taken in order to protect livelihoods of human being and the environment.

In 2007, an act namely the Solid Waste and Public Cleansing Management Act, 2007 was established by the government. The act was introduced with the purpose of providing guidelines and regulations towards the management of waste (Sin et al., 2016; Romali et al., 2013). This act was initiated by the government for the transferring of executive authority from the local authority to the Federal Government. Through this act, the Department of National Solid Waste Management and the Solid Waste Management and Public Cleansing Corporation are operating throughout peninsular Malaysia and it imposes higher responsibilities on the stakeholders (Sin et al., 2016; Yahaya and Larsen, 2008).

Sanitary landfill is one of the processes in the solid waste management system. Landfill generally known as waste disposal that is widely accepted technology, especially in developing countries, due to its low investment and operational costs (Raghab et al., 2013). Most landfill sites in Malaysia can be categorized as open dump sites which are operating without using proper protective measures for example; lining systems, leachate treatment and gas venting (Ghafar, 2017; Ismail and Manaf, 2013). Minister of Urban Wellbeing, Housing and Local Government stated that Malaysia currently has 170 waste disposal sites throughout the country, but only 14 of them with the status of sanitary landfill (The Sun Daily, 2017). Most of these landfills are poorly managed and thus the migration of leachate from the landfill to surface water and groundwater has been identified as one of the sources for municipal solid waste (MSW) generation, which became a threat to the environment. Therefore, an alternative method in reducing the pollutant for landfill management is necessary to ensure safe and stable groundwater system.

Soil daily cover is an attractive option that can be applied at landfill sites. Its usage is very important in order to occupy more or less continuously during the active phase of the filling operation. Daily cover on freshly placed MSW at an engineered landfill facility is very important in controlling the spread of disease vectors, preventing fires, controlling odors, minimize windblown litter, preventing scavenging, controlling dust and providing a moisture barrier (Aljaradin and Persson, 2015). As stated by Al Yaqout et al., (2005), the water held in the surface soils can penetrate down the solid waste by capillary action. Thus, leachate will eventually migrate toward the water table beneath the landfill contaminating the soil and the aquifer system. Hence, the placement of daily cover system can limit the quantity of surface water that infiltrates to a landfill (Harianto, 2008).

As been noted earlier, landfill soil needs to be mixed with other materials in order to enhance the performance of soil stabilization in terms of its geotechnical and physicochemical properties. This is because soil daily cover in landfill can acts as a medium for the migration of pollutants before seeping into groundwater. Therefore, significance for the present study is to investigate the effect of landfill daily cover on decreasing the concentration of pollutants within the leachate which percolates out of the landfill. In this study, a mixture of peat soil (PS) and rice husk (RH) with laterite soil (LS) was proposed for daily cover applications in MSW landfills.

Peat soil has been identified as one of the major groups of soils found in Malaysia. Malaysia is the 9th country with the highest total area of peat soil, based on the global chart of total peat deposit around the world. The total area of peat soil in Malaysia covers about 2.6 million hectares (26,000 km^2), of which about 13% are in the peninsular Malaysia, over 80 % in Sarawak and about 5 % in Sabah (Adon et al., 2012). The formation of peats is more favorable when the area is waterlogged, with excess rainfall and low permeability ground, irrespective of latitude or altitude (Huat et al., 2011). However, the peat soil is classified as problematic soil due to its natural properties of high compressibility, low shear strength and high initial water content. Due to these geotechnical problems of peat soil, improvement mechanism is so essential when the peat soil exists to deal with it as a soil foundation (Salam, 2017).

The abundant and availability of agriculture byproduct make them a good source of low cost materials for wide uses for instance as natural adsorbents. Rice husk as a low-value agricultural by-product can be made into sorbent materials which are used in heavy metal and dye removal (Daffalla et al., 2010; Wan Ngah and Hanafiah, 2008). Based on the statistics done by the Malaysian Ministry of Agriculture, it was reported that there are 408,000 tonnes of rice husk being generated in Malaysia in a yearly basis (Chuah et al., 2005; Wong et al., 2003). In majority of rice producing countries much of the husk produced from processing of rice is either burnt or dumped for disposal (Mohamed et al., 2015). However, despite being dumped, rice husks can actually be activated and benefited as adsorbents in water purification or the treatment of industrial wastewater. This in return will become an added value for agricultural commodities since they can reduce the cost of waste disposal and consequently provide a low cost alternative for existing commercial carbon (Sharma and Janveja, 2008). Thus, the use of rice husk gives a lower cost adsorbent than activated carbon as it is cheap and easily available.

1.2 Problem Statement

Most of the MSW are simply dumped on land in a more or less uncontrolled manner without any environmental protection. According to Aziz et al., (2016) most landfills in developing countries are not equipped with liners at the base or proper top/daily covers, which can give the problems of ground water/surface water contamination due to the leachate generated from the solid waste landfill. Besides, direct discharge of leachate into water sources tends to threaten the surrounding ecosystem, particularly in cases where landfills are located upstream of water intakes (Aziz et al., 2015).

Leachate from MSW is one of the main sources of groundwater and surface water pollution particularly with heavy metals, chemical oxygen demand (COD), biological oxygen demand (BOD) and suspended solids. Improper disposal facilities at the landfill cause leachate percolation through soil which will finally reach the groundwater system (Salam et al., 2011). Leachate often contains high concentration of pollutants hence they require various physical and chemical treatments that are economical, efficient and effective that gives benefits to the operators, society and environment.

Numerous researches in heavy metals removal show that adsorption is capable of removing certain heavy metals as high as almost 100% (Nwafulugo et al., 2014; Al-Ghouti et al., 2010). Similarly, Babel and Kurniawan (2003) suggested that application of a low-cost adsorbent such as chitosan, zeolite, clay, peat moss, fly ash, coal, natural oxide and industrial waste in adsorption mechanism is another option for heavy metals removal. Clay is also an example of minerals that is far less cheap and easily available that could be used as an adsorbent.

Laterite soil has been the original and most common type of daily cover however the soil does not performs all functions required as a cover such as it was highly permeable and poor adsorption capability (Kasim et al., 2017). Hence, modification of soils to improve their engineering properties becomes essential. Peat soil and rice husk's potential as adsorbent in the study of heavy metal removal have been discussed in previous studies. Rice husk contains 15-22 % SiO_2 in hydrated amorphous form like silica gel, cellulose and lignin (Zafar et al., 2011; Chuah et al., 2005) and seems to have the potential to bind metal ions. Previous study had successfully adopted rice husk to remove Zn, Pb and Cr from textile wastewater (Muneer et al., 2010).

On the other hand, peat soil can be found largely from accumulation of soils residues from disintegration of plants and organic matter. It has plenty of negatively charged sites on its surface (Chaturvedi et al., 2007), high cation-exchange capacity and favorable functional groups (Andreetta et al., 2016) which can be exploited for adsorption of heavy metal ions. However, its potential as an alternative for a daily soil cover is yet to be explored. Thus, this research study aims to examine effectiveness of the mixture of peat soil and rice husk for removal of heavy metals from synthetic solution. In selecting a suitable landfill daily soil cover, several important geotechnical characteristics must meet the standard requirements. Furthermore, the batch study and column study of the materials need to be carried out in order to evaluate the performance of proposed materials as landfill daily soil cover.

1.3 Objectives

The main objectives of this research are as follows:

1. To determine physico-chemical properties of laterite soil, peat soil and rice husk.
2. To determine the characteristic of laterite soil-peat soil-rice husk mixtures in terms of adsorption capacity such as Freundlich and Langmuir isotherms models.
3. To evaluate the best ratio of laterite soil-peat soil-rice husk mixtures on the removal of heavy metals in leachate.

1.4 Scope of Study

This research is focused on the characterization of laterite soil-peat soil-rice husk mixtures and the improvement of landfill daily cover in minimizing the migration of heavy metals in landfill leachate.

Sampling locations of laterite soil, peat soil and rice husk were within the Nibong Tebal, Penang area. Basic properties of LS, PS and RH were investigated. The physico-chemical properties that were being tested involved moisture content, Atterberg limit, specific gravity, compaction, surface area, particle size distribution, cation exchange capacity and heavy metal content. Geotechnical aspects of these laterite soil-peat soil-rice husk mixtures were also determined which involved permeability, compaction test and stress strain behavior.

The laterite soil-peat soil-rice husk mixtures were evaluated against laterite soil alone for their effectiveness in removing heavy metals from solution. Heavy metals for this study were cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni) and zinc (Zn) which are the significant pollutants presented in leachate. The equilibrium removal at varied initial concentrations and contact time were determined through batch experiments. Besides, evaluations of isotherm models were analyzed by applying the data obtained from the batch experiments (effect of initial concentration).

Moreover, optimizations of initial concentration and contact time for the best laterite soil-peat soil-rice husk mixture were performed by using Response Surface Methodology based on the optimum operating variables of the batch experiments. Finally, the best ratio of different percentage weight was further tested by column test to determine the mobility of the pollutant materials.

1.5 Outline of Thesis

This thesis consists of five chapters as follows:

Chapter 1: Introduction. A brief introduction of the research work, problem statement, objectives and scope of the research are provided and discussed throughout this chapter

Chapter 2: Literature Review. This chapter provides information related to the solid waste and solid waste disposal site. This chapter also covers an overview on landfill daily cover, alternative daily cover, characterization of daily cover material and adsorbent materials (LS, PS and RH) that will be used. This research emphasizes more on the behavior of the heavy metals followed by isotherm and utilization of Response

Surface Methodology (RSM) for design parameter optimization. Lastly this chapter touches on column test.

Chapter 3: Materials and Methods. This chapter presents the field sampling, laboratory experimental procedures and equipment that were used in this study. Field sampling involved the collection of laterite soil, peat soil and rice husk. The methods to characterize the samples were also discussed in this chapter. Experimental procedures of the batch study in determination of heavy metal removal from synthetic solution are also included, followed by optimization sequence using RSM and column test.

Chapter 4: Results and Discussions. This chapter provides analytical data obtained from the experimental work. The physico-chemical properties of laterite soil, peat soil, rice husk and laterite soil-peat soil-rice husk mixtures are presented. The removal efficiency of heavy metals (Cd, Cr, Cu, Ni and Zn) is also investigated through batch test study. Moreover, isotherms as well as optimization results obtained from the experiments are plotted for the best fit. Soil column data are discussed in order to evaluate the retardation and breakthrough curve characteristic of soil column through reaction with heavy metals.

Chapter 5: Conclusion and recommendations. This chapter summarized all the findings from this study and then concludes them. Besides that, recommendation for further studies is also suggested in this chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter consists of several sections. The first section discusses the general information of MSW sources. The second section presents the solid waste disposal site and the third section focuses on the overview of landfill daily cover. Next, focuses on the problem of landfill leachate. The fifth section presents the selected heavy metals in more detail. The sixth section discusses about the theory and principle of adsorption and isotherms used in this study followed by the factors affecting the adsorption. The eighth section elaborates about the characteristics of laterite soil, peat soil and rice husk. The ninth section gives a general outline of experimental design and analysis using RSM. The last section discusses about laboratory flow-through (column) method.

2.2 Solid Waste

Solid waste is defined as any scrap material or other unwanted surplus substance or rejected products arising from the application of any process or any substance required to be disposed (Solid Waste and Public Cleansing Management Act, 2007). Solid waste is usually being said as domestic rubbish, sewage sludge, wastes from manufacturing activities, packaging items, discarded cars, garden waste, discarded electronic devices etc. which is generated from industrial, residential and commercial activities in a given area. Each activity will generate different types of waste which will require its own specialize treatment. Hence it will lead to the increase of different wastes (Ngoc and Schnitzer, 2009). Based on their sources, the types of solid waste that is commonly generated in Malaysia are MSW, hazardous waste, agriculture waste and industrial waste (Tchobanoglous et al., 1993). In this study it will focus on MSW landfill which is to enhance the daily soil cover.

MSW can be defined as the wastes generated from domestic, commercial, industrial, and institutional activities but generally exclude hazardous waste (Ravindra et al., 2015; Bashir, 2010). The rapid population growth, urbanisation, economic levels and rise in the community living standards will generate a tremendous rate of MSW which contributes to the biggest environmental problems in Malaysia as reported by Chong et al., (2005). According to Moh and Abd Manaf (2014), the overall waste composition in Malaysia is dominated by MSW (64%), followed by industrial waste (25%), commercial waste (8%) and construction waste (3%).

2.2.1 Composition of MSW

As reported by Visvanathan et al., (2004) the solid waste composition in most Asian countries is highly biodegradable with high moisture contents such as food waste, paper, plastic/foam, agriculture waste, rubber/leather, wood, metal, glass and textiles. The composition data of waste is required to evaluate the impacts of certain types of waste towards landfill. However, reliable data on solid waste composition is difficult to obtain and sometimes it is not up to date (Idris et al., 2004) as the composition of wastes varies from time to time and place to place. The composition of MSW typical of cities in Southeast Asian countries is presented in Table 2.1. As can be seen, the largest fraction is paper and cardboard at 28% of the waste stream. The highly urbanized cities produce a high percentage of organic and mixed inorganic waste (55–70%), and small amount of recyclables such as 10–16% plastic, approximately 3–9% glass and 4–12% metal.

Table 2.1: MSW waste composition in Southern Asian Nations

Country	Waste composition (%)					
	Organic waste	Paper cardboard	Plastic	Glass	Metal	Others
Brunei	44	22	12	4	5	13
Cambodia	55	3	10	8	7	17
Indonesia	62	6	10	9	8	4
Laos	46	6	10	8	12	21
Malaysia	62	7	12	3	6	10
Myanmar	54	8	16	7	8	7
Philippines	41	19	14	3	5	18
Singapore	44	28	12	4	5	7
Thailand	48	15	14	5	4	14
Vietnam	60	2	16	7	6	9

Source: Ngoc and Schnitzer, 2009

In 2006, the average components of MSW in Malaysia are quite similar with the largest categories consisting of food waste (45%), plastic (24%) followed by paper (7%), iron (6%) and lastly 3% for glass and others (Government of Malaysia, 2006). This study focuses on the minimization of heavy metals in leachate from landfill in Malaysia and Table 2.2 illustrated waste composition generated per day in Peninsular Malaysia. As stated by Nadzri (2013) commonly, MSW in Malaysia consists of 50% of food waste, and 70% as disposed at the landfill sites and households are the primary source of MSW in Malaysia.

Table 2.2: Waste composition generated per day in Peninsular Malaysia

Waste compositions	Percentage (amount, %)
Food	45
Plastic	24
Paper	7
Metals	6
Glass and others	18
Total	100

Source: Zainu and Songip, (2017)

2.3 Solid Waste Disposal Site

Many parameters have to be considered in choosing a waste disposal site such as composition of the waste, availability of the land, suitability of the site location, public awareness and environmental impact (Samuding, 2010). The authorities are eagerly looking for a solution to solve the piling up of solid waste related problems such as negative environmental impacts, land scarcity and increasing solid waste. Table 2.3 depicts the practice of waste disposal in Malaysia since 2002 and it also indicates the proposed technologies to be used by 2020. Several methods of waste disposal will be discussed in the following sections (Masirin et al., 2008; Trivedi and Raj, 2002).

Table 2.3: Method of waste disposal in Malaysia

Treatment	Percentage of waste disposed (%)		
	2002	2006	Target 2020
Recycling	5.0	5.5	22.0
Composting	0.0	1.0	8.0
Incineration	0.0	0.0	16.8
Inert landfill	0.0	3.2	9.1
Sanitary landfill	5.0	30.9	44.1
Other disposal site	90.0	59.4	0.0
Total	100.0	100.0	100.0

Source: Agamuthu et al., (2006)

2.3.1 Open Dumping

In most cases, open dumping is being practiced and takes place at about 50% of the total landfills (Masirin et al., 2008). An open dump may inspect and record incoming waste and include limited compaction by bulldozer and compactor. This quick and dirty method is cheap, but fantastically rough on the environment. The wastes are disposed on land without any liner or barrier, treatment facilities and without capping material to cover the top of the waste (Chenayah and Takeda, 2005). Thus, the leachate tends to infiltrate into the soil strata and might pollute the groundwater system. Hence, this practice is gaining less popularity in Malaysia and sanitary landfill has become more widely accepted.

2.3.2 Sanitary Landfill

Landfilling is the most economical and environmentally acceptable method used in the disposal of solid waste (Rodrigues et al., 2004) due to its lower maintenance and operation costs (Aziz et al., 2007). At present, landfilling is the main method of waste disposal (80% usage) in Malaysia. Most landfills in developing country are in bad conditions, and operated without any liners at the base or proper top covers (Ismail and Manaf, 2013) which results in the potential problems of ground water contamination due to the leachate generated from the solid waste landfill (Aziz et al., 2016).

Sanitary landfill for the disposal of municipal solid wastes are widely accepted and used in the several countries. Sanitary landfills use technology to dispose refuse and prevent the leaching out of potentially hazardous substances for instance incorporate a full set of measures to control gas and treat leachate and apply a daily soil cover on waste (JICA, 2010a; Trivedi and Raj, 2002).

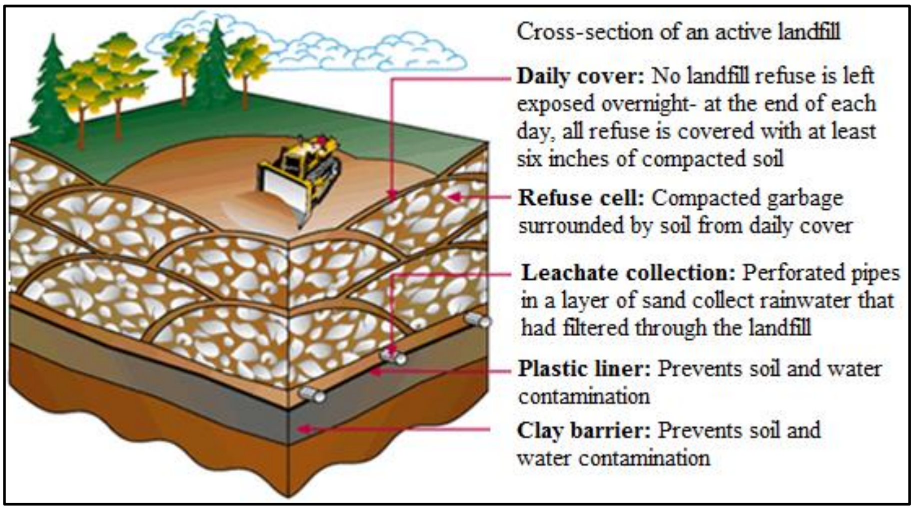

Figure 2.1: Schematic diagram of sanitary landfill (Source: https://www.teachengineering.org/activities/view/cub_enveng_lesson05_activity2)

The selection of sanitary landfill sites usually is based on the result of detailed site survey, engineering design and cost studies and environmental impact assessments in order to meet the satisfactory of this purpose. The environmental impact of landfills depends, to a high extent, on a bottom liner and top capping isolating the landfill from the surrounding (Stępniewski et al., 2011).

In this study the daily soil cover application will be focused in order to minimize the migration of heavy metals through refuse cell. Hence to maintain sanitary conditions, the waste needs to be covered on a regular basis. Cover material ideally should consist of inert, non-combustible, dry and dense materials which include soil, sand, crushed rock, crushed coral rock, ash, decomposed waste from another part of the site, demolition waste, sawdust and garden waste (JICA, 2010b). The soil cover application is very effective in the prevention of environmental pollution (Bashir, 2010). It is important to maintain a landfill site clean and maximize its capacity by good operation.

Three types of cover system usually applied in the construction of a sanitary landfill which is daily, intermediate and final cover soil (He et al., 2015). The typical progression of cover/capping systems employed within a landfill cell can be summarized in Figure 2.2. The use of daily cover is to cover the freshly compacted waste at the end of each working day (Ng and Lo, 2010a) whereas waste deposits that are left for longer than a week or so, a thicker covering of material is usually applied referred to as intermediate cover (EPA, 2014). The function of intermediate cover is the same as daily cover but must be functional over a prolonged period of time. Lastly, final cover is placed over areas of the landfill that have reached full capacity and final design waste grades. Final cover soil should be of good quality and preferably clay to form an effective barrier against rainfall. The types and thickness of final cover soil depends on the planned usage of the completed landfill site (MHLG, 2004). Even though daily and final cover systems are structurally different, the goal of preventing the infiltration of water into the underlying waste layer is the same (Inazumi, 2003).

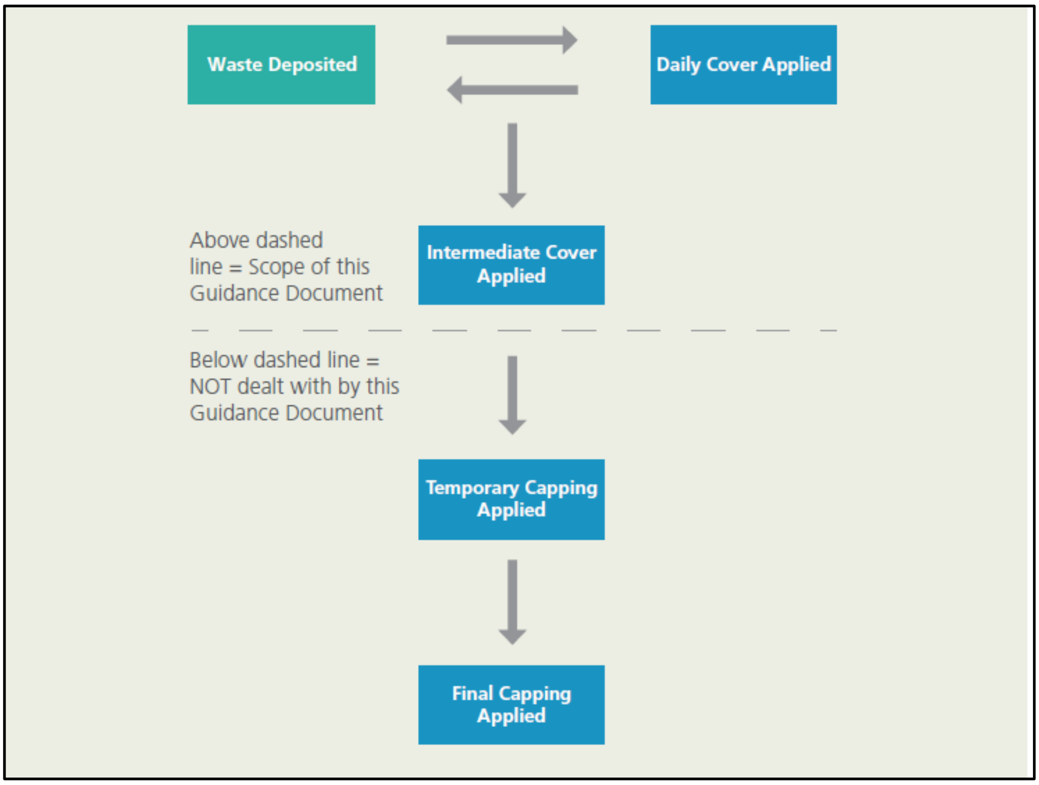

Figure 2.2: Typical progression of cover and capping systems at a landfill (EPA, 2014)

2.4 Overview of Landfill Daily Cover

An engineered landfill is a facility designed for the safe disposal of solid wastes. As mentioned in previous section, necessity of soil daily cover is very important whereby liquid contaminants can migrate through the soil and leach into groundwater. Therefore, the use of daily covers will help in minimizing the moisture infiltration in landfill site prior to development of a new cell or placement of intermediate cover (Bisson and Heuberger, 1995) and thus the generation of leachate (Joosten, 2014). According to Patil et al., (2009) the bottom liner and a top cover, of the landfill are considered as the most critical components. A top cover system should semi-permanently prevent the infiltration of rainwater into underlying waste layer while a daily cover system should suppress the infiltration of rainwater into the waste layer during the waste reclamation stage (Kamon et al., 2002). Therefore, as said earlier the uses of daily cover material is also essential for landfilling operations and perform a number of important functions to minimize the impact of the landfill on the environment (Medne et al., 2015). The schematic view of daily cover is shown in Figure 2.3.

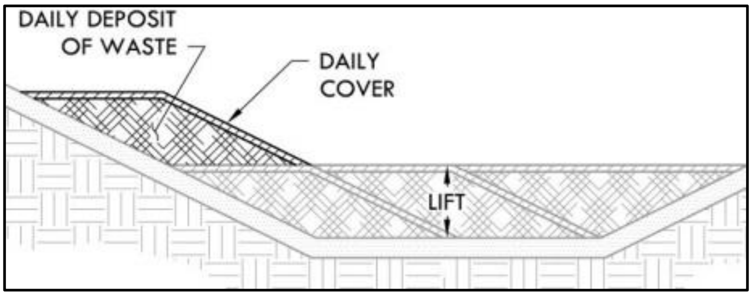

Figure 2.3: Schematic view of a daily cover (Source: Oni, 2016)

Safari and Bidhendi, (2007) indicated that after waste disposal, the major part of the leachate is generated during the early days therefore the daily cover is subject to strong for fresh leachate infiltration during limited period of time. This encourages the concept that heavy metal removal can be achieved through modifying the daily cover soil texture with addition of some adsorbents like lime.

Cover soil can be classified as sand, silt or clay and the permeability differs depending on the soil type. Permeable and porous sand types should be used for daily and intermediate cover for ease of spreading and compaction and to assist with waste decomposition at semi-aerobic landfills whereas the final cover soil needs to resist erosion by rainfall, be low permeability and suitable for sustaining plant growth. (JICA, 2010b). The cover soil shall cover the landfilled wastes properly, sufficiently spread and compacted with proper thickness and gradients (MHLG, 2004).

2.4.1 Application of Landfill Daily Cover

Landfill daily cover is required to be placed on any area with exposed municipal solid waste at the end of each operating day in order to eliminate harmful vectors like flies from breeding, bad odor from spreading (Nolan and Cambell, 2011) and to also can limit the quantity of surface infiltration (Tchobanoglous et al., 1993). Rainfall enters while the waste is being placed. Therefore, the placement of landfill daily cover can limit the quantity of leachate generation. The regulation requires about 15 cm (6 inches) of the material to cover the disposed waste at the end of the day (EPA, 2014; Carson, 1992). When implemented properly, a basic objective of protection of human health could be achieved.

Firstly, daily cover will help in reducing available breeding site for mosquito and discourages solid waste from serving as an attractant to domestic or wild animals. Applying a daily cover provides a barrier between the landfill surface and the waste. Hence, a soil-based cover is least likely to allow fires on the landfill's surface to spread to the waste beneath (Oni, 2009). Next with the 6 inches of soil cover, it will help to control blown litter and serves as an odor filter for odors arising from solid waste (Carson, 1992). Daily cover will improves the aesthetics for site users and neighbors and lastly as mentioned in previous section, it will reduce the infiltration of storm water run on into the filled mass of solid waste and helps to increase run off of precipitation (Hammond, 1996).

Soil is easy to obtain for the use as daily cover, but its use is controversial (Medne et al., 2015). It should be noted that the laterite clay soils form a large part of the soil in Malaysia, since this country is located in the tropical region. However, the use of soils as daily covers contributes to instability of waste mass and its hydraulic heterogeneity reduces the efficiency of the drainage layer due to migration of fine soil particulates and clog formation (Ng and Lo, 2010b). Thus alternative types of cover may have to be considered (Nolan and Cambell, 2011).

2.4.2 Alternative Daily Cover

In order to improve the performance or suitability as landfill cover, mixing or blending of the materials can be done either pre-application or at the landfill working itself. Hence, a variety of alternative cover materials are available for use as daily covers at MSW landfills. The use of waste materials as landfill daily cover encourages the practice of waste recycling and thereby prolongs the life span of existing landfills. Generally, alternative daily covers (ADCs) are mixtures of waste derived and non-waste derived materials. Waste derived materials can include various types of locally available waste materials such as ash, automobile recycling fluff, fine particulates of construction and demolition waste, compost, shredded green waste (vegetation and leaves), contaminated sediment and soil, sludge, and shredded tires. Non waste derived materials can be generally classified into two groups: sprayable material (foams and slurries) and geosynthetic materials or tarps (Medne et al., 2015; Rogoff et al., 2012).

An investigation on waste-derived mixture of the tire chips and paper sludge was conducted by Ng and Lo, (2010a) to study the engineering properties of alternative daily cover in MSW landfills. From the study, the waste-derived mixture of the tire chips and paper sludge was found to be lighter in weight, more impermeable and higher in shear resistance (24kPa) when compared to traditional soil covers. The addition of tire chips to the sludge improved the shear resistance considerably. The optimal tire chip content for shear resistance was found to be 55%

by weight. Thus, the results suggest that the addition of tire chips to the paper sludge has mechanical characteristics that are desirable to be a landfill daily cover.

Previous research documented by Safari and Bidhendi, (2007) in which the possibility of in situ removal of heavy metals found in leachate generated at municipal solid waste landfills was studied through amendment of daily cover soil by addition of lime. The in situ removal experiment was accomplished through a set of seven columns filled with the sampled soil with varying contents of lime (from 0% to 6% by dry weight). The results indicated a substantial increase in removal efficiency through the 3% addition of lime to the daily cover soil.

Evidently, the diversity in land usage and human activities discharging effluent or producing waste had deteriorated the quality of groundwater. Hence, daily soil cover application will help in minimizing the migration of heavy metals in leachate through each cell before reaching groundwater. Mohamad et al., (2014) using natural soil, pressmud & empty fruit bunch (EFB), also revealed that the soil-pressmud-EFB mixtures are highly potential material as a daily cover in landfills due to the excellent heavy metals removal capability (90% removal) if compared to natural soil alone which is beneficial to the environment.

Medne et al., (2015) reported that a sprayable cover material is the most convenient for daily use. The main materials used are clay (10−90%), fibres (20−60%) and polymers (0.5−15%). Form this study, particularly components of sprayable daily covers for the use in local environment (Latvia) are clays, which are found in abundance in local mineral deposits.

According to Samuding, (2010) the soil-EFB mixture has a good potential to be used as filled barrier materials at landfill sites. The removal capability of the soil improved with the presence of the EFB into the soil content. The surface charge of clay mineral and EFB material are predicted to be a contributing factor for the adsorption of heavy metals. The presence of some surface functional groups in the EFB fiber was also capable of adsorbing metal ions. The soil-EFB mixtures have the capability to remove more than 80% of Pb, Cu and Ni and more than 65% of Ni and Zn compared to soil alone (50%). Table 2.4 summarizes the material used and its application in landfill.

Table 2.4: Summary on the material used and its application

Materials	Application	References
Waste-derived mixture of the tire chips and paper sludge	Study the engineering properties of alternative daily cover in MSW landfills	Ng and Lo, (2010)
Daily cover soil & lime	Study the removal of Mn and Zn found in leachate at MSW landfills through the amendment of daily soil cover	Safari and Bidhendi, (2007)
Sprayable alternative daily cover compositions	This paper focuses on alternative daily cover materials intended for use in solid municipal waste landfills	Medne et al., (2015)
Natural soil, pressmud & empty fruit bunch (EFB)	Study the removal of heavy metals found in leachate at MSW landfills through amendment of daily soil cover	Mohamad et al., (2014)
Fibrous paper mill sludge & rice husk	Study of geotechnical properties of organic waste materials as landfill cover	Varghese and Prakash (2017)
Soil-EFB mixture	Study the potential of the materials as filled barrier in landfill sites in minimizing the migration of contaminants	Samuding, (2010)
Modified sewage sludge (sludge, lime, cement, silt, tire-derived aggregate (TDA))	Study the feasibility of modified sewage sludge as landfill cover material and its performance in a complex landfill environment	He et al., (2015)

He et al., (2015) investigated the feasibility of modified sewage sludge as landfill cover material and its performance in a complex landfill environment through strength and hydraulic conductivity tests. As the duration of soaking of modified sewage sludge in synthetic leachate increases, the unconfined compressive strength increases, and the hydraulic conductivity decreases slightly or fluctuates between 1.0×10^{-5} cm/s and 1.0×10^{-6} cm/s, still in the requirements for an interim cover. From this study, modified sludge with sludge:lime:cement:silt:tire-derived aggregate (TDA) weight ratio of 100:15:5:70:15 can be used as an interim cover from the perspectives of strength and hydraulic performance.

2.4.3 Characterization of Daily Cover

In selecting suitable materials for potential use in engineered soil daily cover, characterization of materials need to be conducted and must meet the requirement of the standard agreements. However as reported by He et al., (2015) there is no specification of hydraulic conductivity for daily cover, as its main purpose is not to reduce the rain invasion where the value is not stipulated explicitly in the standard agreements. Hence the requirement of landfill daily cover was based on the standard requirement of the soil liners of engineered landfill.

For landfill sites where there is a potential hazard to groundwater system, the sites must have engineered soil liner, which must have a layer that satisfied the permeability and thickness requirements. Engineered soil liner implemented in the surrounding landfill site must have two main criteria which are low permeability and high adsorption capability/capacity (DOE, 1995; CIRIA, 1996). The permeability and the adsorption capability of the daily soil cover are dependent on the number of variables including particle size distribution, degree of compaction, particle shape, surface area, cation exchange capacity and mineralogy (Yong et al., 1997). As stated by Patil et al., (2009) the main factor affecting the quality of compacted clay liners/covers is its permeability which should not be greater than 1×10^{-9} m/s. With low infiltration, it may take decades to centuries before the field capacity of the waste is reached and full leachate generation to occur (Bouazza et al., 2002)

Compacted clay liners should have a saturated hydraulic conductivity of the order $\times10^{-9}$ m/s ($\times10^{-7}$ cm/s) or less (Ghana Landfills Guidelines, 2002; EPA 2000). Also, according to the United States Environmental protection Agency (USEPA) the compacted soil liner must have a permeability of not more than 1×10^{-7} cm/s. The low hydraulic conductivity will assist to lengthen the lifetime of the landfill by minimizing the leachate migration and the required thickness helps ensures that, the liner meets the required hydraulic conductivity standards (Emmanuel, 2015).

Besides permeability, the compressive strength of the material is among the important parameters to be considered for a landfill daily cover. Shear strength is perhaps the single most important mechanical property of solid waste in landfill engineering (Hossain and Haque, 2009). Therefore, geotechnical test material should be done to determine engineering properties such as the drained or undrained shear strength and the stress-strain behavior of the materials used.

2.5 Landfill Leachate

Solid waste disposal in landfill poses a threat to groundwater and surface water quality if not managed properly as a result of the formation of polluting liquids known as leachate. Landfill leachate can be defined as liquid produced by the percolation of precipitation water through an open landfill or through the cap of a completed site. Leachate in municipal landfill may contain large amounts of organic contaminants, suspended solid, ammonia, heavy metals, phenols and phosphorus

(Aziz et al., 2015). The generation of leachate mainly cause by a release from waste due to successive biological, chemical and physical process of waste deposited in a landfill.

Rainfall is the main contributor to the generation of leachate and causes significant threat to groundwater. In humid climates, cover and/or re-vegetation are usually required for erosion protection and infiltration control (Aziz et al., 2016). The barrier between the cells restricts downward escape of the waste constituents. Therefore daily soil cover system can help in preventing the leachate migration into the ground surface and provides mechanical resistance to external water pressure. (Harianto, 2008)

Heavy metals available at various concentrations in raw leachate include lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) (Ozturk et al., 2003; Aziz et al., 2004). The concentrations of heavy metals in leachate were affected not only by their amounts in the fill materials but also by the degradation processes within the landfill (Chu et al., 1994). Heavy metal content is a major concern owing to the persistent nature where bioaccumulation of heavy metals in aquatic organisms is a threat to human health (Fauziah et al., 2013). The health effects from leachates may occur through the food chain due to the ingestion of other organisms (fish, aquatic plants) that habitat an environment contaminated by leachates.

2.5.1 Problem of Landfill Leachate

Leachate can pose detrimental environmental impacts and health hazards if it is not properly treated. As reported by Natural Resources and Environment Minister Datuk Seri Dr Wan Junaidi Tuanku Jaafar in The Sun Daily (2017), six solid waste