MODIFICATION OF RESIDUAL SOIL WITH PALM OIL FUEL ASH AS POTENTIAL LANDFILL LINER

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To my beloved father and mother for their endless love and support.

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ABSTRACT

In Malaysia, wastes that being disposed of to landfill sites have increased tremendously. This leads to another environmental problem where the leachate penetrates through the landfill barrier system and contaminates the groundwater source. In this study, palm oil fuel ash (POFA) is employed to modify residual soil samples collected from campus of Universiti Teknologi Malaysia (UTM) to enhance the potential of the soil material as the landfill liner. Soil classification, specific gravity, compaction, permeability and zinc adsorption tests were performed on soil sample with 0%, 5%, 10%, 15% and 20% POFA added. Soil sample collected was categorized as gravely silt with very high plasticity (MVG) with liquid limit of 74%, plastic limit of 40.79%, plasticity index of 34.79% and specific gravity of 2.77. As for compaction test, Standard Proctor was applied with optimum moisture content and maximum dry density obtained. The permeability was directly proportional to void ratio of the soil. The lowest permeability was shown in 15% POFA modified soil, which is 6.65×10^{-9} ms^{-1}, whereas soil with more than 15% POFA added had exhibited higher permeability. Zn adsorption tests were conducted on the untreated soil and the lowest permeability soil sample, which was 15% POFA modified soil sample. The result showed that the soil sample modified with 15% POFA had exhibited better adsorption capacity compared to the untreated soil sample and agreed well with Langmuir isotherm. However, the 15% POFA modified soil did not meet the standard of permeability (less than 1×10^{-9} ms^{-1}) that stated in the landfill liner material specifications.

ABSTRAK

Di Malaysia, sisa yang dilupuskan di tapak pelupusan sampah telah meningkat dengan cepat. Keadaan ini mengundang satu masalah alam sekitar di mana air larut lesapmenembusi lapik kambus tanah dan mencemar sumber air bawah tanah. Dalam kajian ini, abu sisa baker kelapa sawit (POFA) telah digunakan untuk mengubahsuai sampel tanah baki yang diambil dari kawasan kampus Universiti Teknologi Malaysia (UTM) bagi meningkatkan potensi sampel tanah sebagai bahan lapik tapak kambus tanah. Ujian klasifikasi tanah, graviti tentu, pemadatan, kebolehtelapan dan ujian jerapan logam berat-zink dijalankan ke atas sampel tanah yang dirawat dengan POFA 0%, 5%, 10%, 15% dan 20%. Sampel tanah yang dikumpul dikategorikan sebagai MVG, kelodak berkelikir dengan keplastikan sangat tinggi dengan 74% had cecair, 40.79% had plastik, 34.79% indeks keplastikan dan 2.77 graviti tentu. Bagi ujikaji pemadatan, *Standard Proctor* telah digunakan, di mana kandungan lembapan optimum dan kepadatan kering maksimum diperolehi. Kebolehtelapan tanah adalah berkadar terus dengan nisbah lompang dalam tanah. Tanah yang dirawat dengan 15% POFA menunjukkan kebolehtelapan terendah, iaitu $6.65x10^{-9}$ ms^{-1}. Ujikaji jerapan Zn telah dijalankan ke atas sampel tanah tanpa rawatan dan juga sampel tanah yang berkebolehtelapan terendah, iaitu tanah yang dirawat dengan 15% POFA. Keputusan menunjukkan tanah yang dirawat dengan 15% POFA meunujukkan keupayaan menjerap zink yang lebih baik dan sejajar dengan isotherm Langmuir berbanding dengan sampel tanah tanpa rawatan. Namun begitu, tanah yang dirawat dengan 15% POFA tidak memenuhi piawai kebolehtelapan (kurang daripada $1x10^{-9}$ ms^{-1}) yang dinyatakan dalam spesifikasi bahan lapik tapak kambus tanah.

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LIST OF ABBREVIATIONS

Al_2O_3	-	Alumina
BS	-	British Standard
Cd	-	Cadmium
Cr	-	Chromium
Eq.	-	Equation
HDPE	-	High-density polyethylene
Hg	-	Mercury
LL	-	Liquid limit
NGOs	-	Non-government Organizations
Ni	-	Nickle
Pb	-	Lead
PI	-	Plasticity index
PL	-	Plastic limit
POFA	-	Palm oil fuel ash
PVC	-	Polyvinyl chloride
SiO_2	-	Silica
U.S.	-	United States
USEPA	-	United States Environmental Protection Agency
UTM	-	Universiti Teknologi Malaysia
Zn	-	Zinc

LIST OF SYMBOLS

I_p	-	Plasticity index
ρ_d	-	Dry density
ρ_L	-	Density of the liquid
W	-	Moisture content of soil
w_L	-	Liquid limit
w_P	-	Plastic limit
G_s	-	Specified gravity
D	-	Diameter
a	-	Cross sectional area of burette
A	-	Cross sectional area of soil sample
h_1	-	Hydraulic head across sample at the beginning of test
h_2	-	Hydraulic head across sample at the end of test
k_h	-	Permeability
L	-	Sample length
t	-	Elapsed time of the test
E	-	Void ratio
q_e	-	Amount of metal adsorbed by soil
C_e	-	Equilibrium concentration of metal in the liquid
q_m	-	Maximum adsorption capacity
K_a	-	Langmuir isotherm constant
n	-	Adsorption intensity of absorbent (Freundlich Isotherm)
k_F	-	Adsorption capacity (Freunlich Isotherm)

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Chapter 1

INTRODUCTION

1.1 Background of Study

As Malaysia has followed the steps of urbanization and globalization of the world, country, no matter in the arena of physical-infrastructures, economy or social, It is getting into progress. These improvement and progression bring along the pros and cons. Society becomes more affluent in terms of lifestyle and living standards. Things used in life are getting more advanced and high-technology, especially those electronic appliances. As the things become more and more, unwanted or those things that have lost their values in sense of usage will increase dramatically overnight.

In facts, the loading of daily wastes (refer to those unwanted or undesired thing) in Malaysia is increasing every second. Malaysia's population about 24 millions people generate almost 0.8 kg per day per person. The total wastage

generated per day is 20,000,000 tons.

Malaysia is currently in the process of development and those arable lands or even the natural virgin forest area have been deforested for development. Malaysia is facing problem of land lackadaisical to build new disposal sites for incoming large amount of wastes generation. With the statistic proven, the disposal sites in Malaysia will be full in coming 20 -30 years time. This will definitely become the most critical problem faced by policy-makers.

There are more and more wastes have been dumped to the landfill sites without a proper segregation process at the source. This situation has led to over-loading of wastes in the landfill sites. Over-dumping and over-occupying of wastes in the dumping sites will cause another problem to be arisen, where the landfill site has to withstand the overloading. Undeniably, tonnage of wastes will bring certain level of weight pressure to the existed landfill liners and become a burden to it. This can seriously lead to some side effects, such as compaction pressure from overloading. This condition can cause the soil liners to lose their strength in holding the mass of wastes disposed of. It is resulting in the collapse of the liners and destroys the main purpose of the landfill site.

Besides, strength losing of the landfill liners can also lead to the leakage and leaching of the leachate to underneath of the landfill. Leachate can be defined as the potential polluting liquor which is resulted from the percolation of rainfall, runoff and some chemical reactions, such as wastes decomposition in nature that occur beneath the landfill cover soil (Tchobanoglous *et al.*, 1993). The leachate formed is mostly consisted of many different kinds of chemicals, organics and impurities from the mixtures of domestic and even scheduled wastes. Therefore, they might contain

some of the heavy metals, such as Pb (lead), Cd (cadmium), Cr (chromium), Hg (mercury) and Zn (zinc).

As the landfill leachate is formed and begins to go into the landfill liner, some pollutants in leachate will be retained in the soil layer. Heavy metals in the leachate itself might not cause any negative impact but they will contaminate the soil layers and lead to some environmental problems when the leachate is leaching out through the landfill liner beneath the site. Until certain level where the soil layer is fully retained with leachate or in other words, the selective particles are passing through the permeability limit of the clay liner, they will enter the groundwater source and deteriorate the water quality of groundwater. Heavy metals with certain concentration can lead to food-poisoning or even fatal to the consumers.

Nowadays, public awareness towards health and safety is getting higher. Everyone cares about own health and safety in taking or drinking anything. This causes the problem of groundwater contamination by the landfill leachate becomes a paramount concern of the society to be discussed. Government agencies and some Non-government Organizations (NGOs) have participated in some campaigns and have some talks on this issue. Policy-makers have to be aware of whatever research reports that have been carried out in order to take appropriate action to solve the problem. For example, government has appointed a few companies, such as Kualiti Alam, Radicare (M) Sdn.Bhd. to treat those scheduled wastes before disposing of the to the landfill sites.

Undeniable, landfill liners play an important role in controlling the natural leaching process of the landfill leachate. The geomechanical and geotechnical structure of the landfill liners have to be taken into account to control the leachate

from entering to the underneath of the liner and polluting the groundwater. Therefore proper and appropriate management of a landfill site is very essential in ensuring public safety and environmental health.

In order to reduce the risk of being polluted, heavy metals in the landfill leachate should be retained and trapped in the matrix structure of the clay soil liner built. At the same time, the clay soil used as the landfill liner should be in low permeability, in order to reduce the amount of leachate to be penetrated through. The landfill liners normally have to be designed by having hydraulic conductivity of less than 1×10^{-7} cm s^{-1} to inhibit the movement of the leachate.

At this moment, the landfill liners construction is still under improvement. Due to insufficient strength structure of the clay soil liners, those liners usually cannot totally inhibit the penetration of leachate through the liners for long term. Moreover, leachate that passes through the liners will still consist of almost same amount of heavy metals concentration. It shows that the landfill liners do not have significant influence or change to the amount or concentration of the heavy metals in the leachate that penetrate through the landfill clay liners.

From other researchers, it is found that recent year, there is a trend on soil stabilization. It has evolved innovative techniques of utilizing local available environmental and industrial waste material for the modification and stabilization of deficient soil. With these findings, some studies on the landfill liners should be carried out in order to improve and enhance the structure and physical properties of the landfill liners.

1.2 Problem Statement

The dramatic increasing amount of wastes to be disposed to the landfill sites has caused the occurrence of some cases where the soil layers and groundwater near to the landfill are contaminated by the landfill leachate. Some toxic and hazardous matters, such as heavy metals will leach out of the landfill clay liner after some time and enter the groundwater. It can pollute the groundwater source and lead to drinking water source contamination. Commonly the landfill leachate will consist of heavy metals, such as lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Zinc (Zn), Copper (Cu) and mercury (Hg) (Tchobanoglous *et al.*, 1993). It will definitely affect health when the groundwater has been used to be one of the drinking water sources, especially in Kelantan and Kedah states. Certain level of concentration of the heavy metals will lead to food-poisoning or even fatal. Hence, this issue has provoked public awareness towards the public health and safety. In this research, Zn has been listed as one of the dangerous heavy metal. According to Environmental Quality Act 1989, the concentration of zinc cannot exceed the standard concentration, which is less than 2mg/L.

Thus, in order to reduce the risk of being polluted, the heavy metals in the landfill leachate should be retained and trapped in the matrix structure of the clay soil liner built. The clay soil used as the landfill liner should have low permeability in order to reduce the amount of leachate that can penetrate through. The landfill liners normally have hydraulic conductivity of less than $1 \times 10^{-7} cms^{-1}$ to inhibit the movement of leachate. At this moment, landfill liners construction is still under improvement. Due to insufficient strength of the clay soil liners, those liners usually cannot totally inhibit the penetration of leachate through the liners for a long term. Moreover, leachate that passes through the liners still consists of almost same amount of heavy metals concentration. It means that the landfill liners do not have

significant influence or change to the amount or concentration of the heavy metals in the leachate that penetrate through the landfill clay liners.

1.3 Objectives of the Study

This project is carried out in order to fulfill the objectives as follow:

1. To determine the permeability and other engineering properties of soil sample collected.
2. To study the adsorption capacity of the soil sample on zinc adsorption in the leachate.
3. To investigate the effect of modifying soil by adding different ratio of palm oil fuel ash (POFA) on the permeability and adsorption capacities towards the adsorption of zinc metal in leachate.
4. To compare and evaluate the permeability and zinc adsorption capacities of modified soil and the raw soil sample based on the landfill liner material specifications.

1.4 Scope of Study

This research is carried out using soil that to be collected in the Universiti Teknologi Malaysia (UTM) campus, Skudai. The residual soil is chosen because it is widely distributed around Johor state and can be obtained easily. In order to improve and enhance the containment of zinc in leachate, the compacted soil liner has been

modified using additive, palm oil fuel ash. The mixture of soil with palm oil fuel ash is made on different ratio of percentages.

Soil classification test and permeability test are carried out on the soil in order to determine the physical and chemical properties of soil. There is another adsorption test on zinc concentrations left in the synthetic leachate carried out on the soil and mixture of soil with palm oil fuel ash after the synthetic leachate is leaching through the modified soil layers. Zinc element has been chosen because the composition percentage of zinc in typical leachate is considered high compared to other elements and have to be reduced.

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