Enhancement of Natural Local Soil in Minimizing the Migration of Heavy Metals Using Pressmud

Maheera Mohamad, Harlina Ahmad, Norli Ismail, Norhashimah Morad and Kamarudin Samuding

***Abstract*—** The presence of heavy metals constitutes a potential threat to human health and ecosystem. The potential sources of heavy metals as a contaminant are from industrial effluents and leachates from municipal and mining solid waste disposal sites. This study emphasizes on the leaching behavior of heavy metals in soil column test. In this study, the local soils were mixed with pressmud at different percentage in weight (10%, 30%, 50% and 100%). The physico-chemical properties of the local soil and soil-pressmud mixtures were determined. The properties studied were compaction behavior, permeability, cation exchange capacity, compressive stress test and surface functional groups. The leaching test method conducted in the laboratory by using a series of column test. From the studies, pressmud has a good potential material to be used as an admixture in the landfill soil cover in reducing heavy metals concentration. The migration of heavy metals through compacted soil columns are monitored in leaching column tests to study the soil interactions with heavy metals.

***Keywords*—**leaching behavior, column test, local soils, pressmud, heavy metals and admixture.

I. Introduction

RECENTLY, solid waste generation in Malaysia reached a crucial perspective especially in terms of the amount and composition. Rapid development and an increasing the quantities of pollutants are being spewed into the environment. Therefore, these gives a major health hazard in most countries especially in term of solid waste problem. The largest generated waste by Malaysian consists of organic waste that comes from food waste and this waste generally contain lots of moisture and when being dumped into the landfill, the liquid waste will leach out from the source known as leachate. Typical disposal methods practised in Malaysia is landfill, where most of the waste produced from residential area, commercials and non-scheduled waste from industry are dumped. These wastes will mix and produce leachate that may contain unwanted substances such as residue or excess of heavy metals coming from industrial waste.

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Pressmud is an industrial byproduct of the process of ethylic alcohol distillation, produced by biological fermentation of the raw material namely molasses that presents a dark coloration and a great turbidity [1]. Large amount of press mud are released by the sugarcane industry and the disposal of this by-product is a major issue. In many cases, press mud is burnt in brick kilns resulting in the loss and wastage of millions of tonnes of nutrients through burning, which ultimately degrades the environment. One of the common utilization is to use it as a fertilizer, either unprocessed or processed form. There are some research studies in the processes used to improve its fertilizing value including composting, treatment with microorganisms and mixing with distillery effluents. Several studies have been conducted on pressmud for its suitability to use in agriculture and for energy production [2-8].

This research investigates and evaluates the ability of pressmud mixed with local soil to reduce and minimize the leachability of heavy metals in landfill leachate.

II. Methodology

A. Sampling

Local soils were sampled from Pulau Burung Landfill, Seberang Perai Tengah, Pulau Pinang and pressmud was sampled from the sugar mill, Malaysian Sugar Manufacturing (MSM) Sdn Bhd, Seberang Perai, Pulau Pinang.

B. Characterization Study

Several local soil-pressmud mixture ratios were investigated for their physical and chemical properties. The physical properties tested includes pH, specific gravity, moisture content, organic carbon, permeability and compaction test which in accordance with British Standard

[9]. The surface physical morphology of the local soil-pressmud mixtures was observed using a Scanning Electron Microscopy (FESEM/EDX) model Philips XL40.

Chemical properties tested includes cation exchange capacity (CEC) and chemical content of pore fluids. The test methods are as illustrated in the Laboratory Manual, Geotechnical Research Centre, McGill University, Montreal Canada [10]. The CEC was determined using batch test incorporating ammonium acetate exchanges [11]. The surface functional group was performed by Fourier Transform Infra-Red Spectroscopy (FTIR, Perkin Elmer Spectrum GX).

C. Column Test

Local soils and pressmud samples were air-dried and sieved through 2 mm sieve to remove all coarse pebbles. Physico-chemical characterization test were determined in order to select the best mixture ratio for leaching column test. The soil mixed by using different ratios of pressmud and soil (pressmud:soil). The ratios were 10:90 (PM10), 30:70 (PM30), 50:50 (PM50) and 100:0 (PM100). The soil alone was also investigated in soil column test. The influent used for the column was the synthetic heavy metals solution (pH below 2). The pH needs to be reduced below 2 and stored in a refrigerator and maintained at 4^{o}C to avoid precipitation of heavy metals during the column test. The influent and effluent from the column test was determined by using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) Optima 7000 DV. Figure 1 shows the series of column test in laboratory.

Fig. 1 Series of column test

The column test was assisted under a constant air pressure of 15 psi. This was to increase the permeation taken from the synthetic heavy metals solution through the leaching cell. The effluent was collected every 1 pore volume (PV). The PV of the samples was calculated based on the porosity and the volume of the sample analyzed. Column experiments were conducted with different materials which were laterite soil alone and 4 different ratios of laterite soil and pressmud mixtures (10:90, 30:70, 50:50 and 100:0).

D. Determination of heavy metals concentration

The heavy metals concentrations in the influent, C_o and effluent solutions, C_e was determined using an ICP-OES. The effluent pH was measured using the pH - meter. From the experimental data, a graph of breakthrough curve was obtained by plotting influent concentration to effluent concentration ratio (C_e/C_o) versus pore volume of the solution or time.

III. Results and Discussion

A. Local Soil Characteristics

Basic physical properties of the local soil samples were shown in Table 1. The result of pH is 4.42 which was in acidic condition whereas the moisture content showed only 18.4%. Specific gravity of soil was 2.24. Organic carbon content in local soil shows 0.23%. The average value of the permeability test using distilled water as a medium was 3.2241 x 10^{-6} cm/Sec.

TABLE I
LOCAL SOIL PROPERTIES

Characteristics	Value
pH	4.42
Moisture Content (%)	18.40
Specific Gravity	2.24
Organic Carbon (%)	0.23
Permeability Test (cm/sec)	3.2241 x 10^{-6}
Cation Exchange Capacity (meq/100g)	5.9

Figure 2 shows the compaction behavior of the local soil at various percentages that was investigated in terms of dry density and moisture content. From the results, it was found that the optimum moisture content was 15.21% while the maximum dry density was 1.845 mg/m^3.

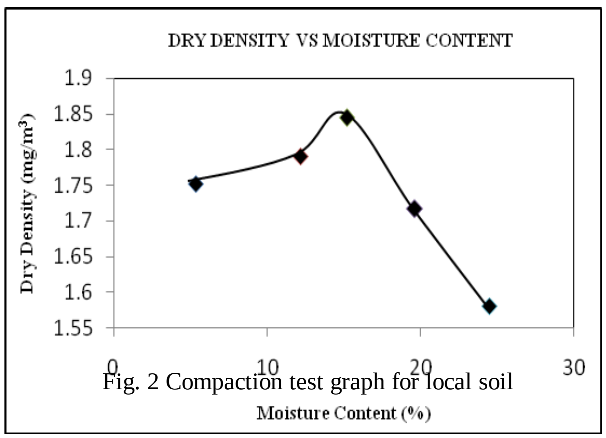

Fig. 2 Compaction test graph for local soil

Figure 3 shows the particles of soil layer in 5000 times magnification. Usually, the negative charges clay layer has a tendency to attract the positive charge of cation as a physical-sorption [12].

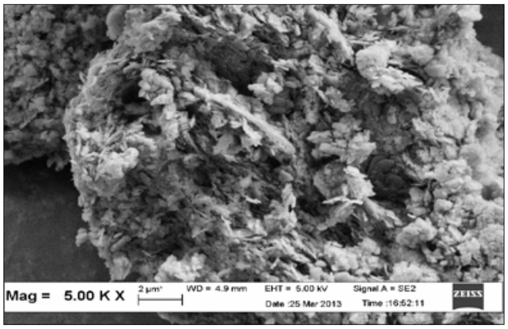

Fig. 3 The surface physical morphology of local soil

The chemical properties for CEC indicated 3.19 meq/100g as shown in Table I, proving the value of CEC is low. Figure 4 presents the percentage transmission for various wave numbers given by the FTIR spectrum of the local soil alone. The broad and flat band at band at 3640-3400 cm^{-1} could be assigned to hydroxyl group that was probably attributed to adsorbed water.

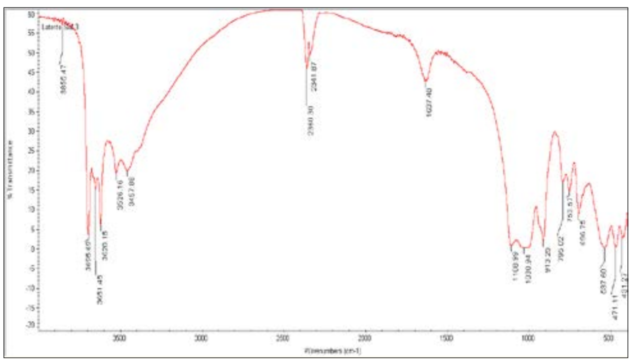

Fig. 4 The FTIR spectrums of local soil

Table II shows the list of heavy metal contents in the local soil. It was found that, the presence of some heavy metals in soil for instance Chromium (Cr), Manganese (Mn) and Zinc (Zn) showed 0.01, 0.197 and 0.182 mg/L respectively. Other heavy metals like Copper (Cu), Nikle (Ni) and Lead (Pb) were non-detectable.

TABLE II
HEAVY METALS CONCENTRATION IN LEACHATE

Elements	Concentration in mg/L
Cr	0.01
Cu	ND
Mn	0.197
Ni	ND
Pb	ND
Zn	0.182

B. Pressmud Characteristics

Basic physical properties of the pressmud are shown in Table 3. The result of pH is 8.06 which were in alkaline condition whereas the moisture content shows 31.4%. Specific gravity of pressmud is 1.76. Organic carbon content in pressmud was higher than local soil, showing 3.05%. The average value of the permeability test using distilled water as medium was 1.8409 x 10^{-5} cm/sec increased than local soil.

Figure 5 shows the compaction behavior of the pressmud at various percentages that was investigated in terms of dry density and moisture content. It was found that the optimum moisture content increased; which was 29.50% compared to local soil. The maximum dry density was 1.168 mg/m^3 lower than local soil. A decreased in the dry density was assumed due to the lighter weight of pressmud compared to the local soil.

TABLE III
PRESSMUD PROPERTIES

Characteristics	Value
pH	8.06
Moisture Content (%)	31.4
Specific Gravity	1.76
Organic Carbon (%)	3.05
Permeability Test (cm/sec)	1.8409 x 10^{-5}
Cation Exchange Capacity (meq/100g)	44

On physical examination of the compacted samples, 'good bonding' was observed between the pressmud and the soil, which improves as the moisture content increases. Good bonding refers to the interaction and mixing between soil particles and pressmud fiber. Cracking was observed with the lower moisture content mixtures and it was minimized when the samples were compacted at moisture contents at least 2% above optimum [12].

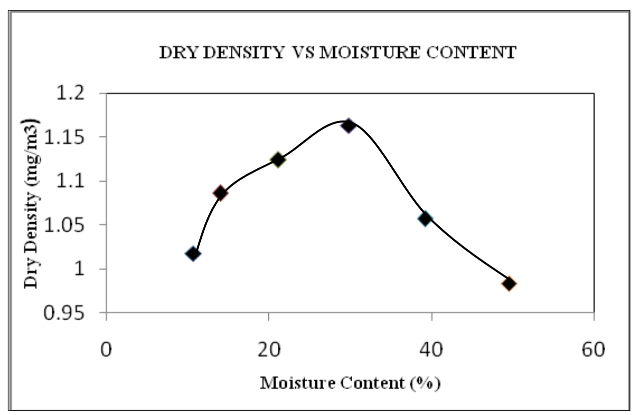

Fig. 5 Compaction test graph for pressmud

Figure 6 shows the surface physical morphology of the pressmud in 5000 magnification. Pores of different sizes and shapes can be observed. Micropores play an important role to attract and bind the heavy metals ion from the pollutants. Several particles were trapped into the pores and can be possibly block the entry of pores to some extent.

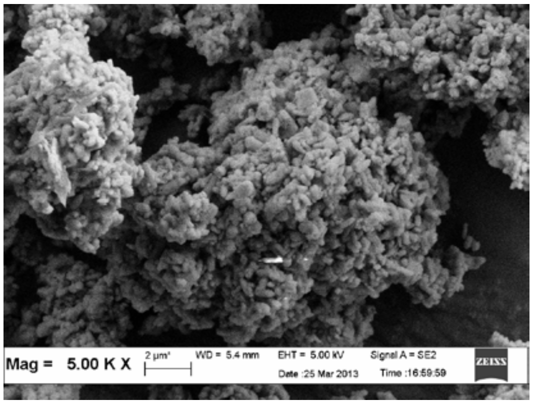

Fig. 6 The surface physical morphology of pressmud

Figure 7 shows the FTIR spectrums for pressmud, the absorption bands and peaks provided the evidence of the presence of some surface functional groups such as carboxyl, hydroxyl, etc. that are capable of adsorbing metal ions. The broad and flat band at 3640-3400 cm-1 could be assigned to hydroxyl group, which was probably attributed to adsorbed water. The range for 2990-2850 cm^{-1} shows the presence of two bands of $–CH_2$ group. The broad peak at 2750-2350 cm^{-1} could be assigned as stretching of NH. The sharp peak observed at 2360.46 and 2340.52 cm^{-1} indicated the presence of amines hydrohalides. While the wave number at 1796.70 indicated the stretching of C=O either anhydrides or aliphatics. At the 1440-1320 cm-1 is H-C=O bend for aliphatic aldehydes. The 1424.47 cm-1 indicated to NH deformation mode. This reveals the presence of several functional groups for binding heavy metals ions on soil-pressmud mixtures surface.

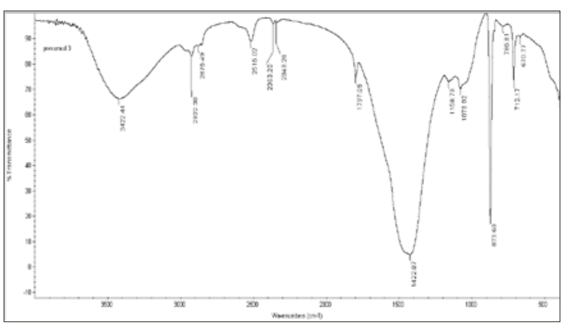

Fig. 7 The FTIR spectrums of pressmud

C. Column Test

a. Local Soil

Figure 8 shows variation in ratio of effluent (C_e) to the initial concentration (C_o) over pore volumes (PV) of the solution for local soil as a media. The relative concentration (C_e/C_o) for Cr, Cu, Fe, Mn, Ni and Zn show the immediate increase to 0.5 after 8 PV indicates that poor attenuation or retention capability of the local soil with respect to the heavy metals mobility. The breakthrough curves of several heavy metals for local soil are shown in Figure 8. According to [13] the breakthrough of particular ion occurs when the relative concentration, C_e/C_o = 0.5. The 50% point on the ordinate marks is the point of breakthrough of the target pollutant in the soil being tested [14].

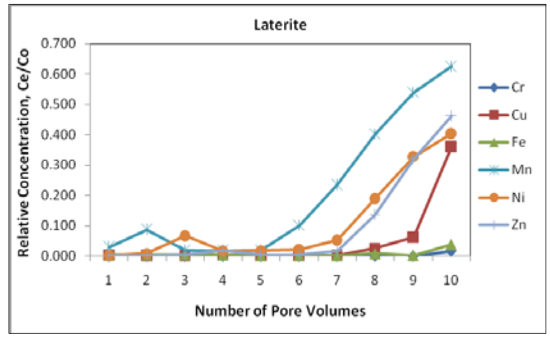

Fig. 8 Breakthrough curve of heavy metals for local soil

2. Pressmud (PM100)

Figure 9 shows variation of ratio of effluent (C_e) to the initial concentration (C_o) over pore volume of the solution for pressmud (PM100) as a media. From the figure, it shows that the column was exhausted at the 3 PV of the experiment for all heavy metals. The breakthrough of particular ion occurs when the relative concentration, C_e/C_o was less than 0.5 in this column. On the other words, the pressmud alone or 100% pressmud was with higher magnitude than that of local soil alone.

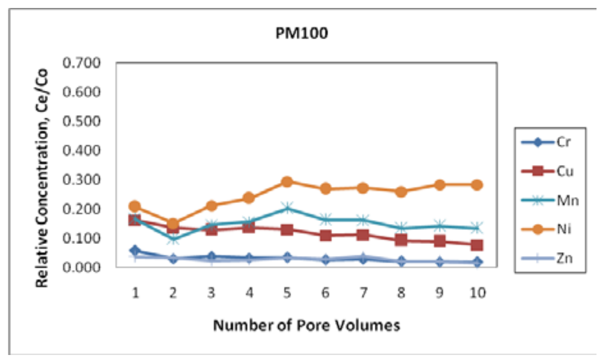

Fig. 9 Breakthrough curve of heavy metals for PM100 (pressmud)

3. PM10

Figure 10 shows variation of ratio of effluent (C_e) to the initial concentration (C_o) over pore volume of the solution for PM100 as a media. The saturation point achieved at 1 PV until 10 PV for PM10.

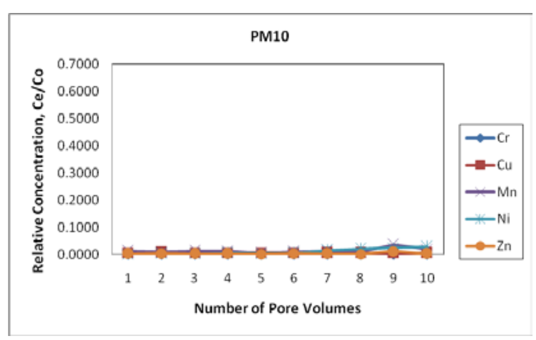

Fig. 10 Breakthrough curve of heavy metals for PM10

4. PM 30

Figure 11 shows variation of ratio of effluent (C_e) to the initial concentration (C_o) over pore volume of the solution for PM30 as a media. Similar to the PM10, the saturation point achieved at 1 PV until 10 PV for PM30.

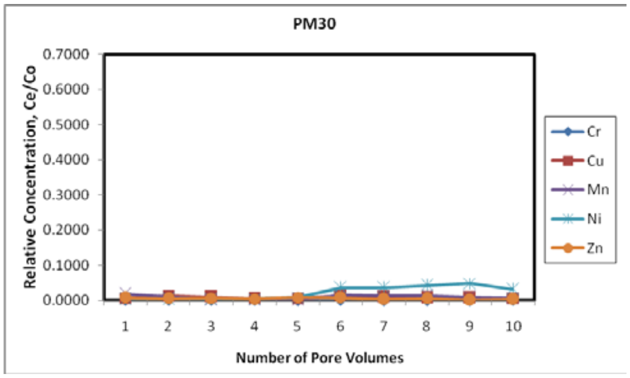

Fig. 11 Breakthrough curve of heavy metals for PM30

5. PM50

Figure 12 shows variation of ratio of effluent (C_e) to the initial concentration (C_o) over pore volume of the solution for PM50 as a media. From the figure, it shows that the column was exhausted at 1PV for Cr, Cu, Fe, and Zn. Based on the breakthrough curve data, it was indicated that the Ni was more mobile, whereas Mn was less mobile in the column test.

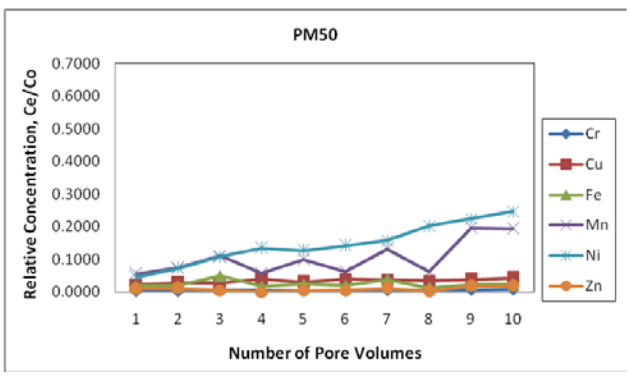

Fig. 12 Breakthrough curve of heavy metals for PM50

IX. Conclusion

Based on the leaching column test results; the following conclusions can be made:

1) Soil alone showed poor sorption capability.
2) Soil amended by 10% of pressmud indicated good sorption capability whereas 30% and 50% have high sorption capability.
3) Addition of pressmud in the soil can enhance the adsorption mechanism.

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