Enhancement of Landfill Daily Cover in Minimizing the Migration of Heavy Metals in Landfill Leachate by Using Natural Soil, Pressmud& Empty Fruit Bunch (EFB) in PulauBurung Landfill

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Abstract— *This study emphasizes on the removal of heavy metals in landfill leachate by using natural soil mixed with agricultural wastes. The agricultural wastes used in this study werenatural soil or known as laterite soil, pressmud which is a waste from sugar refinery process and Empty Fruit Bunch (EFB), one of many forms of waste fromoil palm industry. The laterite soil was mixed with these wastes at different percentages of weight ratio namely 50S:40P:10E, 50S:30P:20E, 50S:25P:25E, 50S:10P:40E and 50S:20P:30E. The terms S, P and E each refers to soil, pressmud and empty fruit bunch respectively.Removal efficiency tests were also carried out and the results showed that the mixtures of laterite soil have the ability to remove concentrationsof As^{2+}, Cd^{2+}, Cr^{2+}, Cu^{2+}, Fe^{2+}, Ni^{2+} and Zn^{2+}between a range of 86% (minimum) and 99% (maximum) compared to removal via soil per se. Ergo, the laterite soil-pressmud-EFB mixtures signify great potential to be made as a daily cover material that minimizes heavy metals migration in landfill leachate, eliminates odor issues and providesadditional protection from further infiltration.*

Keywords*— *Heavy metals, leachate, soil, pressmud, EFB, agricultural wastes and daily cover.

I. INTRODUCTION

Municipal solid waste (MSW) is a category of diverse waste, generated from different sources like residential, commercial, municipal services and agriculture; each of which is itself heterogeneous. Due to the environmental impacts associated with MSW, there are signficant concerns on the ever-growing volume, the commingled nature of the wastes as well as the suitable disposal methods to be employed in the long run (Sharifah and Latifah, 2013).Malaysia is one of the South East Asiancountries where landfill is important yet, despite being used for a very long time, there is a dire need to improve the local waste managementstandards. The country comprises of thirteen states and three federal territories, with a total surface area of 329,700 km^2. However, most landfills at present are still bereft of proper design in accordance with the sanitary landfill scheme. The main concern on landfill operation is the uncontrolled leachate production that can migrate to natural waterbodies when there is inadequate barrier between the landfill and the environment. All landfills produce leachate by a process known as ‘leaching’ whereby rainwater percolates through the permeable waste heap. Therefore, streams and other forms of water bodies are at risk of contamination due to the migration of leachate (Jaffaret al.,2009), especially if the landfill is not designed properly as to avoid environmental threats.

There are many parameters to be considered when selecting the befitting waste disposal method such as composition of the waste, availability and suitability of the site, public awareness and environmental impact. Generally, the disposal method should follow strict regulations formulated by responsible agencies. The method should be environmental-friendly, economical, poses no effect on public health and availability for maximum recycling option. Despite the complexity of waste produced, the standards of landfills in most developing countries are still poor; these include inadequate waste treatment facilities, inefficient collection and storage systems, co-disposal of municipal waste with hazardous waste, inefficient utilisation of disposal space, lack of environmental abatement measures and poor documentation. As a consequence, a great deal of contamination, especially to surface water, soil and ground water will in turn threaten the health of exposed populations and ecosystems (Zhang et al., 2010). Amongst solid waste disposal ways that can be used are open dump, sanitary landfill, incineration, composting, grinding and discharge to sewer, compaction, hog feeding, milling, reduction, and anaerobic digestion.

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 et al., 2015). 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, highly polluted liquid called "leachate". The sanitary landfill must bedesigned to isolate the wastes from the environment until it is rendered safe through biological, chemical and physical decaying processes. Basically, a sanitary landfill is determined by the following criteria: site selection and capacity are based on environmental risk assessment; extensive site preparation; leachate and gas management; daily and final cover; compaction; fencing; record keeping of waste volume, type, and source; and no waste picking and trading. One of the paramount components of isolation is by introducing alternative daily soil cover in order to minimize the migration of heavy metals in landfill leachate. Numerous methods can be used to attain isolation of leachate from surrounding environment but it all boils down to one's resources availability. The daily cover plays an integral part in leachate production control. Its basic functions are to limit infiltration by intercepting precipitation directly, thereby improving evaporation from the surface, and to reduce percolation through the cover material by taking up soil moisture and transpiring it back to the atmosphere. A site with a poor daily cover may also experience erosion which cuts gullies through the cover soil, allowing precipitation to flow directly into the landfilled waste (Technical Guidelines for Disposal to Land, 2016).

An engineered sanitary landfill can be known through three common elements: 1) compaction of the wastes, 2) daily covering (with soil or other material) to eliminate them from outside influence, 3) control the negative impacts on public health and environment (UNEP, 2005). Figure 1 shows the application of daily cover in landfill site.Three types of cover system usually applied in the construction of a sanitary landfill are daily, intermediate, and final cover. Daily soil cover serves an important function to occupy more or less during the active phase of the continuously filling operation. Itprevents vectors, litter, odours, fire, and moisture. Besides that, the main function of daily soil cover is to enhance the infiltration process by reducing the amount of leachate in landfill. Soil material that has stability such as clays, gravels, etc. may as well be usedto improve the stabilization of landfill soil (Bagchi, 2004).

Fig.1: Daily cover in Pulau Burung Landfill

Most landfills in Malaysia useonly laterite soil as a daily cover in their operations. In particular, when there is a heavy rainfall, the soil may not be an ideal cover material as it does not reduceinfiltration process. Laterite soils are residual soils, affluent in regions with tropical climate. The soils are formed through leaching of lighter minerals like silica and subsequently gets enriched withheavier minerals such as iron and aluminium oxides. It is reported that the degree of laterization can be estimated by knowing the silica-sesquioxide ratio (Makasa, 2004).The chemical properties of laterite are generally based on the iron and alumina content within the soil giving it a reddish look that is rich in iron oxide, derived from rock weathering under strongly oxidizing and leaching conditions (Akeem *et al.,* 2012). Natural laterite and clay soils are the most commonly compacted soil made as daily cover in sanitary landfills. However, their suitability is dependent on several factors, but most importantly on the distribution of grains, type of clay mineral present and permeability characteristics.

Pressmud is a rejected waste material coming from sugarcane industries or classified as residue of the filtration of sugarcane juice. Build up of such waste exacerbated with untreated discharge into the immediate waterbodies surrounding the sugar mills can strain the aquatic ecosystem(Bhosale *et al.,* 2012). Besides that, the sugarcane industry generates several other co-products of immense potential values including press mud (filter cake), molasses and spent wash. The pressmud is produced during clarification of sugarcane juice in which about 3.5 - 4% fromcrushed sugarcane ends up as press mud (i.e. 36-40 kg of pressmud is obtained after 1 ton of sugarcane crushing).Pressmud is a very soft, spongy, amorphous and dark brown material containing sugar, fiber and coagulated colloids including soil particles. It consists of 80% water and 0.9-1.5% sugar, organic matter, nitrogen, phosphorus, potassium, calcium, sulphur, coagulated colloids and other materials in varying amounts. Back then, when the cost of chemical fertilizer skyrocketed and appealed unaffordable by many farmers, pressmud was a promising source of plant nutrient to be made as a medium for raising sugarcane seedlings and leguminous inoculants (Yadav, 1992).When used in combination with natural soil, pressmud, like other organic materials can affect the physical, chemical and biological properties of soil (Lamberton and Redcliff, 1960). Plus, due to its bulky nature and high wax content, it is deemed problematic especially if it is directly applied to soil as manure. The wax content might deteriorate the soil physical properties such as permeability, aeration, soil structure and composition etc. and with the passage of time, the deterioration can be worsened (Bhosale *et al.*, 2012). Therefore, by using pressmud as an admixture in soil, it will enhance the capability as organic manure.In a study conducted by Nitin and Sanjiv (2012), sugarcane wastes (especially pressmud and bagasse) were mixed with jeevamrutham (effective microbial suspension) and let to partially decompose. Following the decomposition, the mixtureturned out being an excellent, palatable raw material for vermicomposting using *Eisenia fetida* earth worm.On the other hand, Harlina *et al.*, (2016) evaluated the effect of combining pressmud and rice husk in the removal efficiencies of heavy metals in acidic synthetic wastewater. The ratios of pressmud to rice husk were varied at different percentages of weight ratio (0%, 20%, 40%, 60% 80% and 100%) and observation was made on the resultant removal of heavy metals concentrations. The result showed that the removal efficiency increased with the addition of pressmud up to 100%. By using only pressmud,almost 95% to 100% of heavy metals removal can be achieved whereas the use of rice husk alone managed to remove merely 10% to 20% of heavy metals. The study also demonstrated that pressmud behaved as a natural acid neutralizer. The presence of pressmud in a synthetic acidic wastewater had increased its initial pH which was originally below 2(acidic) to a range between 6 to 8 (more alkaline).

Empty fruit bunches (EFB) refer to the remaining solid residues obtained after the fruit bunches are pressed at oil mills and the oil gets extracted. The amountof EFB producedkeeps rising from year to year because of the expansion of mature planted area, favorable weather conditions and rainfall distribution as well as constant sunshine throughout the year. However, the large quantities of unused EFB that are produced by palm oil mill industries give serious problem for the country. Given its large stock of lignocellulose material that is contained therein, it would be a waste to keep it underutilized. With high cellulosic fiber content and the fact that it is an abundant agricultural waste in Malaysia (Wan Nik et al., 2006; Rahman et al., 2006), EFB is now being utilizedas an absorbent material in removing heavy metals from wastewater and landfill leachate. At present, many researchers are soliciting to transform EFB into a more valuable substrate or product as a solution to the problem that it brings (Faradilla, 2006).Kamarudin (2010) used EFB mixed with local soil to minimize the migration of contaminants in Taiping Landfill and he concluded that the degree of heavy metals removal varies from 65.3% to 94.4%.There is also another study onthe use EFB and its potential application as a fiber filter media to remove oil and grease, turbidity and organics in terms of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) from palm oil mill effluent treatment process. Oil palm empty fruit bunch (OPEFB) fibers were modified with chitosan solution before processed into a mat-type filter medium. From the microscopic images, changes in the surface morphology of the fibers could be observed due to the chemical treatment. Meanwhile, the bench-scaledexperiment results indicate that pre-treatment using the fiber filtration system was able to remove upto 66% of turbidity, 67% of Total Suspended Solid (TSS) and 85% of oil and grease. This marks a great potentialfor thelignocellulosic fiber filter to be used in primary wastewater treatment (MohdGhazali et al., 2008).

This research aims to investigate and evaluate the ability of pressmud and EFB mixed with local soil to reduce and minimize the migration of heavy metals in landfill leachate. It consists of field data collection and laboratory experiments where a field data collection involves acquiringleachate samples from a municipal solid waste disposal site and fresh soil from several areas in Nibong Tebal, Penang.The laboratory experiments on the other hand, involves physico-chemical analysis andcharacterization of soil and suitability of the soil when implemented at the landfill. Selected soil samples were mixed with certain ratio at different weight percentages.

II. MATERIALS AND METHODS

The local soilsample, which is used as daily cover was taken from hilly areas around Penang whereas the leachate was collected from Pulau Burung landfill.Pressmud was collected from a sugar mill company, Malayan Sugar Manufacturing (MSM) Sdn. Bhd. at Seberang Perai, Penang. Empty Fruit Bunches (EFB) of oil palm was obtained from United Oil Palm Industries Sdn. Bhd., a local millat Nibong Tebal, Penang. The collected local soil, pressmud and EFB were then air-dried and sieved through 200 mm sieve to remove large and coarse materials. The soil samples, pressmud and EFB were then dried again and analyzed for their physico-chemical characteristics. Raw leachate was collected from the main leachate pond at Pulau Burung Landfill. Upon collection, all leachate samples were kept in High Density Polyethylene (HDPE) bottles and preserved at approximately 4°C temperature. The leachate sample was then analyzed for their heavy metals concentrations by using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES, Model Varian 715-ES).

The laterite soil was mixed with pressmudand EFBat different percentages of weight ratio namely 50S:40P:10E, 50S:30P:20E, 50S:25P:25E, 50S:10P:40E and 50S:20P:30E respectively. The mixture specifications are shown in Table 1. Eachmixture was then grounded in a rotary blender to achieve homogeneity and when mixing completed, all samples were kept in sealed plastic bags to control and retain mixture moisture contentfor further analysis.

Table.1: Individual material and mixtureratio

Materials	Specification
Soil	100% soil
Pressmud	100% pressmud
EFB	100% EFB
50S:40P:10E	50% soil+40% pressmud+10% EFB
50S:30P:20E	50% soil+30% pressmud+20% EFB
50S:25P:25E	50% soil+25% pressmud+25% EFB
50S:10P:40E	50% soil+10% pressmud+40% EFB
50S:20P:30E	50% soil+20% pressmud+30% EFB

Batch Equilibrium Tests (BET) were performed to evaluate the removal efficiency of heavy metals such as As^{2+}, Cd^{2+}, Cr^{2+}, Cu^{2+}, Fe^{2+}, Ni^{2+} and Zn^{2+}using soil, pressmud, EFB and sample of soil-pressmud-EFB mixtures. From this test, the adsorption capability of the tested soil samplescan be determined by using a percentage removal equation.

Heavy metal species were selected based on the concentration of heavy metals present in raw landfill leachate. In this study, the initial concentrations of heavy metals were preset at 1, 2, 4, 6, 8 and 10ppm which acted as a synthetic landfill leachate. A synthetic leachate will have no interference from other parametersand makes it easier to evaluate the effect of chemical permeants on the migration of heavy metals into landfill soils (Badv and Omidi, 2007; Ruhl and Daniel, 1997; Joseph *et al.,* 2001; Weber *et al.,* 2002; Shang and Rowe, 2003; Kolstad*et al.,* 2004; Hraporic and Rowe, 2002; Rittman *et al.,* 2003).

In this experiment, synthetic landfill leachate with initial concentrations of heavy metals were mixed with the materials (individual samples of soil, presmud, EFB and mixtures of soil- pressmud-EFB) at a ratio of 10:1 (10 mL solution and 1 g of sample). The samples were placed in a tube and shaken using a horizontal shaker for 24 hours in accordance to the standard method (USEPA, 1992). After reaching an equilibrium point, the tubes werecentrifuged at 5,000 rpm for 25 minutes to separate the liquid and solid portions. Next, the supernatant fluid was filtered with Whatman filter paper (No. 42) and then analyzed using ICP-OES.

From the analysis, the concentration of heavy metals that remained in the filtrate was used to calculate the amount of heavy metals absorbed by the soil, pressmud, EFB and soil-pressmud-EFB mixtures. The removal percentage of heavy metals from initial concentration (C_o) in the leachate was calculated from Equation 1 (Shaw, 2001). Adsorption capacity and percent removal were then used to optimize the material conditions:

$$\% \, Removal = \frac{Co - Ce}{Co} \qquad \text{Equation 1}$$

Where,

Co= initial concentration of the solution (mg/L)

Ce = the equilibrium concentration left in the solution (mg/L)

III. RESULTS AND DISCUSSION

Concentration of Heavy Metals in PulauBurung Landfill Leachate

Table 2 shows the range of heavy metals concentration in the leachate from PulauBurung Landfill. From the results, the highest concentration is found to be $Fe^{2+}$with 4.79-10.19 mg/L. Concentrations of As^{2+}, Cd^{2+}, Cr^{2+}, Cu^{2+},Mn^{2+}, Ni^{2+}, $Pb^{2+}$and $Zn^{2+}$are 0.11-0.27 mg/L, 0.22-0.35 mg/L, 0.09-0.16 mg/L, 0.04-0.05 mg/L, 0.42-1.41 mg/L, 0.24-0.43 mg/L. 0.05-0.08 mg/L and 0.28-0.60 mg/L respectively. It is good to note that some heavy metals concentrations such as As^{2+}, Cd^{2+}, Cr^{2+}, Fe^{2+}, Mn^{2+} and Ni^{2+}exceeded the maximum permissible concentration (MPC) limits stipulated in the Malaysian EQA 1974 leachate discharge standards in Malaysia.

Leachate is a liquid effluent that is released or seeps from a landfill area that ends up at the bottom of the waste piles. As water percolates through the waste material, they will accumulate and produce an aqueous effluent. The characteristic of the leachate relies heavily on weather condition, waste characteristic and composition, landfill age and depth of buried waste (Ghazali et al., 2008, Hassan et al., 2001 and Mohamad, 2014). Young leachate tends to be acidic due to the presence of volatile fatty acid with a pH of 6-7 or lower and it is more polluted as the BOD_5can reach up to 81000 mg/L compared to old leachate witha $BOD_5$of 4200 mg/L (Bashir, 2010).

Table.2: Heavy metals concentrations in PulauBurung Landfill leachate

Heavy Metals	Concentration of Heavy Metals in mg/L (ppm)	Concentration of Heavy Metals in mg/L (ppm) from previous research (Harlina et al., 2016)
Arsenic, $As2^{+}$	0.11-0.27	-
Cadmium, Cd^{2+}	0.22-0.35	-
Chromium, Cr^{2+}	0.09-0.16	0.55-0.70
Copper, Cu^{2+}	0.04-0.05	0.48-0.86
Iron, Fe^{2+}	4.79-10.19	-
Manganese, Mn^{2+}	0.42-1.41	0.19-0.66
Nickle, Ni^{2+}	0.24-0.43	0.18-0.54
Lead, Pb^{2+}	0.05-0.08	0.18-0.61
Zinc, Zn^{2+}	0.28-0.60	0.93-3.5

Background of Heavy Metals Contents in Local Soil, Pressmud and EFB

Basic properties and heavy metals content of soil, pressmud and EFB are shown in Table 3, which are based on British Standard BS1377 (1975) and ASTM Standard (ASTM, D2216-17). The results from the grain size analysis showed that the soil contains 14.45% gravel, 48.78% sand, 32.67% silt and 4.1% clay. This clearly illustrates that the grain size of soil is silty sand. Meanwhile grain size analysis of pressmud shows 2.04% sand, 95.67% silt and 2.29% clay. This simply means that the grain size of the pressmud is silty. Specific gravity of soil, pressmud and EFB are 2.44, 1.61 and 0.87 respectively.

The results of Atterberg limits for the soil revealedits liquid limit of 27.65%, plasticity limit of 17.45% and plasticity index of 10.2%. The results of Atterberg limits for the pressmud showed the liquid limit to be 37.27%, plasticity limit of 20.8% and plasticity index of 16.47%. Generally, both soil and pressmud are classified as materials with low plasticity as the liquid limits are less than 50% according to the US unified soil classification system. The specific surface area of the soil particle is 22.9 m^2/g which is influenced by the presence of mineralogy content in the soil. The specific surface area of the pressmud particle is 17.80 m^2/gwhereas EFB shows an area of 18.3 m^2/g. The pH value of soil is at 4.45 which is in acidic condition primarily due to the low lime content. From previous studies, laterite soil is considered to be strongly acidic, exhibiting pH 4.4 (Parvathi, 2012). The pH of pressmud and EFBare 8.06 and 8.63 respectively which are slightly inclined towards the alkaline state. The heavy metals concentrations in the soil samples are very low and someof them are not detectable, meaning that the selected samples are notcontaminated soil.On the contrary, the heavy metals concentration background in the pressmud and EFB fiber are quite high compared to the soil, but still very low and consideredin a background level.

Table.3: Basic Properties and Heavy Metals Content of Soil, Pressmud and EFB

Characteristics	Soil	Pressmud	EFB
<u>Particle Size (%)</u>			
Gravel	14.45	0	-
Sand	48.78	2.04	-
Silt	32.67	95.67	-
Clay	4.1	2.29	-
Specific Gravity	2.44	1.61	0.87
Liquid Limit (%)	27.65	37.27	-
Plastic Limit (%)	17.45	20.8	-
Plasticity Index (%)	10.2	16.47	-
Specific Surface Area (m^2/g)	22.9	17.8	18.3
pH	4.45	8.05	8.63
Moisture Content	18.51	34.53	14.4
<u>Heavy Metals Content (mg/L)</u>			

Arsenic, As	0.43	0.12	0.18
Cadmium, Cd	0.08	0.02	ND
Chromium, Cr	0.23	0.08	0.08
Copper, Cu	0.05	0.26	0.22
Iron, Fe	215	8.68	5.80
Manganese, Mn	0.66	0.69	0.4
Nickle, Ni	0.03	0.07	0.02
Lead, Pb	0.57	0.14	0.09
Zinc, Zn	2.56	1.13	1.53

Removal Efficiency of Heavy Metals

Effect of Initial Concentration of Heavy Metals on Removal Efficiencies

Batch test was used to study the removal efficiency of the materials. According to Jessberger et al., (1997), batch test provides a relatively quick method of estimating the contaminant adsorption capacity of any liner material. The effect of initial heavy metals concentration on the removal efficiency by variant soil mixtures of 50S:40P:10E, 50S:30P:20E, 50S:25P:25E, 50S:10P:40E and 50S:20P:30E was systematically investigated by modifying the initial concentration from 1 to 10 ppm (1 ppm, 2 ppm, 4ppm, 6 ppm, 8 ppm and 10 ppm). Figure 3-9 show the percentage removal of As^{2+}, Cd^{2}+, Cr^{2+}, Cu^{2+}, Fe^{2+}, Ni^{2+} and Zn^{2+}.

Figure 3 shows the percentage removal of As^{2+} by the soil and soil-pressmud-EFB mixtures ranges from 1-10 ppm as an initial concentration. From the results, it is observed that the percentage removal of heavy metals from the solution by the soil-pressmud-EFB mixtures sample increased with the increase of initial concentration. This indicates that the removal efficiency of the samples is influenced by the heavy metals concentration and a positive correlation between the sorption capacity and basic properties of soils and soil-pressmud-EFB mixtures. The removal of As^{2+} by the soil alone dramatically reduced to 61.1% at concentration 1 and 10 ppm while soil-pressmud-EFB mixtures achieved 99.3% removal at concentration of 4 ppm. It clearly indicates that the soil-pressmud-EFB mixtures have great potential in removing heavy metals contents in the soil. However, use of pressmud alone only yielded 79.0-98.2% percentage removal between concentration 1 until 10 ppm but the value is higher compared to using only soil. Meanwhile, EFB only showed 33.7% removal of As^{2+}.

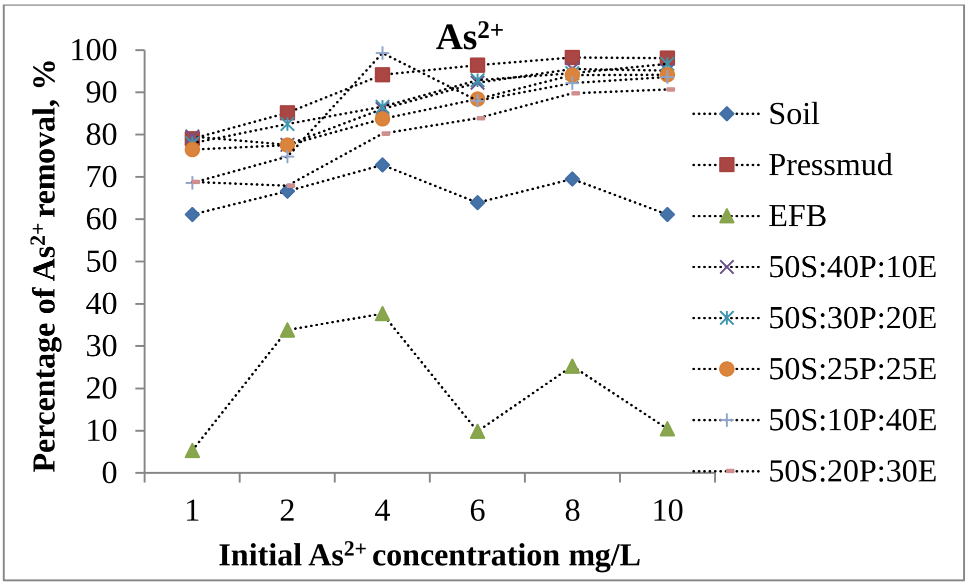

Fig.3: Effect of initial As^{2+} concentration on the removal efficiency

Figure 4 shows the percentage removal of Cd^{2+} by the soil-pressmud-EFB mixtures. The percent removal of heavy metals from the solution by the soil-pressmud-EFB mixtures decreased with the increase of initial concentration. The maximum percentage removal from soil-pressmud-EFB mixtureswas foundat concentration of 2 ppm with 98.8%. Meanwhile soil alone just removedless than 5.35% at the same aforementioned concentration. From the results obtained, it can be said that the adsorption capability of the soil will improve with the presence of pressmud and EFB in the soil. The results obtained from this experiment are similar to studies done byMunaf et al. (1997) and Vaca-Paulin et al. (2006) despite using other organic matter as a soil admixture.On a positive note, pressmud showedexcellent and the highest Cd^{2+}removal of 99.9% compared to EFB.

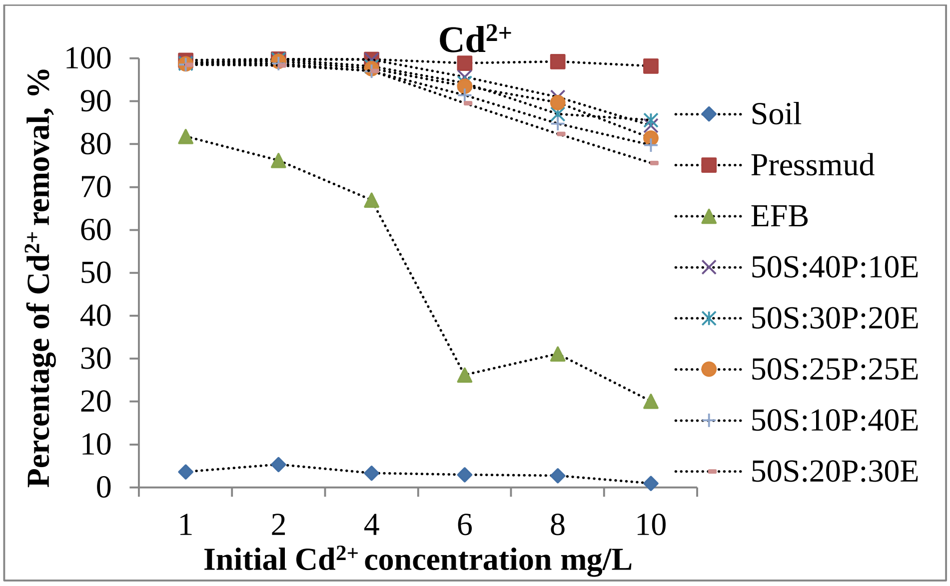

Fig.4: Effect of initial Cd^{2+} concentration on the removal efficiency

The removal of Cr^{2+} by the soil-pressmud-EFB mixtures is depicted inFigure 5. The mixtures percentage removal was observed to be 99.5% when tested at concentration 1 ppm. This is due to the existence of surface charge of clay mineral, pressmud and EFB material that contributes to the adsorption of heavy metals. Meanwhile the percentage removal of soil alone gradually reduced to only 17.5% removal at concentration 10 ppm. Percentage removal of Cr^{2+} for pressmud also gave the highest readingsspanning from 97.6-98.7% removal while EFB showed only 87.2% removal.

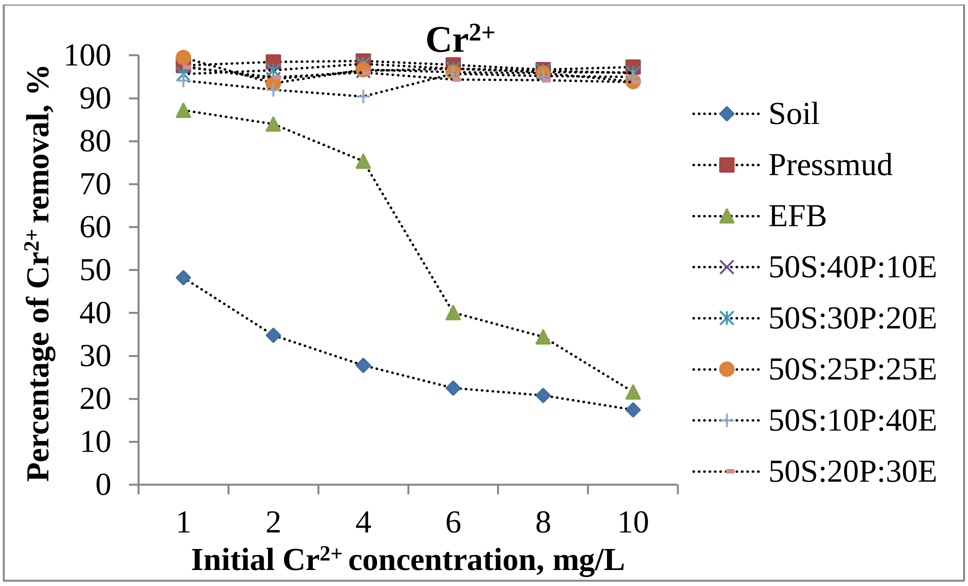

Fig.5: Effect of initial Cr^{2+} concentration on the removal efficiency

Figure 6 indicates the percentage removal of Cu^{2+} by the soil alone and soil-pressmud-EFB mixtures. All soil-pressmud-EFB mixtures exhibited a minimum percentage removal of 97.1% at concentration 6 ppm. Soil's maximum Cu^{2+} removal was recorded at 33.8% while pressmud and EFB presented highremoval values of 96.3% and 90.0% respectively. Most soil-pressmud-EFB mixtures removed Cr^{2+} more than 97%. This is akin to several other studies in a sense that admixture of soil can enhance the capability of adsorbing metals especially materials with very high organic content. Previous studies also indicate that one of the possible mechanisms that control heavy metals removal in a solute environment is sorption activity (Christensen et al., 2001).

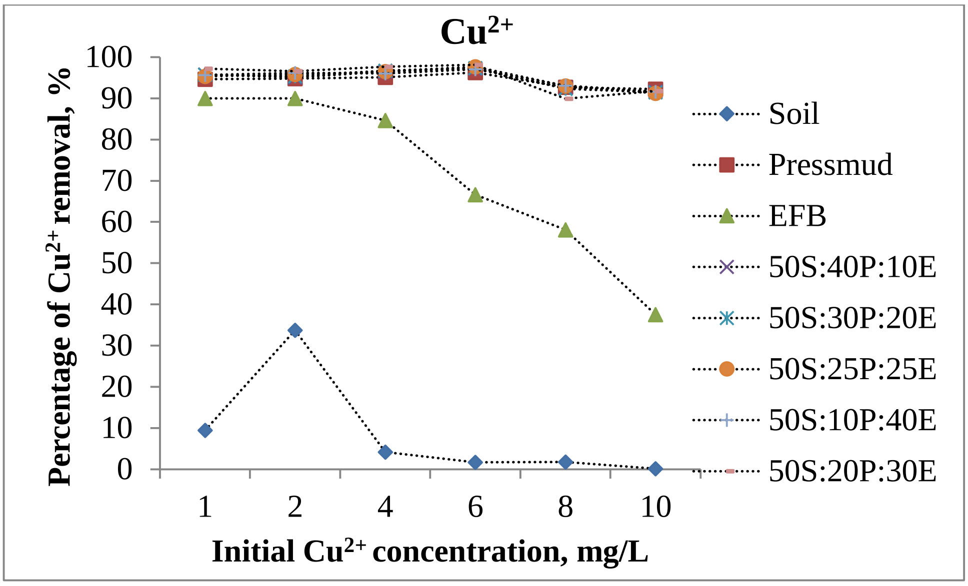

Fig.6: Effect of initial Cu^{2+} concentration on the removal efficiency

Figure 7 shows the percentage removal for Fe^{2+} for soil alone and soil-pressmud-EFB mixtures. The percentage removal increasedas the initial concentration increased. The highest percentage removal by the mixtureswasobserved to be 98.9% at concentration 6 ppm while the lowest was 97.6% at concentration 10 ppm. It clearly shows that most percentage removals are more than 97%. By incorporatingpressmud and EFB into the soil, the performance of metals ion adsorption was seen to increase and improved. Similar to the previous result, pressmud indicated the highest removal value of 99.3% followed by EFB with only 61.4%.

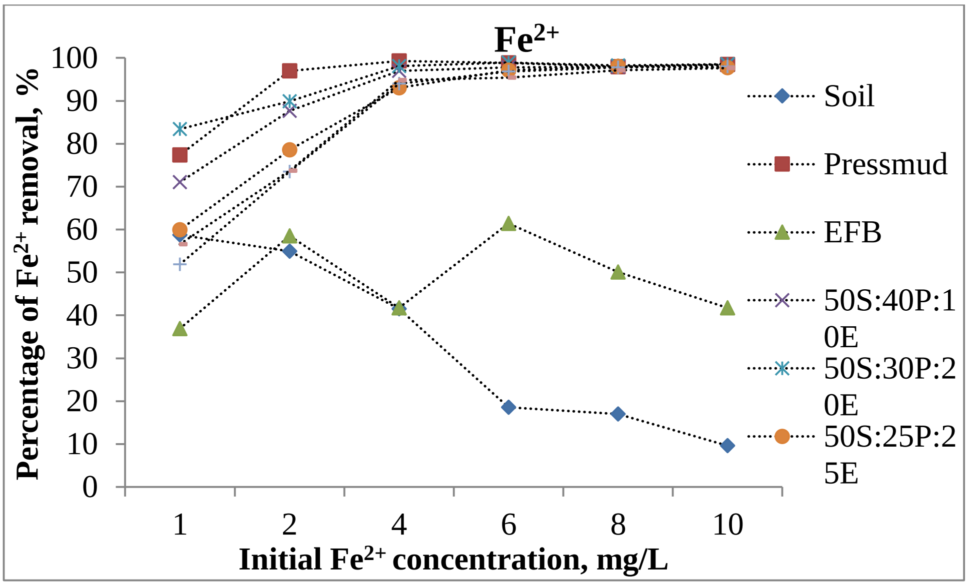

Fig.7: Effect of initial Fe^{2+} concentration on the removal efficiency

The removal percentage of $Ni^{2+}$is shown in Figure 8. It clearly shows the percentage removal decreasedas the initial concentration increased. The highest removal was 89.9% while the lowest was 86.3% both at concentration 1 ppm. Using only soilcould remove maximum 32.6%. Therefore, it can be said that soil alone cannot help to adsorb the heavy metals efficiently, which exerts a need toalso usepressmud and EFB as admixtures into the soil. As a result, there will be an enhancement in the capacity and capability of the media to adsorb pollutant or heavy metals. For Ni^{2+}, pressmud and EFB did not show much disparity in terms of percentage removal with the former removing 85.1% andthe latter removed 86.3%.

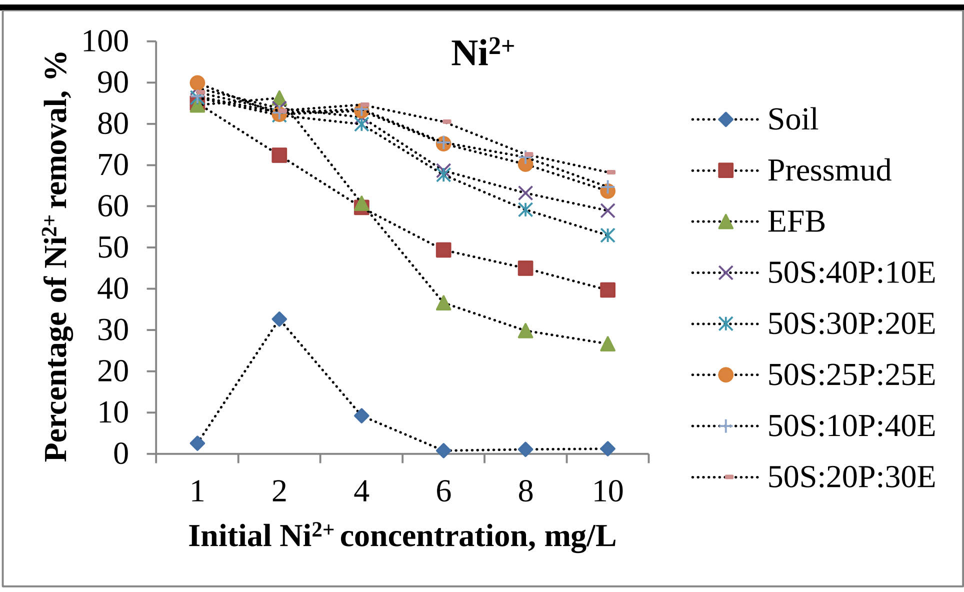

Fig.8: Effect of initial Ni^{2+} concentration on the removal efficiency

Figure 9 shows the percentage removal of Zn^{2+} for soil and soil-pressmud-EFB mixtures. It also shows a trend of the decrease of percentage removal as the initial concentration increased similar in the case of Ni^{2+}. The highest removal performed by soil-pressmud-EFB mixtures was 99.8% while the lowest was 98.1% but the highest of percentage removal of soil alone was only 6.76%. However, percentage removal of pressmudwas quite high around 98.8% while EFB presented moderate Zn^{2+}removal of 64.6%. By and large, the results are strong proofs to signify the efficacy of using these mixturesto remove heavy metals concentration in lieu of using only soil.

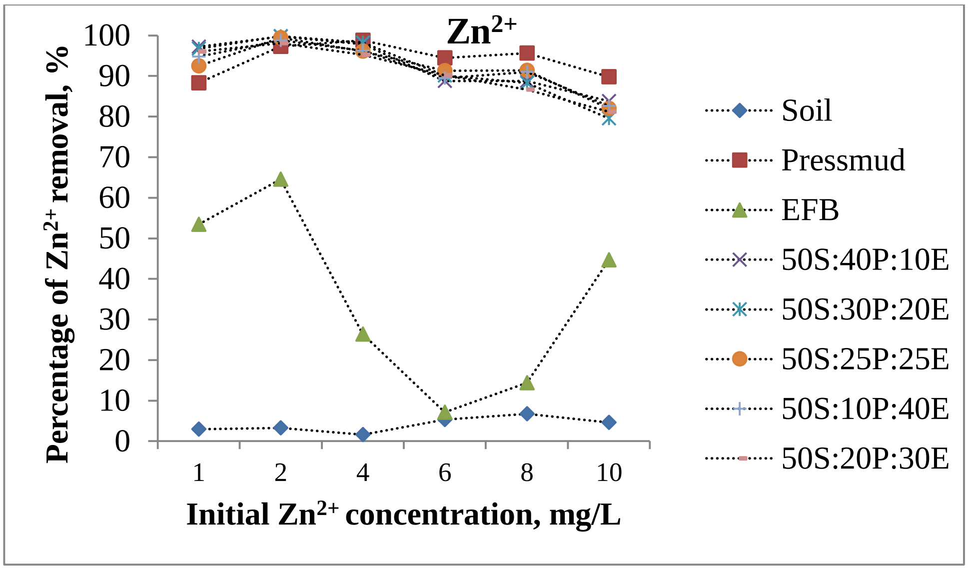

Fig.9: Effect of initial Zn^{2+} concentration on the removal efficiency

IV. CONCLUSIONS

As a conclusion, the soil-pressmud-EFB mixtures are highly potential material, which can be a daily cover substitute due to the excellent heavy metals removal capability if compared to individual soil use. The best mixture ratiosto eliminate As^{2+}, Cd^{2+} and $Cr^{2+}$are 50S:10P:40E, 50S:30P:20E and 50S:25P:25E that achieved percentage removal of 99.3%, 99.8% and 99.5% respectively. For the case of Cu^{2+}, Fe^{2+}, Ni^{2+} and Zn^{2+}removal, it is more suitable to use mixture ratios of 50S:20P:30E, 50S:30P:20E,50S:25P:25E and 50S:30P:20E with percentage removal of 98.2%, 98.9%, 89.9% and 99.8% accordingly. Vis-à-vis the use of only soil as the conventional method, the experiments signify that most soil mixtures were able to remove heavy metalsup to the highest percentage of 99.8%. Amongst main contributing factor to the excellent performance is due to the high organic and fiber content present in pressmud and EFB.

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