PERFORMANCE OF HYBRID RICE HUSK AND KAPOK FIBER AS ALTERNATIVE LINER MATERIALS IN LANDFILL

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ABSTRACT: Generation of waste from agricultural activities like rice husk (RH) and kapok fiber (KF) is on the rise annually. Some of the arising issues are landfill limitation and air pollution because of burning activities. This paper presented a potential application of agricultural waste as an alternative material in landfill. A series of standard tests were conducted such as hydraulic conductivity test (falling head method), batch adsorption test (COD, TSS and heavy metals testing). These tests were conducted in the ratio of 1:1 and 1:2 of hybrid RH:KF. The results yielded that the hydraulic conductivity of the hybrid RH:KF in the ratio of 1:1 was lesser than 10-9 m/s, satisfying the requirement of landfill liner. The hybrid arrangement (RH:KF) for 1:1 ratio as adsorption media was able to reduce at least 45% of the bulk parameter (COD) whereas for 1:2, ratio, about 43.5% of heavy metal (Zn) was reduced in leachate. The proposed hybrid arrangement (RH:KF) is a green material for the landfill (bulk parameters and heavy metal adsorption capacity) that improves landfill workability, minimizing manpower on site and cost.

KEYWORDS: *Hybrid; Liner; Permeability; Waste; Leachate*

1.0 INTRODUCTION

Conventionally, agricultural waste in Malaysia has been disposed through landfilling or burning process at agricultural sites. However, due to the landfill limitation and air pollution effects, this waste can be converted into useful products such as landfill liner. Landfill liner is usually found in engineered landfill as a protection layer or barrier to reduce the contamination effect between the leachate and the environment. Leachate is the black water produced from the interaction between waste and rainfall (in high moisture condition) [1]. In addition, leachate contains high toxicity chemical causing harmful effects to both surface and groundwater [2-3].

In practice, liners are divided into single liner (clay soil/geo-synthetic clay liner as the barrier and waste at the top) and double liner or composite liner (consists of a series of geo-synthetic liners (GL) combined with clay as a bottom layer) [4-6]. The composite liner structure is unique and able to prevent direct leachate penetration effect in case of accidental leakage [7]. In landfill construction, clay liner has been selected by the landfill operators due to its low permeability value (lower than 1 x10-9 m/s), cheaper and good adsorption capacity [5,8]. However, the increasing demand on the usage of clay material has forced the landfill operators to search for other alternatives that are cheaper and having similar capability with clay.

Studies have been conducted widely to find an alternative to clay material. One of the alternative materials to clay is waste material. Wu et al. [9] used coal gangue in his study and found that the hydraulic conductivity of coal gangue is smaller than the regulatory requirement (1x10-7 cm/s) with a void ratio less than 0.60. Nik Daud et al. [10] conducted a study on the application of palm oil fuel ash (POFA) mixed with granite residual soil and found that the lowest hydraulic conductivity value of 8.1 x 10-10 m/s was obtained at 20% POFA.

Other studies that apply polymer-amended fly ash mixed with paper pulp pillings found that the mixed materials have lower hydraulic conductivity [11]. Eberemu et al. [12] investigated the effect of adding rice husk ash into soil in order to evaluate the permeability, shear strength and volumetric shear strength to ensure its acceptance as a landfill liner. Guney et al. [13] have introduced the sepiolite-zeolite mixture as bottom liner material with the ability to increase the heavy metal adsorption capacity and strength. Li et al. [14] introduced shale-clay mixtures and found that the hydraulic conductivity value is lower. An abundance of agricultural waste in Malaysia namely rice husk and kapok fiber provide an alternative to clay as material in landfill. In line with the green technology concept of the 5R's (reduce, reuse, recycle, composting & disposal), the proposed product can be an alternative to geotextile or geo-membrane layer of the landfill. Geotextile functions as a filtration system in landfill for leachate (impermeable layer) whereas geo-membrane functions as a barrier to leachate (permeable layer). Both filtration and barrier system are very important as to reduce the concentration of organic and inorganic materials in leachate and to control the leachate intrusion into groundwater.

This paper presented the potential application of hybrid rice husk and kapok fiber (RH:KF) as alternative landfill material. This paper discussed the results of the removal efficiency of bulk parameters (COD and TSS) and heavy metals (Cu and Zn) in leachate subjected to hybrid RH:KF as adsorption media and hydraulic conductivity value of the proposed material. The proposed samples (single samples, ratio 1:1 and ratio 1:2) were prepared and tested in a laboratory under controlled conditions.

2.0 MATERIAL

Materials used in this study were raw materials such as kaolin clay, rice husk and kapok fiber. The rice husk (RH) and kapok fiber (KF) used in this study were obtained from BERNAS factory (rice milling process centre), Paya Keladi, Pulau Pinang and orchard nearest to Nibong Tebal, Pulau Pinang, respectively. The RH and KF obtained from the sampling sites were prepared in terms of raw samples (actual size of the samples). Type of clay used in this experiment was kaolin clay (KC). KC is white in colour and in the form of soft powder. It is mostly constituted of kaolinite minerals derived from the weathering of orthoclase (potash) feldspar which is an essential mineral of granite [16].

2.1 Leachate Characterization

The Leachate sample in this study was taken from Pulau Burung Sanitary Landfill (PBSL), located within Byram Forest Reserve in Nibong Tebal, Pulau Pinang. This site was constructed as a semi-aerobic sanitary landfill. Samples taken were raw leachate and 80% of treated leachate. Raw leachate and 80% of treated leachate were taken directly from the Equalization Pond 1 (EQP 1) and treatment pond, respectively. Grab sampling method was applied to retrieve leachate samples. Samples were stored in 5 litre polyethylene plastic containers that were not tightly covered in order to allow for gas release during transportation of these samples to laboratory.

3.0 METHOD

Materials used in this study were raw materials such as kaolin clay, rice husk and kapok fiber. The rice husk (RH) and kapok fiber (KF) used in this study were obtained from BERNAS factory (rice milling process centre), Paya Keladi, Pulau Pinang and orchard nearest to Nibong Tebal, Pulau Pinang respectively. The RH and KF obtained from the sampling sites were prepared in terms of raw samples (actual size of the samples). Type of clay use in this experiment was kaolin clay (KC). KC is white in colour and in the form of soft powder. It is mostly constituted of kaolinite minerals derived from the weathering of orthoclase (potash) feldspar which is an essential mineral of granite [15].

3.1 Leachate Characterization

The raw leachate sample was characterized for pH while 80% of treated leachate was then characterized for pH, chemical oxygen demand (COD), total suspended solid (TSS) and heavy metals (copper and zinc) concentration. The analytical procedures of standard method for examination of water and wastewater [16] and HACH water analysis handbook were followed. Leachate characterization was carried out by diluting the raw leachate and 80% treated leachate to the ratio of 1:10 of the initial concentration. This is to ensure that the contaminant of the leachate was highly concentrated. The results obtained were compared with the standard A and B of the Environmental Quality Act of Malaysia 1974 [17].

3.2 Batch Adsorption Study

Figure 1 shows the arrangement of mixture for hybrid rice husk and kapok fiber in a column reactor for adsorption study. One liter of leachate sample was poured in the column reactor. The reactor was immediately sealed with a rubber stopper after the samples was placed inside the column reactor. The ratio of 1:1 and 1:2 of kapok fiber to rice husk were tested. Samples were extracted after one day using a syringe. Extracted leachate was diluted to 1:10 ratio for the chemical analysis. The results were calculated in terms of removal efficiency of the chemical properties of the leachate using the following formula:

$$\frac{C_i - C_f}{C_i} \times 100\% \qquad (1)$$

Percentage removal where Ci is the initial concentration of the substance and Cf is final concentration of the substance.

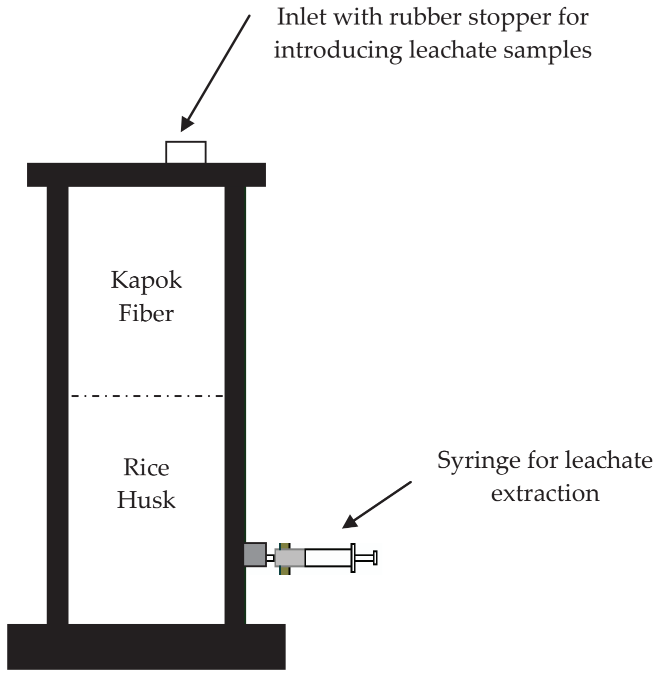

Figure 1: Arrangement of hybrid rice husk and kapok fiber mixture in the batch reactor

3.3 Index Properties Test

The index properties test was conducted in accordance to BS 1377: 1990:4.3 i.e. liquid limit (Part 2:4.3), plastic limit (Part 2:5.3), and specific gravity (Part 2:8.3). For these experiments, the sample must passes through the 425 μm of pan sieve size.

3.4 Compaction Test

The standard Proctor test (BS1377: Part 4:1990:3.3) was carried out to get the maximum dry density (MDD) of the soil with the optimum moisture content (OMC). All samples were compacted at dry and wet of the optimum water content. Soil sample should be smaller than 20 mm. The 2.5 kg rammer was used as a compaction load. The sample was divided into 3 parts with 27 blows in each layer.

3.5 Permeability Test

The hydraulic conductivity test represents the ability of soil to allow water or leachate flow through its medium. In this experiment, the sample was submerged in water tank at minimum time of 24 to 48 hours for full saturation. Then, the standpipe was connected to the sample. The connection of the standpipe to the sample should be intact to make sure that the presence of air was minimized. The valve was opened and the water was filled into the standpipe to a marked initial height of the standpipe. The initial readings for height, h1 and time, t1 were recorded before the commencement of the test. The valve was closed and the test began by observing the flow of water and time of the reduction in order to measure the quantity of water that flowed through the sample within a period of time. Figure 2 shows the arrangement of hybrid rice husk and kapok fiber mixture in the mold (compaction apparatus).

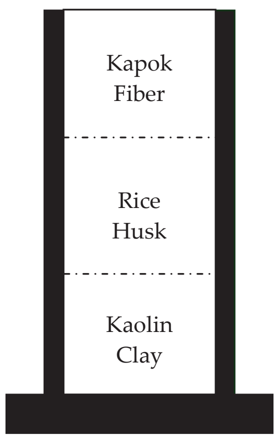

Figure 2: Arrangement of hybrid rice husk and kapok fiber mixture in the mold (compaction apparatus)

4.0 RESULTS AND DISCUSSION

4.1 Leachate Characterization

Table 1 shows the characteristic of raw leachate (pH) and 80% treated leachate (pH, COD, TSS, Zn, Cu) taken from Pulau Burung Sanitary Landfill (PBSL) in comparison with the standard of the Environmental Quality Act (EQA 1974). Based on the table, pH values of the leachate samples were pH 8.18 (raw leachate) and pH 7.9 (80% treated leachate), which were attributed to the methanogenic leachate. The characteristic of landfill leachate is contributed mostly by the different types of waste composition, stabilization stage and rainfall intensity [18-19]. The pH value obtained is in rhyme with a study [20] for (PBSL). The measured pH and values for both raw leachate and 80% treated leachate remained within the allowed limit listed under EQA 1974 [17]. Value of 114 FAU was recorded for turbidity at PBSL. The obtained COD and TSS values were greater than the allowed level of 100 mg/L listed under the Environmental Quality Act (EQA) 1974 [17]. This is inline with the reported value for COD ranging from 500 and 4500 mg/L [20]. The value obtained for Zn was more than the allowable limit whereas the value for Cu was lower as compared with the allowable limit.

Table 1: Characteristic of 80% treated leachate taken from PBSL compared with the standard of the EQA 1974 [17]

Parameter	Sources	Obtained Value	EQA 1974	
			Standard A	Standard B
pH	Raw leachate	8.18	6 - 9	5.5 - 9
	80% treated leachate	7.90	6 - 9	5.5 - 9
COD (mg/l)	80% treated leachate	697	50	100
TSS (mg/l)	80% treated leachate	2472	50	100
Zn (ppm)	80% treated leachate	0.46	0.2	0.2
Cu(ppm)	80% treated leachate	0.05	0.2	0.2

4.2 Removal Efficiency

Figure 3 shows the concentration of parameters (COD, TSS, Zn, Cu) before and after subjected to hybrid rice husk and kapok fiber (ratio 1:1) as adsorption media. The concentration of COD and TSS were reduced about 45% and 15% respectively. However, there was only a small reduction of Zn and no reduction rate was shown for Cu concentration when subjected to adsorption media.

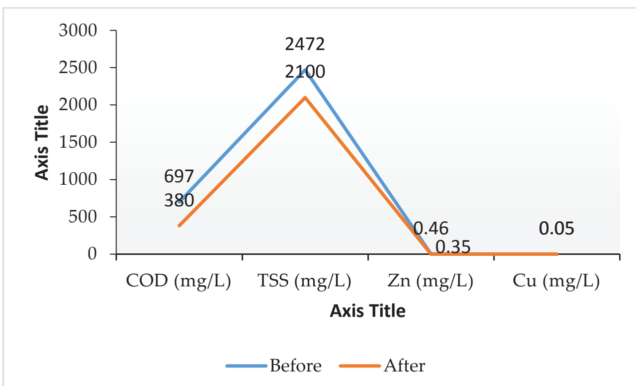

Figure 3: Concentration of parameters before and after subjected to adsorption media (ratio 1:1)

Figure 4 shows the concentration of parameters (COD, TSS, Zn, Cu, NH3+) before and after subjected to hybrid rice husk and kapok fiber (ratio 1:2) as adsorption media. The concentration of COD and TSS were reduced about 38.9% and 18.6% respectively. The highest reduction rate was Zn at 43.5%. However, there was only a small reduction of Cu concentration when subjected to adsorption media.

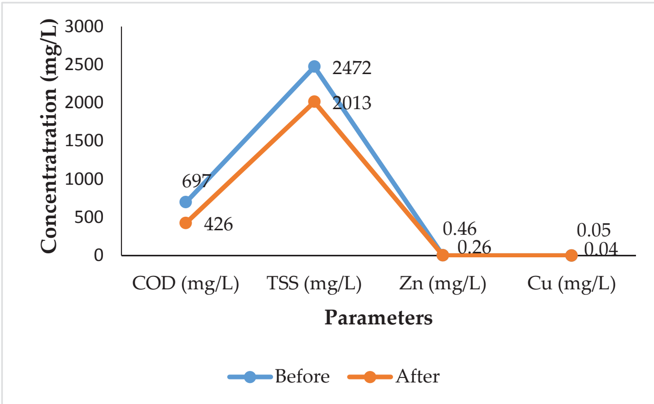

Figure 4: Concentration of parameters before and after subjected to adsorption media (ratio 1:2)

Based on Figure 3 and Figure 4, the nature and size of the rice husk and kapok fiber affected the removal efficiency of the parameters especially COD, TSS and Zn. The solid particle in leachate was entrapped in the small void of the rice husk and kapok fiber. A study has proven that rice husk is able to act as a selective material for adsorption [21]. The rice husk contains lignin and silica which is the main components of the adsorbent which has been recognized to facilitate the adsorption process. The rice husk contains about 20% of silica and is a good sorbent of many metals and basic dyes while kapok fiber has a poor affinity toward metal ions [22-23]. Wahi et al. [24] conformed that both rice husk and kapok fiber are able to remove oil from aqueous state. The kapok fiber possesses good buoyancy and has no tendency to be sunk in mixtures of oil and water [25]. Cu shows a small or no reduction of concentration when subjected to RH:KF hybrid for both 1:1 and 1:2 ratio.

Figure 5 shows the removal efficiency of the parameters (COD, TSS, Zn, Cu) subjected to hybrid rice husk and kapok fiber (RH:KF) (1:1 ratio and 1:2 ratio) as adsorption media. Removal of COD via RH:KF hybrid for 1:1 ratio was higher as compared with 1:2 ratio whereas for removal of TSS through RH:KF hybrid for 1:2 ratio was higher as compared with 1:1 ratio. The difference of 3.6% for TSS removal (between 1:1

and 1:2 ratio) was affected by the different quantity of kapok fiber in the arrangement. The higher the quantity of the materials in the arrangement, the filtering capacity (trap more solid particles) increased.

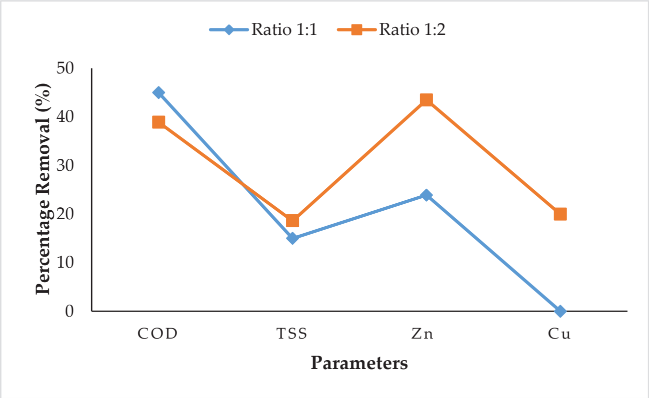

Figure 5: Removal efficiency of parameters subjected to adsorption media (1:1 ratio and 1:2 ratio)

4.3 Permeability

Figure 6 shows the hydraulic conductivity value of the single samples (kaolin clay, rice husk and kapok fiber) and hybrid samples (Rice Husk:Kapok Fiber (RH:KF) with 1:1 ratio. The hydraulic conductivity value of the hybrid RH:KF was lower than those of the single samples. Obtained values for the single layer of rice husk and kapok fiber were 8.914 x 10-9 m/s and 5.209 x 10-9 m/s, respectively. These values were higher than the acceptable standard and not suitable to install directly as landfill layer in landfill. However, the hybrid RH:KF arrangement shows a low hydraulic conductivity value of 7.29 x 10-11 m/s, conforming to the minimum values stated for liner material [7].

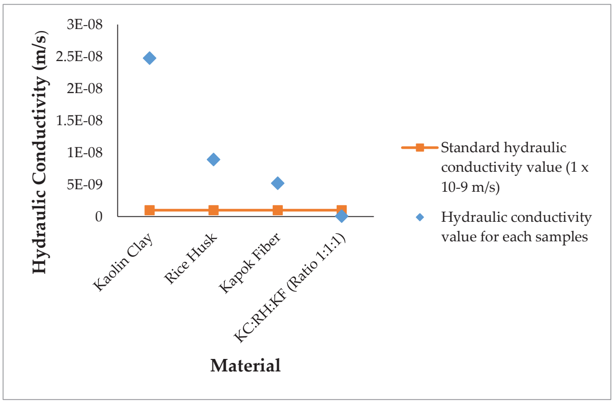

Figure 6: Hydraulic conductivity value for each material in comparison with standard [8]

5.0 CONCLUSION

The potentials of hybrid rice husk and kapok fiber (hybrid RH:KF) as landfill liner materials have been presented. This proposed RH:KF hybrid is excellent and feasible as adsorption medium for removal of leachate contaminants taken from PBSL. The removal efficiencies of COD from leachate contaminants is greater using proposed RH:KF hybrid for 1:1 ratio, whereas Zn through RH:KF hybrid for 1:2 ratio as adsorption medium. The hydraulic conductivity values are however lower than the standard, thus satisfy the minimum requirement to be accepted as landfill liner. In a nutshell, findings from this study will contribute reliable knowledge in the application of agricultural waste as alternative to liner in landfill and at the same time support the Government Policy on green technology.

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