Kufa Journal of Engineering
Vol. 15, No. 2, April 2024, P.P. 93-105
Article history: Received 12 December 2023, last revised 11 March 2024, accepted 12 March 2024

APPLICATION OF TERMITE MOUND-BENTONITE MIXTURE AS BOTTOM LINER FOR INDUSTRIAL WASTE CONTAINMENT

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https://doi.org/10.30572/2018/kje/150207

ABSTRACT

The indiscriminate disposal of waste into various dumpsites with noncompliance to the existing environmental laws and the inadequate provision for leachate containments have resulted in the degradation of environmental resources over the years. The research investigated the practicability of enhanced termite mound-bentonite mixture as an alternate landfill bottom liner. The percentage weight ratio of mound soil and bentonite used for the experimental study were (100:0), (95:5), (90:10) and (85:15) respectively. The study was conducted on a pilot scale artificial landfill (800 x 800 x 400 mm) with four sections AX, AY, BX and BY. Bottom liner was exposed to wastewater for 26 weeks retention period. The pilot scale experimental study revealed that liner mixtures in sections AX, AY and BX failed during the 6, 11 and 17th week retention periods respectively with a corresponding seepage amounting to 1.1×10^6, $0.5 \times 10^6$and 0.4×10^6mm^3 respectively. However, no seepage was recorded for liner mixture in section BY which connotes that wastewater leakage was prevented throughout the experimental framework. Conclusively, the application of termite mound soil enhanced with 15% bentonite is recommended as a bottom liner in a waste contain.

KEYWORDS: Artificial Landfill, Bentonite, Landfill Liner, Termite Mound Soil, Wastewater.

1. INTRODUCTION

Landfills are holistically planned containment systems, built to mitigate the effect of solid and hazardous wastes on environmental resources and human health. Both developed and developing countries are challenged with the comprehensive management of daily generated wastes (Opafola et al., 2020; Opafola et al., 2021). Landfilling systems are classified based on level of control as low (semi controlled facility), Medium (controlled facility), medium-high (engineered facility) and high (state-of the-art facility). Most developing countries utilize non-engineered landfill sites for waste management. Unfortunately, the technique endangers groundwater due to biological or physiochemical processes, as well as the release of volatile gases into the environment (Idowu et al., 2019). Disposal is the most adopted waste management principle in Nigeria. Research has shown that 68% of solid waste produced by communities was indiscriminately dumped, 21% disposed of through appropriate landfill sites and 11% burnt (Adeniran et al., 2014; Regassa et al., 2011).

The indiscriminate disposal of waste into various dumpsites without compliance to the existing environmental laws and the inadequate provision for leachate containments had resulted in the degradation of environmental resources over the years. However, the environmental menace could be mitigated through the application of a barrier soil also known as a landfill liner which serves as leachate containment. According to (Amadi et al., 2015), the provision of landfill liners in a waste containment system is to defend the environment from the adverse effects of leachate and to drain the leachate to treatment facilities. Compacted soil liners (CSLs) establish a dynamic component of hydraulic barriers in engineered landfills based on the constituent and thickness of the liner (Emmanuel et al., 2020). The general objective of CSLs is to decrease the soil pore spaces and its hydraulic conductivity. Several geo-environmental researchers have studied the application of bentonite enhanced natural zeolite, sand, lateritic soil and coal ash mixtures as an alternate landfill bottom liner (Tuncan et al., 2003; Tong, 2015; Amadi & Eberemu, 2013; Nayak, 2015) due to the low permeability hydraulic barrier of bentonite.

Amadi, (2013) investigated the swelling properties of soil-bentonite mixtures as a liner in a municipal waste landfill. The results revealed that swell pressures of compacted soil mixtures improved with increasing quantity of bentonite with treated tap water and three leachate solutions. (Kavya and Anjana, 2016) examined the use of soil amended with Na-bentonite for containment of municipal solid waste. They discovered that soil amended with Na-bentonite of 12% was found to satisfy all the criteria of landfill liner. (Tuncan et al., 2016) investigated the applicability of sepiolite-zeolite mixtures as a liner. The sepiolite/zeolite mixture having a ratio of 0.3 was used while copper (Cu) and Chromium (Cr) solutions were used as contaminants.

The experimental results showed that the sepiolite-zeolite mixtures having a ratio of S/Z: 0.3 can be applied as a hazardous landfill liner.

Opafola et al., (2021) investigated the use of bentonite- mound soil mixture as filter for wastewater treatment. The analysis revealed that filter with 15% bentonite and 85% termite mound soil generally displayed great and effective pollutant removal efficiencies.

Termite mounds are direct threat to wooden infrastructure due their destructive tendency. They possess excellent thermal properties, comparative compressive strength, low hydraulic properties and efficient chemical filter qualities (Ayobami et al., 2020; Opafola et al., 2021). Processed mound has been developed as construction resources (Ayobami et al., 2020; Millogo et al., 2011; Ikponmwosa et al., 2011), an adsorption resource in the decontamination of a polluted aqueous solution (Abdus-Salam and Itiola, 2012) and filter material for wastewater treatment (Opafola et al., 2021). However, the engineering capabilities of mound soil as a bottom liner to mitigate the impact of leachate to the environment are yet to be explored which explains the novelty of the research.

This research is based on the recommendation of (Opafola et al., 2020). The characterization of engineering properties of bentonite-mound soil revealed that the blend of 15% bentonite is suitable for the design of liner in a waste containment system. Hence, the feasibility of mound-bentonite mixture as an alternate bottom liner is being investigated using a pilot scale artificial landfill.

2. MATERIALS AND METHODS

2.1. MATERIALS

The termite mound soil was acquired from Ifo town, Ogun state while the bentonite was sourced from obtained from a supplier in Lagos state. Paint Industrial Wastewater (PIWW) used for this research work was collected from the manufacturing plant of a paint company located in Lagos state. According to (Opafola et al., 2020), bentonite used is a montmorillonite dominated mineral, yellowish-brown in colour with 20.1% sand, 20.4% silt and 59.5% clay. The reddish-brown mound contains mainly of quartz as the dominant mineral, 87.5% sand, 2.3% silt and 10.2% clay.

Fig. 1. Termite mound.

Fig. 2. Bentonite.

Fig. 3. PIWW.

2.2. METHODS

Bentonite of varying percentages (0%, 5%, 10% and 15%) was mixed with termite mound soil by dry weight to enhance its engineering properties. The index and engineering properties of the soils mixtures were analyzed in accordance with the methods defined in BS 1377 (1990). The study was conducted on a pilot scale artificial landfill (800 x 800 x 400 mm) with four sections AX, AY, BX and BY. The prepared soil mixtures Fig. 4 were placed into each section and compacted in three layers to achieve 100 mm thickness using a 7kg hand compactor Fig. 5. The mixtures were cured for 28 days Fig. 5. Wastewater (16 litres) was poured above the cured soil mixture. The artificial landfill was covered with polythene to prevent evaporation Fig. 5. The liner mixtures were subjected to paint industry wastewater loading for 26 weeks retention period as shown in Fig.6.

Fig. 4. Sample preparation prior to placing and compaction.

Fig. 5. Placing and compaction procedures.

Fig. 6. Pilot Scale Artificial Landfill.

3. RESULTS AND DISCUSSION

3.1. Assessment of paint wastewater

The assessed parameter of the wastewater is displayed in Table 1. Heavy metals such as lead, cadmium and chromium were within the recommended limits. The concentrations of parameter such as total dissolved solids, biochemical oxygen demand, chemical oxygen demand, copper and nickel were above the recommended limits of (NESREA , 2009).

Table 1. Characterization of paint industry wastewater (NESREA, 2009).

Parameter	Concentration	Permissible Limit NESREA
pH	7.48	6-9
Colour (TCU)	5.5	7
TDS (mg/l)	585	500
TSS (mg/l)	11.28	25
BOD_5 (mg/l)	254	30
COD (mg/l)	569	60
Lead (mg/l)	0.35	<1.0
Chromium (mg/l)	0.76	<1.0
Copper (mg/l)	1.43	<1.0
Cadmium (mg/l)	0.43	<1.0
Nickel (mg/l)	9.45	<1.0

3.2. Elemental Composition of the Soil Samples

XRF analysis revealed the existence of following elements such as Aluminium, Silicon, Phosphorus, Sulfur, Potassium, Calcium, Titanium, Vanadium, Iron, Tungsten, Niobium, Molybdenum, Tin, Antimony, Cobalt, Chromium, Copper, Manganese, Nickel, Lead, and Zinc.

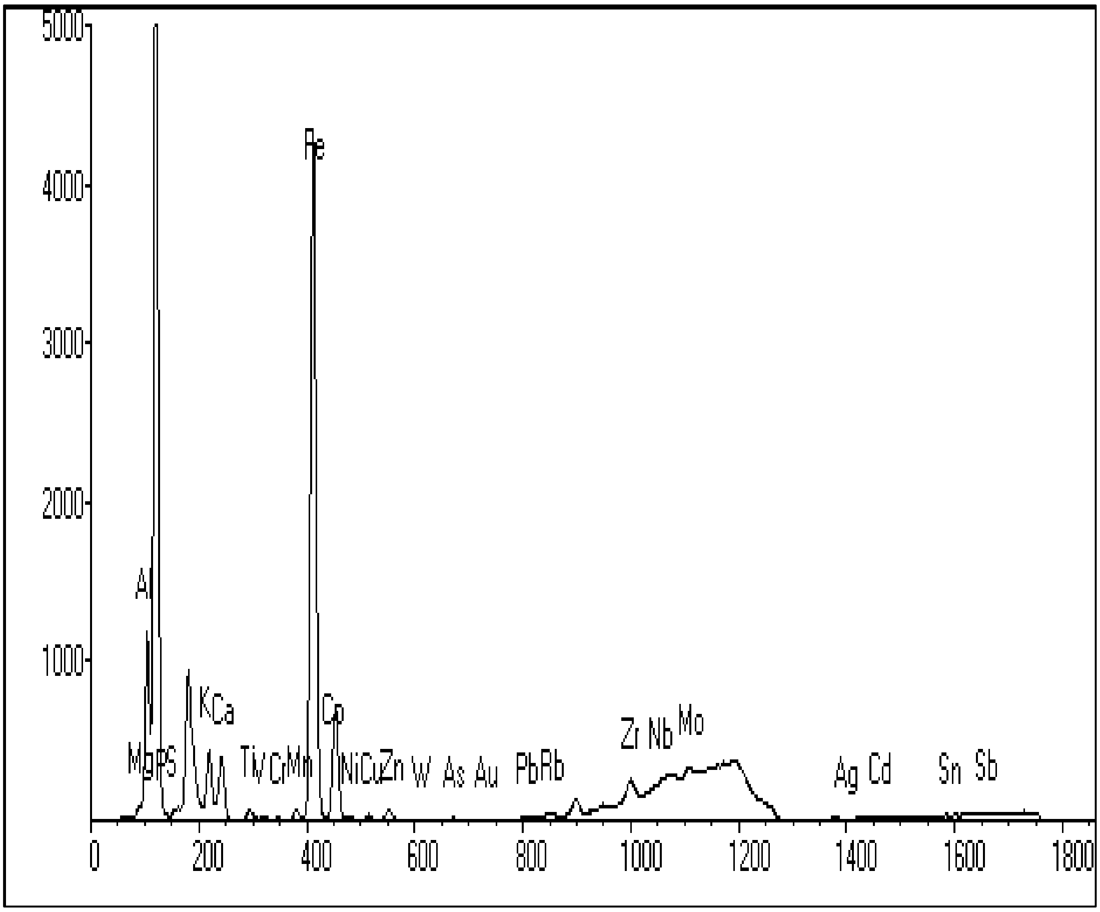

Fig. 7. Elemental variation in bentonite.

The primary occurring elements in bentonite are 8.91 wt.% of Aluminium, 25.19 wt.% of Silicon and 17.92 wt.% of Iron while termite mound has 14.11 wt.% of Aluminium, 25.82 wt.% of Silicon and 10.50 wt.% of Iron. The variation of the elemental composition is graphically illustrated in Figs. 7 and 8 respectively.

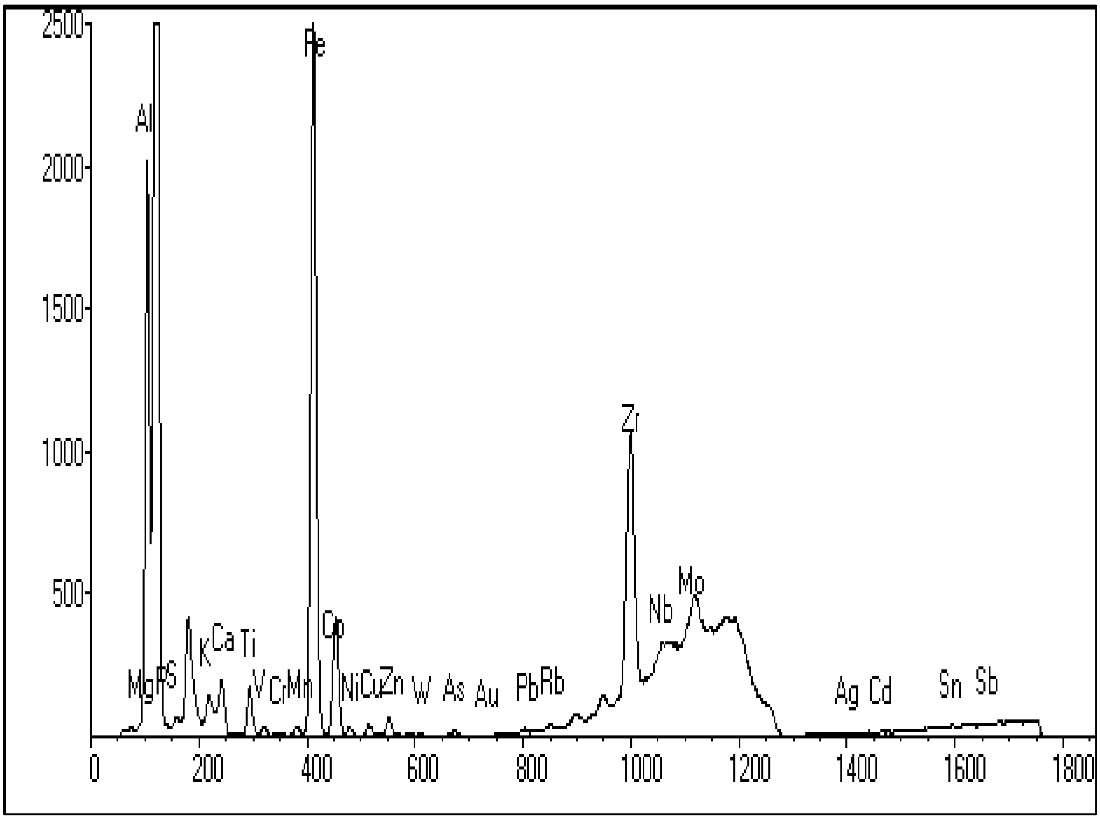

Fig. 8. Elemental variation in mound soil.

3.3. Characterization of the index and engineering properties

The summary of index and engineering properties analyzed are presented in Table 2. Sample T1 with no bentonite content has the lowest Liquid Limit (LL) and Plastic Limit (PL) values of 49% and 27% respectively while sample T4 with 15% bentonite content has the highest LL and PL values of 66% and 32% respectively. The result obtained is similar to that of (Oyediran and Iroegbuchu , 2013; Amadi and Eberemu ,2013). The Maximum Dry Density (MDD) for the control (T1) decreases from 1.88 to 1.72 g/cm3 for mix T4 with 15% bentonite content and optimum moisture content increases from 13.80 to 18.52% with the progressive increase of bentonite content. The result is in conformity with the recommendations of (Amadi et al. , 2015; and Tuncan et al. 2016) which state that MDD ≥ 1.50 g/cm3 for soil to be used as landfill bottom liner. The highest permeability value of 789.4 x 10-9 m/s was recorded for mix T1 while the lowest value of 0.23 x 10-9 m/s was recorded for mix T4 as shown in Table 2. The result obtained for sample T4 is in tandem with that of (Guney et al., 2013; and Widomski et al., 2018). According to US EPA (1989), the hydraulic conductivity of any liner material should not be less than 1x 10-9 m/s.

Table 2. Engineering properties of the liner.

Sample	Mixture	LL (%)	PL (%)	MDD (g/cm^3)	OMC (%)	Permeability (m/s)
T1	BC 0 : 100 MS	49	27	1.88	13.80	783.4×10^{-9}
T2	BC 5 : 95 MS	58	29	1.86	14.29	19.14×10^{-9}
T3	BC 10 : 90 MS	60	30	1.74	18.20	4.17×10^{-9}
T4	BC 15 : 85 MS	66	32	1.72	18.52	0.23×10^{-9}

3.4. Evaluation of bottom-liner performance

The seepage trends and quantification of leached samples (leachate) obtained after the experimental study are presented in Table 3. Liner in section AX with 100% MS (control) failed during the 6th week of the retention period. Wastewater of 1.1×10^6 mm^3 leached beneath the artificial landfill in section AX Fig. 9. The liners in sections AY and BX with 5% and 10% BC failed during the 11th and 17th week of the retention periods respectively. Wastewater of 0.5×10^6 and 0.4×10^6 mm^3 leached beneath the artificial landfill in sections AY and BX respectively Figs. 10 and 11. However, no seepage was recorded for the liner mixture in section BY with 15% BC which connotes that wastewater leakage was prevented throughout the experimental period Fig. 12. Hence, the mix ratio 15% bentonite amended with termite mound soil can be used for the design of liner in a waste containment system.

Table 3. Seepage Trends of the Liner Mixtures.

Section	Mixtures	Quantity Leached $\times 10^6$ (mm^3)	Seepage trends (weeks)
AX	BC 0 : 100 MS	1.1	6
AY	BC 5 : 95 MS	0.5	11
BX	BC 10 : 90 MS	0.4	17
BY	BC 15 : 85 MS	-	No Seepage

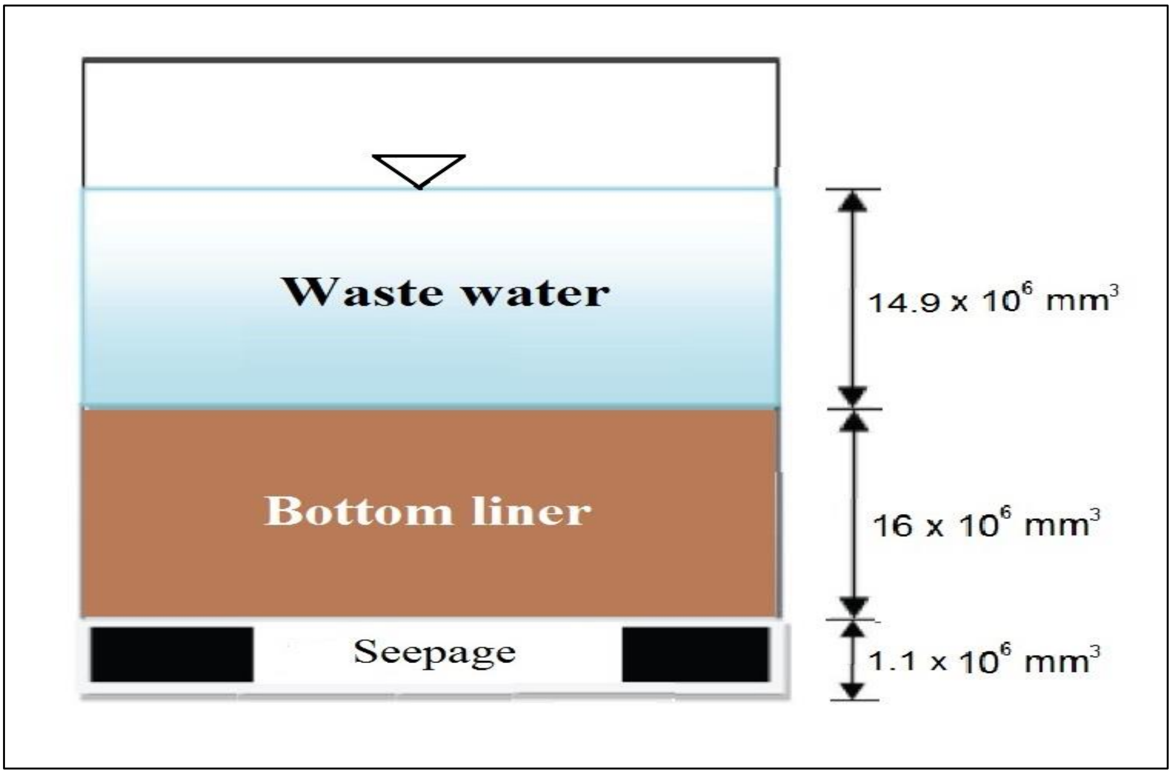

Fig. 9. Schematic Content of Section AX (0% BC + 100% MS).

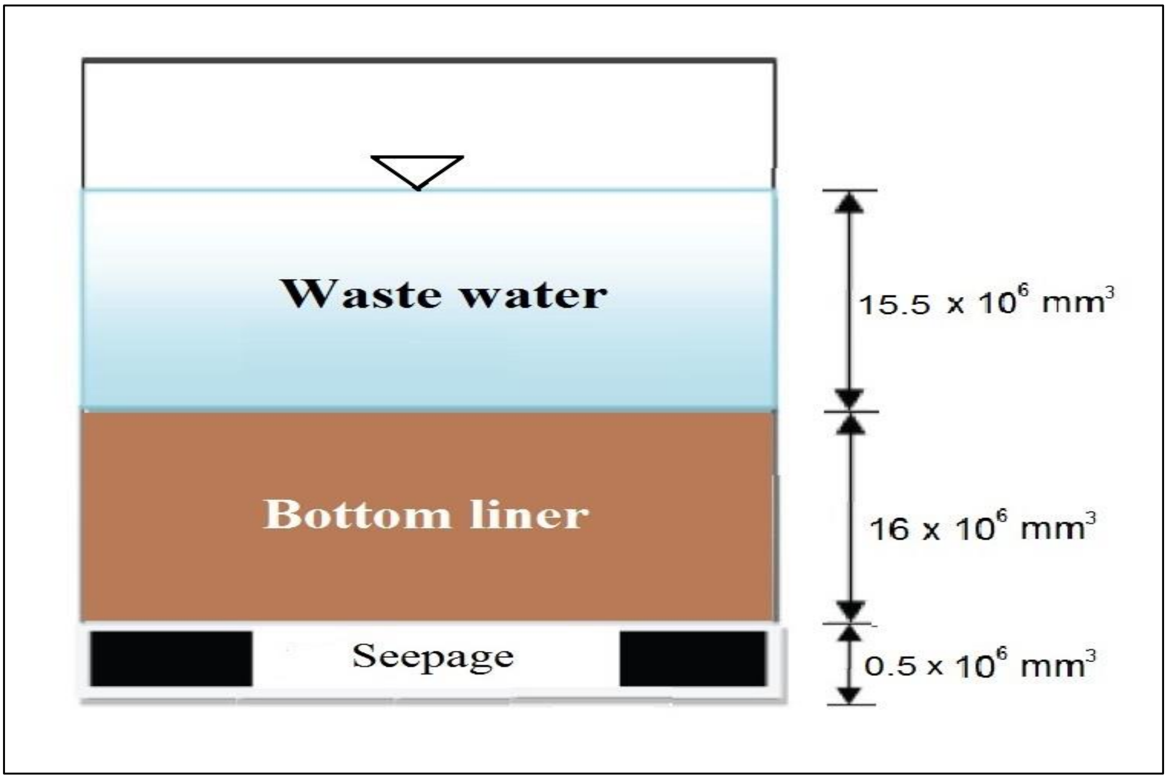

Fig. 10. Schematic Content of Section AY (5% BC + 95% MS).

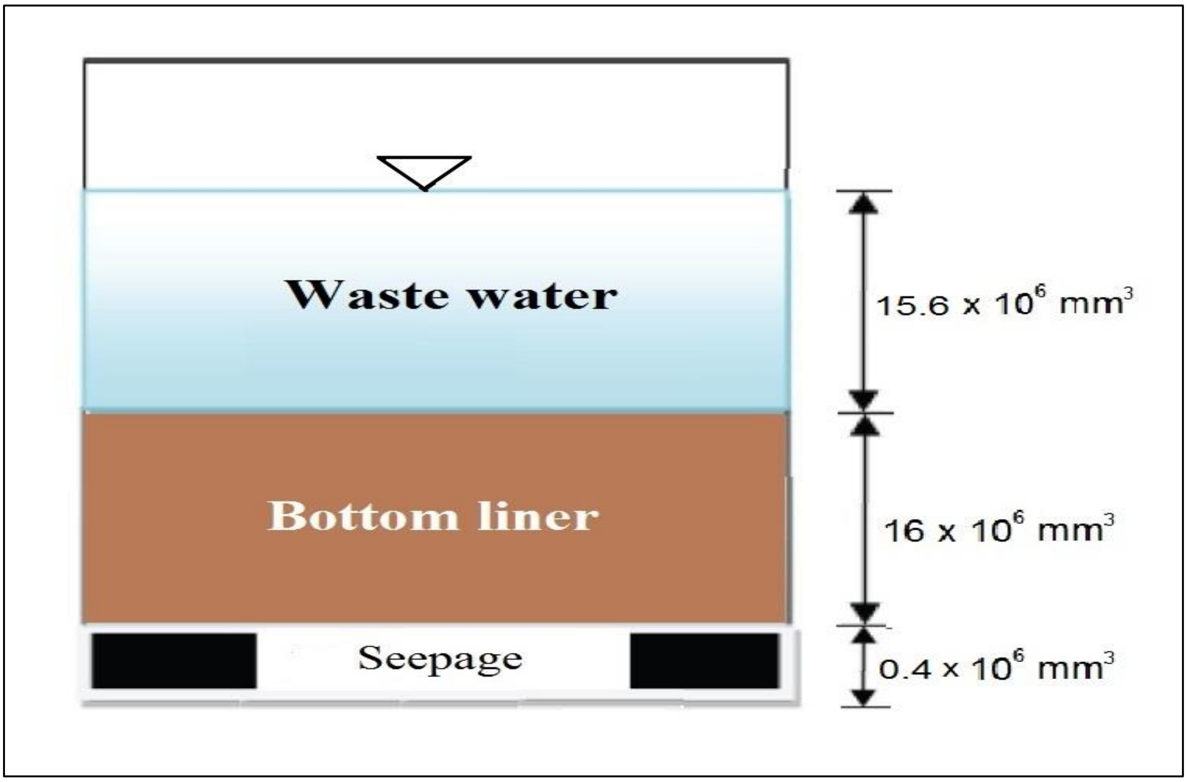

Fig. 11. Schematic Content of Section BX (10% BC + 90% MS).

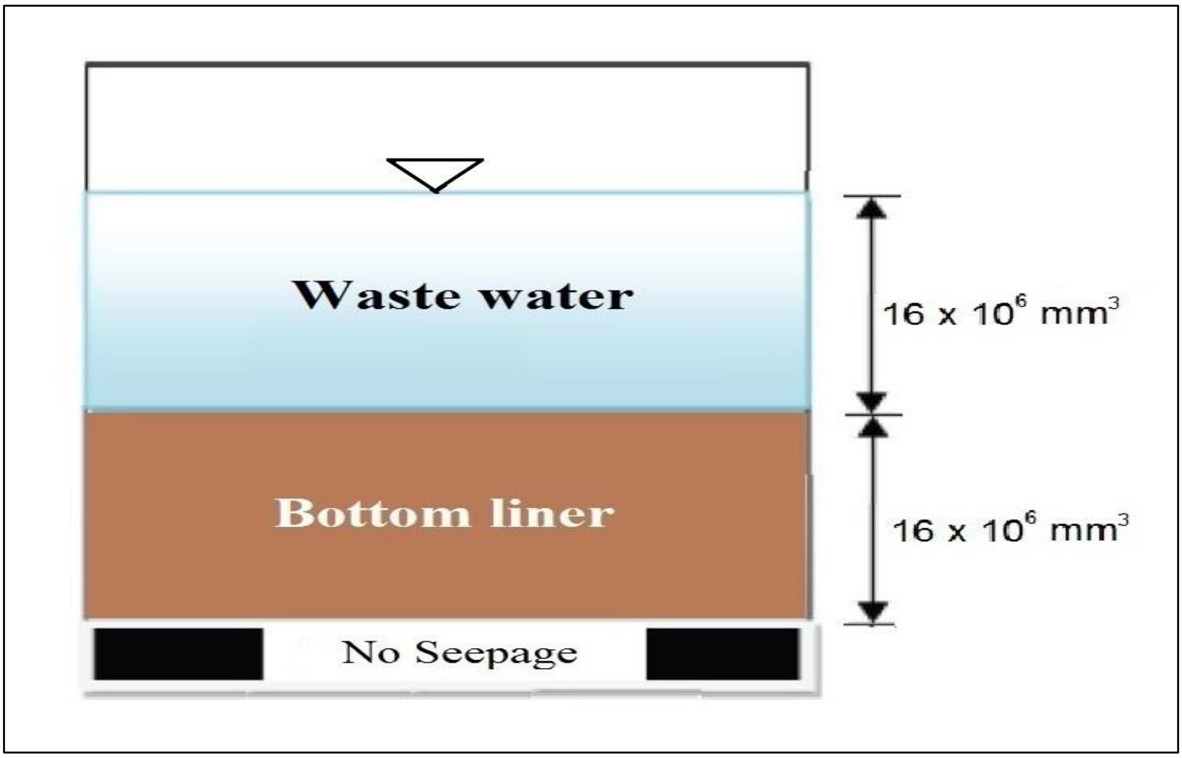

Fig. 12. Schematic Content of Section BY (15% BC + 85% MS).

4. CONCLUSION

The study revealed that ordinary termite mound soil is unsuitable as a liner material in a waste containment system. The introduction of bentonite (5%, 10%, 15%) mixed termite mound soil enhanced the engineering properties of the soil. The pilot scale experimental study showed that wastewater leaked in sections AX, AY and BX while no seepage was recorded for liner mixture in section BY with 15% bentonite which connotes that wastewater leakage was prevented by the soil mixture throughout the experimental framework. Conclusively, the application of termite mound soil enhanced with 15% bentonite is recommended for the design of liner in a waste containment system and the blend ratio can be effectively applied for industrial waste management.

5. CONFLICT OF INTEREST

All the authors declare that there is no conflict of interest in this research.

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