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AN INNOVATIVE SANITARY LANDFILL SYSTEM WITH DREDGED MARINE SOILS (DMS) AS LINER MATERIAL: GEO-ENVIRONMENTAL STUDIES

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ABSTRACT: The dredging process in Malaysia commonly ends with the dredged material being disposed offshore in designated dumpsite. Nowadays the disposal of dredged marine soils (DMS) into the sea is gradually being discontinued in developing countries due to concerns for the marine environment. Hence, such large volumes of DMS have created a greater challenge for sustainable disposal practice. Recently, a number of studies have reported the potential of DMS as a raw material for transformation into useful products of economical value. Since marine soils such as them are considered harmless, the construction of landfill barriers can be potentially carried out by using this material. This paper aims to determine the ability of DMS to be used as a liner material as geosorbent to remove pathogenic bacteria in landfill leachate. The DMS are subject to a variety of physical and chemical tests**.** Findings from this study showed that hydraulic conductivity of DMS was within the range stated in the standards for liner material. Based on the result, it is found that the bacteria were able to survive in such extreme salinity at neutral pH condition. Taken together, these results suggest that the use of DMS as liner material in landfill site will help to remove the bacteria in landfill leachate.

Keywords: Dredged marine soils; Liner material; Hydraulic conductivity; Bacteria growth

1. INTRODUCTION

The objective of landfill barrier (liner and cover) is to minimize or eliminate the infiltration of leachate into the subsurface soils below the landfill. Minimization of leachate infiltration would minimize the risk of water sources contamination. Natural clays or compacted clay soils, commercial clays (bentonite mixed with sand), geomembrane (made from synthetics resins such as polyethylene or other polymers) as well as geosynthetic clay liner (made from thin clay layer usually sodium bentonite and supported by geotextiles or geomembranes) are usually used as commercially available landfill liners. However, compacted clay soils are widely used as landfill liner to isolate contaminants from reaching into groundwater [1].

The design details of liners are closely related to the applicable local regulations. Liner can come in either single, composite or double forms. A single liner is constructed of natural clay or geomembrane, a composite liners consist of two layers (bottom is clay, top is geomembrane), while a double liners has either two single liners, two composite liners or one of each [2]. In general, the more layers included, the more protective the liner system is and the more cost would be required. Alternatively, landfill sites with non-permeable ground layers such as clay would be advantageous as these layers could act as natural barrier.

A potential reuse area yet to be explored is the utilization of dredged marine soils (DMS) as geosorbent to retain pathogenic bacteria in landfill leachate. The use of DMS as geosorbent in landfill site could be considered as a new way of environmental friendly solid waste management. By laying DMS at the base of landfill like conventional clay liners, the geowaste could be simultaneously disposed of and act as passive geosorbent for microbes in leachate.

The relationship between marine soil properties and the sorption of chemical contamination has been investigated. However, the possibility of applying this material to remove pathogenic bacteria remains unknown. The objective of this paper were to determine the DMS hydraulic conductivity and to investigate grow of bacteria in the neutral condition of DMS (pH and salinity factor). Findings from this study can be used as a base to advancing knowledge in reused DMS as geosorbent in landfill.

2. PROPOSED LINER

Clay is a material with low permeability and frequently used in landfill site as a final cover or liner system. High plasticity of clay allowed absorption of water as much as their weights [5]. Naturally abundant of clay soil or re-compacted clay liner is essential in reducing natural soil liners' hydraulic conductivity in landfill sites.

Compacted clay liner (CCL) is expected to isolate waste components from the environment and to protect the soil and ground water from contaminant originating from landfill site. In [4] discusses to use the dredged marine soils (DMS) as a potential geosorbent (liner material) in landfill for removing pathogen bacteria in leachate. CCL is a type of commonly used liner worldwide due to their large capacities, cost effectiveness and low hydraulic conductivity (< 10^{-9} m/s). Usually, the liner consists of a 0.5 to 1.0 m thick layer of compacted clay [6].

Fig. 1 Schematic diagram for proposed landfill liner system

Fig. 1 show a schematic diagram for proposed landfill liner system using DMS as liner material. The lining system are place on top by a coarse material (e.g gravel) to prevent movement of waste particle into the leachate collection pipe (perforated pipe). The leachate collection pipes are installed and heading to the leachate collection pond or to the leachate treatment facility. DMS material will acting as hydraulic barrier to prevent leaching of pathogenic bacteria into the groundwater.

3. EXPERIMENTAL WORK

3.1 Geotechnical Properties

Dredged materials were retrieved in Kuala Perlis near the Kuala Perlis Terminal. DMS was considered as disturbed sample due to the dredger machine used which backhoe dredger was. The samples were scooped with manually and were taken into the storage box with double-layered plastic bags. It was to prevent the moisture loss during transportation back to the laboratory. In this study, sand with size ranged 2 – 2.36 mm been used to act as additional drainage material and surcharge. Fig. 2 shows the size-distribution for DMS and sand for this study. A standard oedometer test had been conducted by following the procedures described in BS 1377. Single drainage (one-way) were applied for this test, where the porous stone was placed at the top only while the bottom only the non-porous (brass plate).

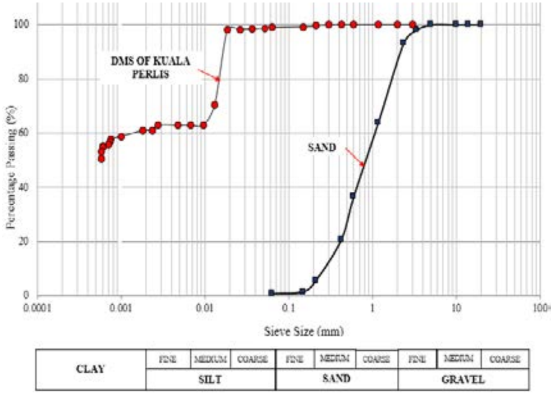


Fig. 2 Size distribution for DMS and sand

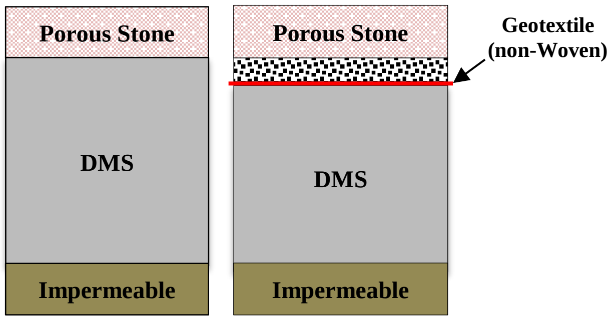


Fig. 3 Test plan for standard oedometer test

As in Fig. 3, 50% of sand were placed at the top with geotextile (non-woven) as a separator for sand and DMS. The used of geotextile is to make sure the sand do not seep into DMS sample when the loading been applied. The incremental vertical stress was applied from 5, 12.5, 25, 50, 100, 200, 400 and 800 kPa, with each load being maintained for 24 hours.

3.2 Leachate Sampling

Leachate sample were collected from non-sanitary landfill. Prior to restricted issues, the exact location for the conventional landfill is not be mentioned in this paper. The site is located few kilometers from resident areas, receiving 300 – 600 tonne/day of waste. The landfill receives both municipal and industrial waste. It is equipped with leachate collection pond with no liner and cover material.

3.3 Characteristic of Leachate

Physicochemical analysis of leachate such as pH, conductive and temperature were performed using probe immediately after collecting the samples. For the Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) analysis, the samples were assessed according to the Standards Methods for the Examination of Water and Wastewater [7]. Isolation of bacteria in leachate was conducted according to the British Standards

(BS 6068: Section 4.2: 1989).

3.4 Bacteria Growth

3.4.1 Isolation of bacteria

Bacteria was isolated from leachate sample using the streak plate method. This method is rapid and simple in obtaining pure isolated colonies. A large concentration of bacteria was diluted to a small, scattered population of cells. Indicator bacteria namely *Escherichia coli* (*E. coli*) was isolated using selective media agar, Chromocult Agar (CCA).

3.4.2 Inoculation of bacteria

Subculture of bacteria was obtained by transfer colonies from the plate culture to a growth media namely Nutrient Broth (NB). The growth media was sterilized before being inoculate with the bacteria colonies. The fresh inoculate medium allowed for bacteria growth as normal until such time the cells are used for experiments.

3.4.3 Microcosms preparation

Microcosms were prepared with the dominated salt solution, sodium chloride (NaCl). Each microcosm consisted 50 ml of saline water brought to appropriate salinity. Salinity of solution was expressed in parts per thousand (‰). Microcosms with salinities 0, 18 and 35 ‰ were prepared and inoculated with 1 ml of culture consists 10^6 CFU of *E. coli* [3]. The pH of microcosms was adjusted by drop-wise addition of 1M hydrochloric acid (HCl) or sodium hydroxide (NaOH). The pH values obtained was 7. The microcosms were prepared in triplicate and incubated at room temperature. The number of *E. coli* was determined starting from before incubation until 28 days. Data obtained from the experiment were measured using optical density measurement and reported in Abs.

4. DISCUSSIONS

4.1 Oedometer Test

Each vertical stress increment and hydraulic conductivity, k was estimated and their variation with effective vertical stress, $\sigma_{v'}$ was plotted as shown in Fig. 4 and Fig. 5. As seen in the compression curves, the control specimen (DMS only) significantly improve about 10 % when there has granular material been added at the top of DMS. Again, both specimens were tested for single drainage only. The used of sand was to shorten the consolidation time and improve its characteristics as well. Hydraulic conductivity, *k* of specimens for the control are in order of 3.16 x 10^{-9} m/s to 3.23 x 10^{-10} m/s initially at $\sigma_{v'}$ = 5 kPa, but fluctuate at 50 kPa then declines abruptly at the next vertical stress. While $k_{DMS+Sand}$ values shows the declines with significantly when the load increment been applied. The k_{avg} for both specimens are $k_{control}$ (1.30 x 10^{-9} m/s) and $k_{DMS+Sand}$ (1.45 x 10^{-9} m/s). During the loading and unloading stages, the hydraulic conductivity values of both specimens are similar and below 10^{-10} m/s. Seems that the water in DMS dissipate faster with the additional sand layer compare to the control specimen only in one- way drainage. The hydraulic conductivity of DMS was within the range as set in the design of landfill guidelines for tropical climates provided by the International Solid Waste Association (ISWA). The permissible hydraulic conductivity value is 10^{-8} m/s – 10^{-9} m/s [14].

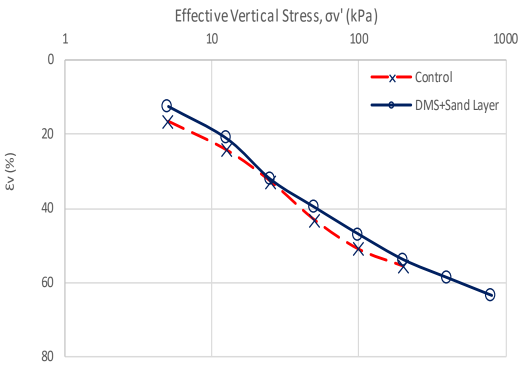


Fig. 4 Compression curve

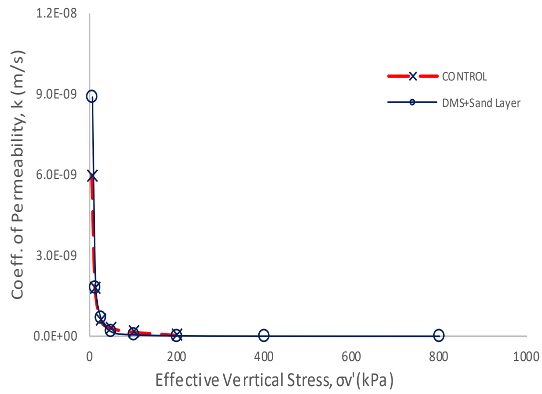


Fig. 5 Coefficient of hydraulic conductivity

4.2 Characteristic of Leachate

The characteristic of leachate can be best significant by Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) which serve as the main chemical features of environmental threats [8]. The result physico-chemical analysis of leachate are summarized in Table 1. The analysis also focused on the identification of several pathogenic bacteria in landfill leachate. The pH, BOD and COD value of examined leachate showed that the leachate was categorized as intermediate (within 5 to 10 years). The microbiology analysis showed that several pathogenic bacteria were detected in leachate. The present data in agreed with [9] where twelve pathogenic bacteria were isolated from the leachates. The isolated pathogenic bacteria suggest that the leachate could be a potential risk as pathogen disperser especially for the landfill worker.

Table 1. Characteristic of raw leachate

Parameters	
pH	6.5
Biological Oxygen Demand (mg/l)	1187
Chemical Oxygen Demand (mg/l)	8600
Salinity (ppt)	18
<u>Pathogenic bacteria</u>	
Salmonella	Detected
Shigella	Detected
Escherichia coli	Detected

The characteristic of leachate leaching out from landfill can be influenced by several factors such as age of landfill (young, intermediate, stabilized, old), type of waste dumped in the landfill (chemical compositions, initial moisture content, biodegradability), climatic and hydrological conditions (groundwater intrusion, rainfall), management and operational of landfill (sanitary or conventional landfill, refuse pretreatment, compaction) as well as internal processes inside landfill (heat and gas generation, decomposition of organic materials). The leachate characteristic not only differ from site to site, but also from the same sampling locations from time to time due to the variation in the above factors [10].

4.3 Variation of Bacteria Growth

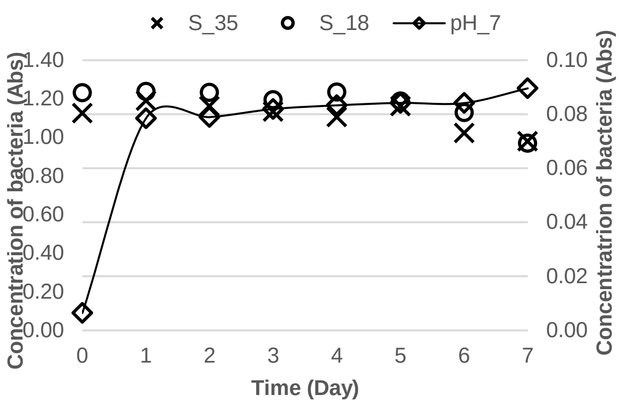
The role of marine soils as a reservoir for bacteria have been explored in previous study. Persistence of bacteria was found to be greater in marine soils than water column. To further investigate the potential of DMS as liner material, impact of pH and salinity factor were tested for bacteria growth. Study on the effect of pH and salinity have been conducted previously [11][12]. The results showed that the number of *E. coli* grew higher in alkaline and lower salinity condition.

Fig. 6 shows the seven days of bacteria growth at variation of salinity. The tests were carried out under two different salinity level (18‰ & 35‰) at pH value of 7. The origin salinity at pH 7 was 0‰ (neutral condition). This were meant to stimulate the natural salinity of leachate (salinity = 18‰) and marine soils (salinity = 35‰)

As known DMS provide extreme saline environment to the bacteria. As shown in Fig. 6, *E. coli* were adapted well to the environment in the beginning of experiment. The growth rate of bacteria was characterized by equilibrium between dying and dividing cells for all microcosms. The results suggest that the bacteria will able to grow in DMS. It is somewhat surprising that the growth of *E. coli* began to decrease in salinity 18 and 35 during Day 6. Meanwhile the bacteria slightly increase under neutral condition experiment. The growth of bacteria were further analyzed until Day 28 (Fig. 7).

Fig. 6 A Bacteria growth for pH 7 and salinity 35 for 7 days.

Fig. 7 Bacteria growth for 28 days of experiment



It seems possible that these results are due to the bacteria started to accumulate toxic products leading to decline in the number of cell. This phenomenon is known as a death phase. During this phase, the dead cells release nutrients. Remaining living cell used these nutrients to growth and survive [13]. In this paper, the experiment were conducted in a control condition. Further study should be done under variable condition to establish this findings.

5. CONCLUSIONS

From the present study, the hydraulic conductivity (*k*) of dredged marine soils (DMS) was 10^{-9} m/s to 10^{-10} m/s. The *k* value of DMS was obtained from oedometer test. It falls within the range as stated in the ISWA guidelines (k = $10^{-8} – 10^{-9}$ m/s) for liner material. Thus, the material can be accepted to be used as landfill liner. The study also has gone some way towards enhancing our understanding of bacteria growth in DMS. To further investigate the potential of DMS as liner material, impact of pH and salinity factor were tested for bacteria growth. As known DMS provide extreme saline environment to the bacteria. Based on the result, it is found that the bacteria were able to survive in such extreme salinity at neutral pH condition. Taken together, these results suggest that the use of DMS as liner material in landfill site will help to remove bacteria in landfill leachate. More study is needed to better understand bacteria removal in landfill leachate which could be accomplished by sorption mechanisms onto the DMS material.

6. ACKNOWLEDGEMENTS

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