A PARAMETRIC STUDY OF DREDGED MARINE SOILS AS PASSIVE GEOSORBENT FOR *ESCHERICHIA COLI* REMOVAL IN LEACHATE

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DEDICATION

My humble effort I dedicated to:

My sweet and loving parents, Tn. Hj. Anuar Abas and Pn. Hjh. Rahimah Hassan
My supportive husband Abdul Wafi A. Razak
My strongest motivator Nur Laila Maisara Abdul Wafi
My lovely siblings Alia, Nabila and Zafira
In memory of Tok Mak Hjh Kalos Sulaiman and Mak Ngah Hjh. Kamaliah Hassan.

Al-Fatihah.

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ABSTRACT

A high demand for dredging in the Malaysian water has resulted in a large amount of geowaste name dredged marine soils (DMS). The material are discarded in designated disposal sites on- and off-shore. A large number of studies in reusing this material within recent years demonstrate the importance of finding better management of DMS after the dredging process. The effective use of DMS as an adsorbent to remove chemical contaminants from leachate as potential alternatives to landfill liner has received widespread attention because of the environmentally friendly nature of clay material. A potential reuse area yet to be explored is the utilization of DMS to remove *Escherichia coli* (*E. coli*) from leachate. Effect of DMS geotechnical properties is a key point laid behind understanding passive removal of *E. coli* in leachate. Therefore by simulating landfill site, the efficiency of DMS as a geosorbent was studied. This study explored the effect of pH, soil particle size, salinity and temperature on *E. coli* removal from leachate. Geosorbent samples from various depths of each reactor were also retrieved and assessed to profile the spatial distribution of the *E. coli*. This study showed that the hydraulic conductivity of DMS fell within the acceptance range for liner material. The output count of *E. coli* was lower after 35 days of exposure to a high salinity level. *E. coli* removed by lower pH were antagonistic as their presence in the leachate was decreased. Also, the finer particle size required a longer time to adsorb the *E. coli* due to the soils' porosity. The measured result in a higher temperature degree supported the idea that *E. coli* growth in landfill leachate was suppressed by the increment of the temperature. Concurrently a high number of *E. coli* was counted in the DMS with less than 0.0001% of *E. coli* was found in the effluent. The findings from this study concluded that DMS has the potential to be reused as a geosorbent to retain *E. coli* in leachate.

ABSTRAK

Permintaan yang tinggi untuk pengerukan di perairan Malaysia telah menghasilkan sejumlah besar geo-sisa iaitu kerukan tanah laut (DMS). Bahan tersebut dibuang di tapak pelupusan yang ditetapkan: di dalam dan di luar pantai. Sebilangan besar kajian dalam menggunakan semula bahan ini dalam beberapa tahun kebelakangan ini menunjukkan kepentingan mencari pengurusan DMS yang lebih baik selepas proses pengerukan. Penggunaan berkesan DMS sebagai penjerap untuk membuang bahan cemar kimia daripada bahan larut lesap sebagai alternatif yang berpotensi kepada pelapik tapak pelupusan telah mendapat perhatian meluas kerana sifat bahan tanah liat yang mesra alam. Kawasan guna semula yang berpotensi masih belum diterokai ialah penggunaan DMS untuk membuang *Escherichia coli* (*E. coli*) daripada larut lesap. Kesan sifat geoteknik DMS adalah perkara utama yang diletakkan di sebalik pemahaman penyingkiran pasif *E. coli* dalam larut lesap. Oleh itu dengan mensimulasikan tapak pelupusan, kecekapan DMS sebagai geosorben telah dikaji. Kajian ini meneroka kesan pH, saiz zarah tanah, kemasinan dan suhu terhadap penyingkiran *E. coli* daripada larut lesap. Sampel geosorben dari pelbagai kedalaman setiap reaktor juga telah diambil dan dinilai untuk memprofilkan taburan spatial *E. coli*. Kajian ini menunjukkan bahawa kekonduksian hidraulik DMS berada dalam julat penerimaan untuk bahan pelapik. Kiraan keluaran *E. coli* lebih rendah selepas 35 hari terdedah kepada tahap kemasinan yang tinggi. *E. coli* yang disingkirkan oleh pH yang lebih rendah adalah antagonis kerana kehadirannya dalam larut lesap telah berkurangan. Selain itu, saiz zarah yang lebih halus memerlukan masa yang lebih lama untuk menyerap *E. coli* kerana keliangan tanah. Keputusan yang diukur dalam tahap suhu yang lebih tinggi menyokong idea bahawa pertumbuhan *E. coli* dalam larut larut sampah ditindas oleh kenaikan suhu. Pada masa yang sama bilangan *E. coli* yang tinggi telah dikira dalam DMS dengan kurang daripada 0.0001% *E. coli* ditemui dalam efluen. Dapatan daripada kajian ini merumuskan bahawa DMS berpotensi untuk digunakan semula sebagai geosorben untuk mengekalkan *E. coli* dalam larut lesap.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
°C	-	Degree Celsius
‰	-	Part per thousand
A.D	-	Anno Domini
AOP	-	Advance oxidation process
APHA	-	American Public Health Association
B.C.	-	Before Christ
BB	-	Bukit Bakri
BOD	-	Biochemical oxygen demand
BS	-	British Standard
C	-	Clay
CCA	-	Chromocult Coliform Agar
CCL	-	Compacted clay liner
CDC	-	Centre for Disease Control and Prevention
C_e	-	Final concentration
CFU	-	Colony Forming Unit
C_o	-	Initial concentration
COD	-	Chemical oxygen demand
CS	-	Coarse sand
CWs	-	Constructed wetlands
d.	-	Detected
DAEC	-	Diffusively Adherent Escherichia coli
DMS	-	Dredged marine soils
DNA	-	Deoxyribonucleic Acid

dS/m	-	Decisiemens
EAEC	-	Enteroaggregative *Escherichia coli*
EBS	-	Engineered barrier system
EC	-	Electrical conductivity
EIEC	-	Enteroaggregative *Escherichia coli*
EPEC	-	Enteropathogenic *Escherichia coli*
EQA	-	Environmental Quality Act
ETEC	-	Enterotoxigenic *Eschericia coli*
Eu	-	Europian Union
FS	-	Fine sand
FSWS	-	Free water surface system
GCL	-	Geosynthetic clay liner
GW	-	Green waste
h	-	Hour
HDPE	-	High density polyethylene
H_R	-	Effective depth
ISWA	-	International Solid Waste Association
JLM	-	Jabatan Laut Malaysia
k	-	Hydraulic conductivity
kg	-	kilogram
L	-	Leachate
LL	-	Liquid limit
LPI	-	Leachate pollution index
L_s	-	Leachate with adsorbent
m	-	Mass
M	-	Silt
m/s	-	meter per second
m^3	-	Cubic meter
MH	-	Highly plasticity silt
m_L	-	Mass of loss
ml	-	Milliliter

MLSS	-	Mixed liquor suspended solid
MLVSS	-	Mixed liquor volatile suspended solid
mm	-	Millimeter
MS	-	Medium sand
η	-	Viscosity of water
n.d.	-	Not detected
OC	-	Organic content
OD	-	Optical density
PAHs	-	Polycyclic aromatic hydrocarbons
PCBs	-	Polychlorinated biphenyls
PI	-	Plasticity index
PL	-	Plastic limit
ppt	-	Part per trillion
RE	-	Removal efficiency
S	-	Adsorbent
SL	-	Seelong
SR	-	Simpang Renggam
STEC	-	Shiga toxin-producing *Escherichia coli*
SWM	-	Southern Waste Management
SWS	-	Subsurface water system
t	-	Time
USCS	-	Unified Soil Classification System
USEPA	-	United State Environmental Protection Agency
V	-	Volume
WHO	-	World Health Organization
X	-	Number of bacteria adsorbed per gram
XLD	-	Xylose Lysine Deoxycholate
μm	-	Micrometer
ρ_d	-	Particle density

CHAPTER 1

INTRODUCTION

1.1 Background of study

Dredging is an essential part of sustainable waterway management. Dredging activities can occur in either fresh water, brackish water or saltwater environment (Nicholas, 2012). In addition, over the years, large amounts of marine soils are needed to be dredged to maintain inland waterways and harbours (Said *et al*., 2015). Dredged materials are marine soils derived from the excavation of lagoons, harbours, canals, river and marine areas (Lee, 2010). In general, there are five types of Dredged Marine Soils (DMS), namely rock, gravel, sand, silt and clay. Dredged materials arising from dredging activities is considered a waste and are normally disposed or stored at the edge of water bodies (Barbosa & Almeida, 2001). The increasing amount of these dredged materials raises problems such as finding the best way to manage them. To date, these dredged marine soils are either dumped at sea or disposed inland.

The dredging process in Malaysia commonly ends with the dredged material being disposed offshore in designated dumpsite. Nowadays the disposal of 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. This is especially true for DMS which are marginally contaminated or treatable. For instance, Ramli *et al*. (2013) reported that the heavy metal concentrations in the DMS from Kuala

Perlis, Malaysia were below the threshold values set by United State Environmental Protection Agency (USEPA). Since marine soils such as them are considered harmless, the construction of landfill barriers can be potentially carried out by using this material.

The need to manage the disposed of DMS while respecting the regulations have driven researchers to develop various economically viable ways for the re-utilization of this material. A number of recent studies have investigated on the potential of dredged material as a new resource such as in environmental enhancement and engineering used (Jin *et al*., 2011; Baruzzo *et al.*, 2001). The applications explored included erosive process control, coastal stabilization, beach replenishment, as raw construction materials such as road materials, bricks, as well as paving blocks (Said *et al*., 2015). A potential reuse area yet to be explored is the utilization of DMS as geosorbent to retain pathogenic bacteria in landfill leachate.

Landfill leachate usually appears to be yellow or blackish colour and smells offensively acidic (Mahmud *et al*., 2012). The characteristics of leachate are vary depending on the composition of the solid waste, precipitation rates, site hydrology, cover design, waste age, landfill design and operation. Typically, leachate from landfill is collected and stored in surface impoundments or in pond before further treatment. Leachate is characterized by high concentrations of numerous toxic and carcinogenic chemicals, including heavy metals and organic matter.

In addition, leachate can be contaminated with bacteria. With no existence of collection, containment and treatment facilities, raw leachate from landfill will literally seeped into soil compartments to cause soil contamination as well as groundwater contamination (Jayanthi *et al.*, 2017; Emenike *et al*., 2016). Large volumes of groundwater can contaminated even with a small amount of leachate (Mukherjee *et al*., 2015). The knowledge on the impact of leachate on the environment is well known. On the other hand, the knowledge on the pathogenic bacteria in leachate is limited compared to the knowledge on physical and chemical contamination. The pathogenic bacteria in leachate is generally considered to be less imported because leachate is considered toxic to pathogenic bacteria. Nevertheless, few studies have reported occurrence of significant pathogenic bacteria in leachate (Grisey *et al*., 2010; Bodzek *et al*., 2006; Mwiganga *et al*., 2005). The pathogenic bacteria could contaminate water sources, thus their existence must be control to avoid contamination.

According to Chamber *et al*. (2008), there are 80 different species in the total coliforms group. The term total coliforms refer to Gram-negative, rod shaped, able to grow in the presence of bile salts or other surface active agents with similar growth-inhibiting properties and able to ferment lactose at (35-37°C). However, total coliforms are considered less reliable indicator of fecal contamination due to their occurrence in non-fecal environment. *Escherichia coli* (*E. coli*) which considered more specific indicator of fecal contamination is exist in the feces of healthy, warm-blooded animals including birds. Most importantly, the indicator bacteria do not necessarily pose health risk themselves but their existence indicates the potential presence of pathogenic bacteria (Umar *et al.*, 2015; Haller *et al*., 2009). For this reason, the present study was using *E. coli* as an indicator for pathogenic bacteria in landfill leachate.

Despite the fact that here are no regulations concerning the E. coli content of soil, it is possible that the bacteria that are present at low levels multiply in the groundwater or surface water sources when they are exposed to favorable environmental conditions. In fact, several study have shown that the number of bacteria decrease in groundwater sources as the soils serve as reservoirs for bacteria (Gagliardi & Karns, 2000).

In order to prevent the migration of *E. coli* in leachate out of landfill site, a liner technique is applied as barrier. The application of barrier in landfill has been practiced for many years. Compacted clay soils, natural clayey deposits or geosynthetic clay are widely use as landfill barriers to isolate hazardous and other waste materials from surrounding environments, hence preventing contaminations such as from migration of heavy metals into groundwater aquifer. Conventional landfill liner such natural compacted clay, geomembrane and geosynthetic clay liner suffer from several drawbacks. After waste placement in landfill, the liner might be exposed to infiltration of waste leachate. As the leachate infiltrated through the conventional liner, chemical reaction including dissolution, biochemical process, ion exchange, and precipitation might affect the soil's hydraulic conductivity. In landfill facility, heat may be generated in various way. Elevated temperatures are often present in this site and have potential to impact both the hydraulic performance and the durability of liners.

1.2 Problem statement

A geosorbent waste material from dredging activity was usually disposed offshore without treatment causing serious environmental problems. The environmental problems related to the used DMS disposal could be solved by laying the material at the base of landfill site like conventional clay liner. The used of DMS which contains high fine particles will quickly adsorbed the *E. coli* from landfill leachate.

Other researchers have reported the use of marine soils to retain the migration of heavy metals in leachate. Du *et al.* (2000, 2004) and Kamon and Kutsi (2001) provided the basis that marine clay soils could be used as landfill liner due to its low conductivity and high heavy metal sorption capability. A study by Chalermyanont *et al*. (2009) also propounded the potential of marine clay soils as landfill liner with better heavy metals retention than lateritic soils. However, the potential of DMS as a geosorbent material in landfill site to retain pathogen bacteria has yet to be thoroughly studied.

Using DMS as a geosorbent for removing *E. coli* in leachate is naturally occurring phenomenon. Compared with other conventional landfill liner, very little capital expenditure and up skilling is required. The DMS geosorbent has nominal maintenance cost too. 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.

1.3 Objectives

This study aims to determine the potential of dredged marine soils be used as a passive geosorbent in landfills. In order to fulfill the aim, the objectives of this study are:

(i) To identify the physical, chemical and biological characteristic of DMS needed to adsorb *E. coli* from landfill leachate

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