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LEACHING CHARACTERISTICS OF SOLIDIFIED DREDGED MARINE SOILS

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ABSTRACT

Dredging is a process to excavate and remove sediments from the bottom of waterways and marine locations, such as ports and harbours. Dredging activities generate large volumes of dredged marine soils (DMS). DMS are the sediment and debris that were removed during the dredging process and are currently not being recycled. Solidification of DMS needs to be undertaken before the materials can be reused. Soil contamination has the potential to contaminate the ground and surface water through leachates that are produced from the contaminated sites. Synthetic precipitation leaching procedure (SPLP) was used in this study to predict contaminant leachability of the DMS. SPLP test was carried out for the solidified samples at different curing times i.e. 3, 7, 14, 28 and 56 days. It was found that the solidified DMS improved leachate properties of the DMS. Ordinary Portland cement (OPC) was used as a binder in this study and bottom ash (BA) used as granular admixture to solidified DMS. This gives further advantage to OPC-BA solidification of DMS in situ for the geo-environment perspective. Its shown that the solidified DMS can be used safely in actual construction field since it was not contaminated.

Keywords: dredged marine soils, solidification, leaching, synthetic precipitation leaching procedure.

INTRODUCTION

Dredging is a process to excavate and remove sediments from the bottom of waterways and marine locations, such as ports and harbours. Dredging is compulsory for the maintenance of existing navigation channels or construction of new port and harbour facilities (Zentar *et al*,. 2012). Dredging activities generates large volumes of dredged marine soils (DMS).

DMS are the sediment and debris that were removed during the dredging process (Maher *et al.,* 2013). DMS are considered as wastes and are currently not being recycled. Solidification of DMS needs to be undertaken before the materials can be reused. Every year, around hundred million cubic meters of DMS are generated from the dredging operations. Most of the DMS are dumped into the sea or placed at dumping site (Rekik and Boutouil 2009).

In Malaysia, DMS are considered as waste and currently not being recycled. Normally, DMS are dumped back into the ocean with at least 50 m depth from mean sea level due to their bad odour and risks to human health (Bray and Cohen 2010). Apart from that, DMS have poor engineering properties either in wet and dry condition. It is restricted for use due to the possible contaminant.

DMS can be a valuable resource even though most of it is currently disposed because of economic, logistical, legislative or environmental constraints. The use of DMS has a major contribution for sustainable development and it can reduce the quantities of primary resource needed for activities such as construction and habitat creation (CEDA 2010).

Solidification of DMS needs to be undertaken before the materials can be reused. Solidification is a method that aims at improving the engineering properties of soil such as soil strength (Vitton, 2006). Soil solidification involves the use of stabilizing agents or binder materials in soft soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of solidification technology include soils and binders. The binders used normally are cementitious materials (Makusa, 2012). The soils used in this study are dredged marine soils (DMS) while the binders are cement and coal ash (bottom ash).

The possible contaminant in DMS must be trace before consider to reused the DMS. The present of contaminant in soil can affected the ecosystem on earth. Rapid development causes the soil contamination with heavy metal pollution that may have harmful effect to environmental and human health (Roy and McDonald, 2014).

The sources of soil contamination are includes the dumping of solid waste, liquid wastes dumping in ponds, mine waste and others. Liquid substances generates from wastes can contaminated large volume of soil, as it can penetrate and disperse in soil. Soil contamination has the potential to contaminate the ground and surface of water supplies through leachates that are produced from the contaminated sites.

Leachates are the products that passing through the materials which extract the soluble and suspended solids or other component of the materials which had been percolated through it. Leachate is the liquid that had been drains from landfill which contains the heavy metals. Therefore, the leachate need to be remove or reduce the presence of heavy metals in order to diminish the possibility of uptakes by living organisms and prevent them from contaminating surfaces and groundwater by dissolution or dispersion (Yong, 2000).

Thus, synthetic precipitation leaching procedure (SPLP) was used in this study to predict contaminant leachability of the DMS. The SPLP, consist of diluted sulfuric and nitric acids that was designed to simulate

ARPN Journal of Engineering and Applied Sciences

leaching resulting from acidic rain (Wadanambi *et al.*, 2008). The SPLP was used to estimate the actual risk of groundwater contamination (Townsend *et al.*, 2006). Leaching tests for the solidified soils were conducted to determine the level of contamination risk by cement solidification materials.

The concentrations of pollutants or heavy metals contains in leachate was measured and compared to groundwater quality criteria in order to determine the risk of groundwater contamination. The SPLP results applied however are inconsistent among regulatory agencies. This is because of uncertainty whether the SPLP leachate concentrations represent the actual pore water concentrations expected in the waste, or represent diluted concentrations. Thus, the SPLP results can represent either one of the condition (Townsend *et al*, 2003).

MATERIALS AND METHODS

Materials

Three types of DMS were used in this study that are high plasticity clay (CH), high plasticity silt (MH) and low plasticity silt (ML). The samples were collected from different locations. CH samples were collected from Marina Melaka while MH and ML samples were collected from Tok Bali, Kelantan. Figure-1 shows the typical of dredged marine soils. Table-1 shows the properties of DMS.

Figure-1. Typical picture of dredged marine soils e.g: dredged marine soils from Tok Bali, Kelantan.

Table-1. Properties of dredged marine soils (DMS).

Properties	Dredged marine soils		
	Marina	**Tok Bali A**	**Tok Bali B**
Moisture content (%)	142.97	137.60	92.23
Liquid limit (%)	65.00	51.80	36.90
Plastic limit (%)	50.46	35.30	25.83
Plasticity index (%)	14.54	16.50	11.07
Specific gravity	2.56	2.43	2.41
Loss on ignition	9.49	1.38	4.78
pH	8.32	8.53	8.51
Soil classification	CH	MH	ML

Binder is a material used to hold or glue other materials together. Granular admixtures are particles added to a material to improve some properties of the material. In this study, ordinary portland cement (OPC) was used as binder materials while bottom ash (BA) was used as the granular admixture. BA was obtained from Tanjung Bin Power Plant located in Pontian, Johor. Table-2 shows the chemical composition of DMS, OPC and BA.

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Table-2. Chemical composition of DMS, OPC and BA (%).

Chemical composition	Types of dredged marine soils			OPC	BA
	CH	ML	MH		
Al_2O_3	21.60	21.10	24.40	9.52	26.60
CaO	1.93	4.04	4.04	54.10	8.73
Fe_2O_3	7.33	7.05	7.87	5.32	8.51
K_2O	2.97	2.64	2.66	0.88	1.05
MgO	2.18	2.24	1.91	1.20	1.76
SiO_2	57.00	57.00	54.40	24.50	48.80
TiO_2	1.03	0.85	0.87	0.69	1.95
Others	5.96	3.67	4.95	3.79	2.6

Methods

The DMS were mixed with the binders based on water-binders (water-cement) ratio. Calculation for the amount of binders (OPC and BA) for each mixture was done based on mass of dry sample and moisture content of the sample. The water binder ratios of the samples are 1, 3 and 5. Table-3 shows the mixing percentage of the binder and granular admixture.

Table-3. Mixing percentage of OPC and BA.

Percentage of Cement (%)	Percentage of Bottom Ash (%)
100	0
75	25
50	50
25	75

Amount of OPC and BA are different based on the ratio calculation elaborated in Azhar *et al.*, (2014). The mixing percentage of the binders were shown in Table-3. All of DMS samples were then mixed together with the binders at a time. The mixture was first mixed using hand then proceeds with food mixer for 5 minutes. The steps were repeated until all cement and bottom ashes were fully mixed with DMS. The samples were cured at 3, 7, 14, 28 and 56 days.

The solidified sample then was tested with synthetic precipitation leaching procedure (SPLP). SPLP is a method used with soil samples from a contaminated site to estimate the site-specific adsorption-desorption potential of a contaminant that may impact ground water. SPLP test was conducted based on USEPA Method 1312. According to the EPA Solid Waste Manual 846, the SPLP test (Method 1312) is a method to determine the mobility of both organic and inorganic analysis present in liquids, soils and wastes.

SPLP test was carried out for the solidified samples at different curing times i.e. 3, 7, 14, 28 and 56 days. The solidified samples were crushed to reduce the particle size less than 2.0 mm and mixed in 20 ml of leachant solutions with reagent water of 1 L (1: 20 ratio). A mixture of diluted nitric acid and sulpharic acid (pH of 4.20 ± 0.05) were used as leachant solution.

Concentrated sulphuric acid (60g) was mixed with 40g of concentrated nitric acid (60:40). The extraction period of the sample was 18 hours under rotary agitation at 30 rpm. Subsequently, the sample was filtered using Grade GF/F 0.7-µm glass fibre filter paper and pH was measured at the end of the extraction. The final extraction was analysed using inductively coupled plasma mass spectrometry (ICP-MS). Five different contaminants were determined in this study i.e. arsenic (As), copper (Cu), Chromium (Cr), lead (Pb) and zinc (Zn).

RESULTS AND DISCUSSIONS

The results obtained from the synthetic precipitation leaching procedure (SPLP) normally used to assess the risk of groundwater contamination. SPLP is intended to simulate acid rain. Considering the natural environment factor, the worst-case scenario of acid rain was applied.

Two aqueous solutions that are sulphuric and nitric acid with pH 4.20 were used in this test. The SPLP was conducted on solidified DMS to ensure whether solidified DMS is safe to be used in construction or not. According to Townsend *et al*., (2003) diluted SPLP will be compared with the standard for drinking water. This standards was used to monitor whether the samples were safe to used if leacing occur. Table-4 show the show the concentration limit for contaminant (heavy metals) based on standards regulated by United States Environmental Protection Agency (USEPA), World Health Organization (WHO) and Ministry of Health in Malaysia (Malaysian Quality Standards).

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Table-4. Concentration limit for contaminant.

Contaminant	WHO- standard for clean water (mg/l)	USEPA- maximum contaminant level (MCL) (mg/l)	Malaysia-Water quality standard (mg/l)
Arsenic (As)	0.050	0.010	0.010
Copper (Cu)	1.000	1.300	1.000
Chromium (Cr)	0.050	0.100	0.050
Lead (Pb)	0.050	0.015	0.010
Zinc (Zn)	5.000	5.000	3.000

USEPA established the SPLP test to filter dangerous waste. All of five elements (arsenic, copper, chromium, lead and zinc) were found does not exceed the approved limit of drinking water by USEPA. Figure-2 shows the arsenic (As) leaching of solidified DMS with different w/b ratio. Based on the results, it was shown that the leaching solution of As was lower than 0.010 mg/L, USEPA standards for drinking water. pH of solidified samples are in a range of 8 to 10. The pH value was found does not affect the leaching of As. As was also found lower than the WHO standards and Malaysian quality standards.

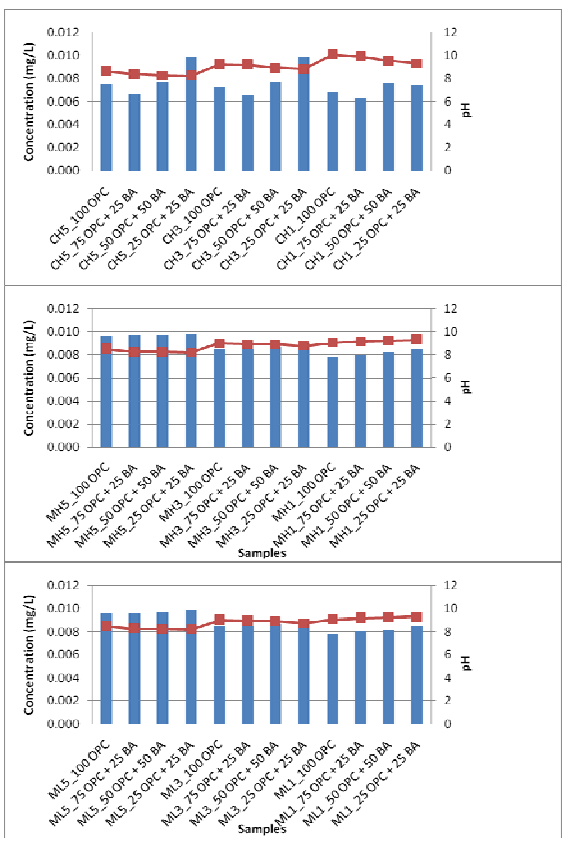

Figure-2. Arsenic leaching concentration.

Figure-3 shows the concentration of copper (Cu) leaching for solidified DMS. After compared with USEPA standards for drinking water, it was found that the leaching solution of Cu is lower than 1.300 mg/L. This finding indicated that the Cu leaching solution is under the allowable limit which means the concentration of Cu for solidified samples is safe for both environmental and human. It was discovered that the pH \ does not affect the leaching of Cu. The same finding was found by Ho *et al.*, (2011). By comparing the results obtained with WHO standard for clean water and Malaysian drinking water standards (Table-4), it was found that the Cu concentration is below the allowable limit.

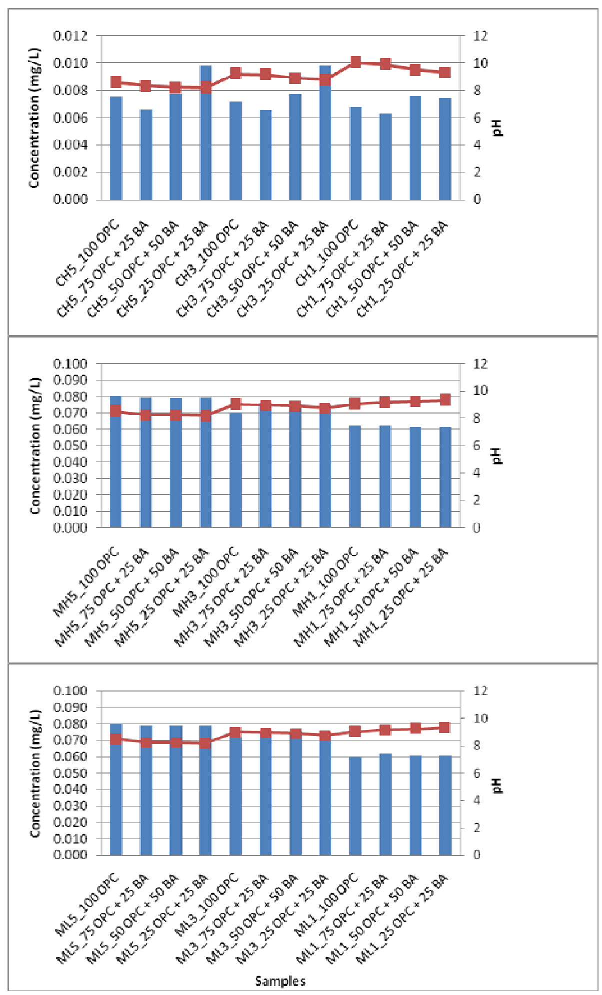

Figure-3. Copper leaching concentration.

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The allowable limit of USEPA drinking water standards for chromium (Cr) concentration is 0.100 mg/L. Referring to Table-4, it was shown that the allowable limit for Cr concentration based on WHO standard for drinking water and the Malaysia water quality standard are 0.050 mg/L Based on the results obtained all of the solidified DMS samples are under the allowable limit. This indicated that the solidified DMS has a low Cr concentration which mean that the solidified DMS samples is safe for both human and the ecosystem. Figure-4 shows the Cr concentration of solidified DMS.

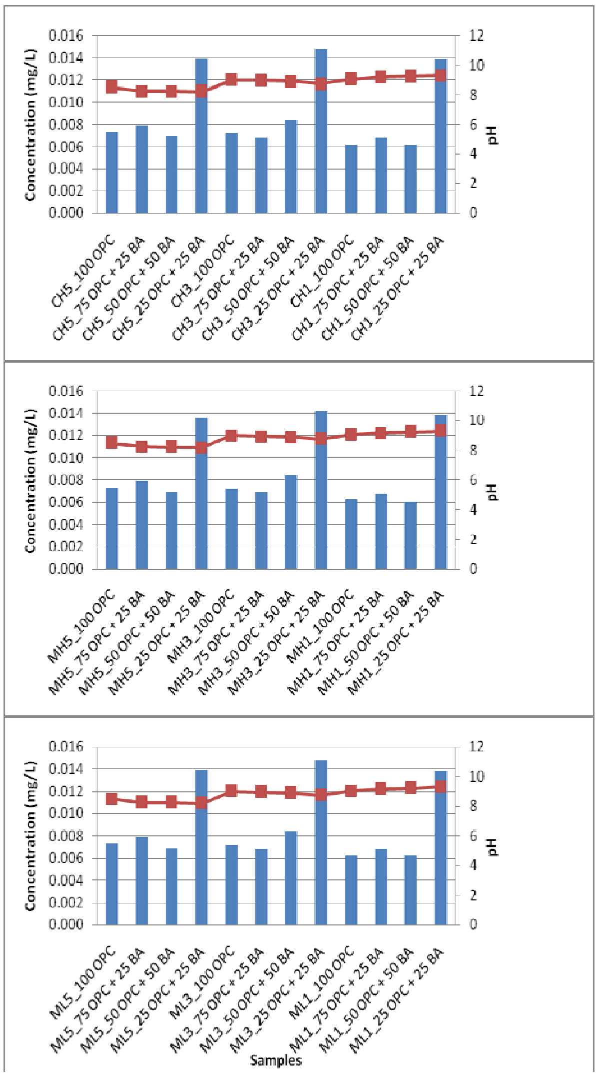

Figure-4. Chromium leaching concentration.

Figure-5 shows the lead (Pb) leaching concentration. The allowable limit for Pb according the USEPA drinking water standard is 0.015 mg/L. The solidified DMS samples show that the leaching concentration of Pb is lower than the USEPA drinking water standard. Pb leaching concentration limit based on WHO standard for clean water is 0.050 mg/L while for Malaysia quality standard is 0.010 mg/L. Based on the results (Figure-5) obtained, it was shown that the reading of Pb concentration for solidified DMS samples were below the detection limit of the ICP-MS. Thus, it was shown that the Pb leacing concentration of solidified DMS is below the allowable limit and safe to use in the construction field.

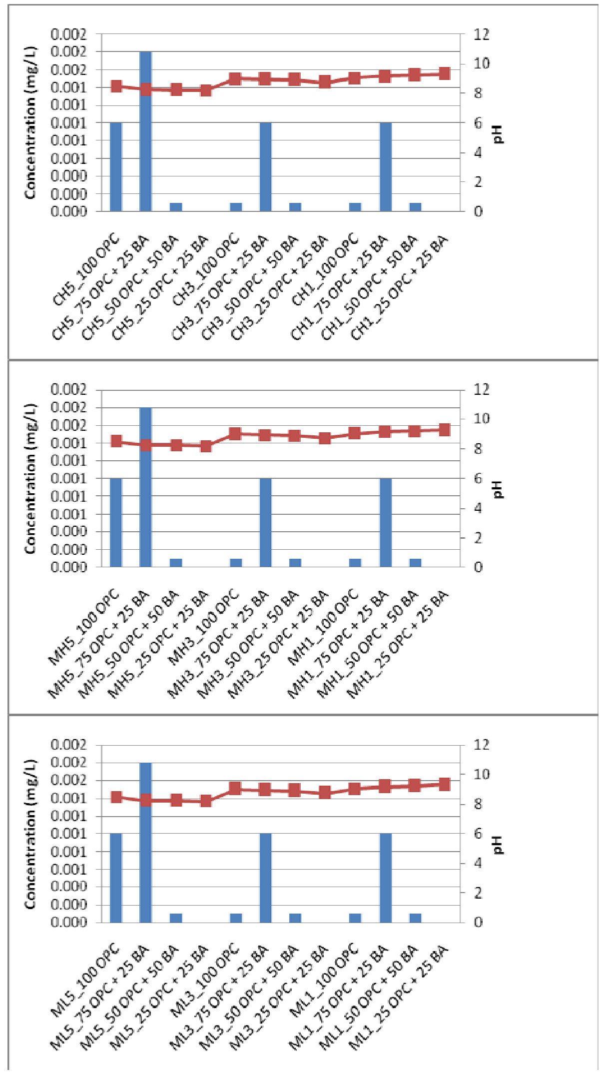

Figure-5. Lead leaching concentration.

Leaching concentration for zinc (Zn) was shown in Figure-6. Based on the results the Zn concentration is under the allowable limit for USEPA drinking water standards which is 5.0 mg/L. Besides that Zn concentration also passed the allowable limit of WHO standard for clean water (5.00 mg/L) and Malaysian standard for drinking water (3.00 mg/L).

Based on the results obtained all of the five contaminants (As, Cu, Cr, Pb and Zn) concentration are below the allowable limit. Thus, it was found that the solidified DMS samples are safe to be reused in construction area and it does not give the harmful effect to human being and the ecosystem.

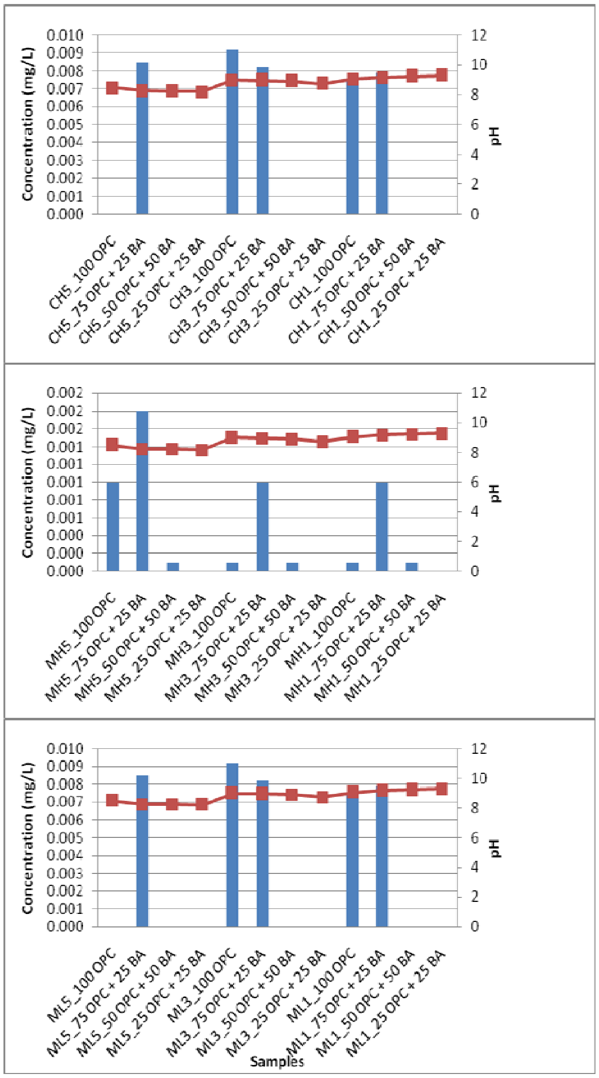

Figure-6. Zinc leaching concentration.

CONCLUSIONS

The synthetic precipitation leaching procedure test was conducted to determine the leaching characteristics of the solidified DMS. It was found that the solidified DMS improved leachate properties of the DMS. This gives further advantage to OPC-BA solidification of DMS in situ for the geo-environment perspective. It's shown that the solidified DMS can be used safely in actual construction field since it was not contaminated. The DMS sample could be spiked with heavy metal such as lead and aluminum to produce an artificial contaminated DMS sample for further study.

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