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Heavy metal sorption capabilities of some soils from active landfill sites in Selangor

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Abstract: In this study, various types of soils collected from or adjacent to active landfill sites in Selangor were tested against Pb, Cu and Zn using batch equilibrium tests. The results indicate that soil sample from Air Hitam in Puchong, Selangor (AHQ) has better sorption capability compared with other soils, i.e. river alluvium soil (SSC) and lateritic soil (SSC) from Sg. Sedu Landfill, lateritic soil from Taman Beringin in Gombak (TBL) and graphitic schist from Ampang Pechah in Hulu Selangor (APS). Heavy metal sorption capability for these soils can be ranked as follow: AHQ>SSC>SSL>TBL>APS for all the heavy metals.

Abstrak: Dalam kajian ini, beberapa tanah yang diambil berdekatan dengan tapak aktiviti perlupusan sisa di negeri Selangor diuji terhadap Pb, Cu dan Zn dengan menggunakan ujian penjerapan berkelompok. Hasil kajian menunjukkan tanah di kawasan Air Hitam di Puchong, Selangor (AHQ) mempunyai kapasiti penjerapan yang lebih baik berbanding dengan sampel tanah alluvial (SSC) dan laterite (SSL) dari landfill Sg. Sedu di Banting, tanah laterite dari Taman Beringin di Gombak (TBL) dan tanah syis bergrafit dari Ampang Pechah di Hulu Selangor (APS). Kapasiti penjerapan logam berat (Pb, Cu dan Zn) untuk tanah-tanah ini boleh disusun seperti berikut: AHQ>SSC>SSL>TBL>APS.

INTRODUCTION

Engineered clay (soil) liner has been widely used as a protective barrier in *state-of-the-art* landfill to prevent a polluted leachate migrates into the environment (into the soil and groundwater systems). Compacted clay liner has several advantages compared with other liner materials (i.e. geomembranes), due to the fact that clay liner can react physically to impede the movement of the pollutants and chemically to retain the pollutants onto soil active components, namely clay minerals, amorphous oxides hydroxides particles, etc. Landfills must be properly sited on the best possible geologic materials that have low in hydraulic conductivity and high attenuation property on pollutants. In this study, some soil samples have been collected from (or adjacent to) active landfill sites in Selangor for batch equilibrium tests; i.e. to study the sorption capacity of these samples on heavy metals.

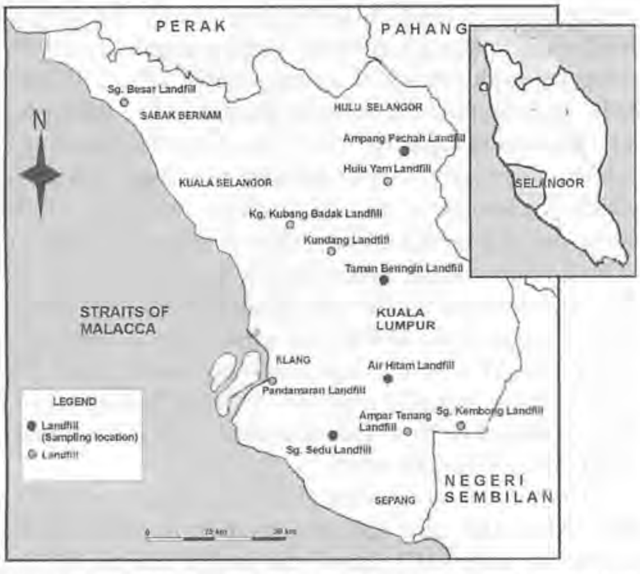

Figure 1. The location of active landfill sites and sampling stations in Selangor.

According to Jessberger *et al.* (1997), batch tests provide a quick method of estimating the contaminant retention capacity of any liner material. The batch test represents an extreme test method, since experimental technique completely destroys the soil structure. Wan Zuhairi and Raihan (2001) used similar test to calculate the maximum sorption capacity of various soil samples. They discovered a positive correlation between the sorption capacity and basic properties of soils.

The main objective of this study is to investigate the best candidate for lining material and their sorption capability against heavy metals Pb, Cu and Zn.

MATERIALS AND METHODS

Five soil samples were collected adjacent to active landfill sites in Selangor namely river alluvium and lateritic soils from Sg. Sedu Landfill (SSC and SSL respectively). Graphitic Schist from Ampang Pechah in Kuala Kubu Baru (APS), weathered metasediment of Kenny Hill formation from Air Hitam in Puchong (AHQ) and finally lateritic soils from Taman Bukit Beringin in Gombak, Selangor (TBL) (Fig. 1). Lateritic soils have been widely used as an inert material to cover the compacted waste after each day of landfill operation.

The soil samples were air dried and then pulverized to pass through 63 μm sieve. Four grams of sample was

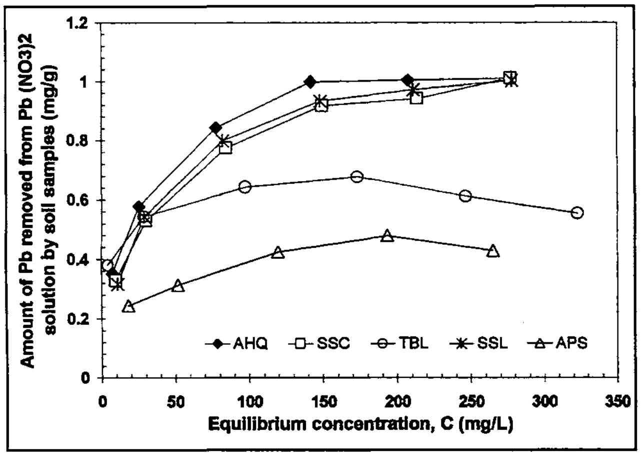

Figure 2. Pb removed from $Pb(NO_3)_2$ solution per gram of soil for all soil samples (soil to solution ratio is 1:10).

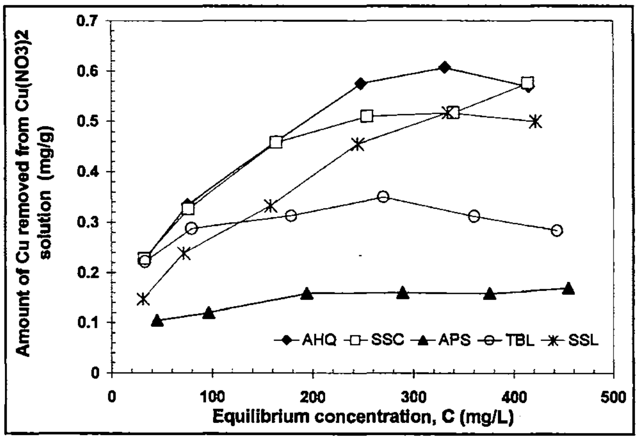

Figure 3. Cu removed from $Cu(NO_3)_2$ solution per gram of soil for all soil samples (soil to solution ratio is 1:10).

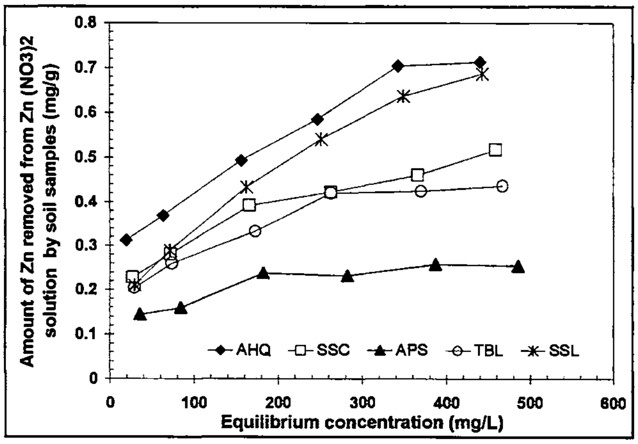

Figure 4. Zn removed from $Zn(NO_3)_2$ solution per gram of soil for all soil samples (soil to solution ratio is 1:10).

weighed into the centrifuge tubes and was mixed with 40 ml of various contaminants (nitrate salts) for 24 hours (USEPA, 1992). Six different stock solutions at different concentrations, i.e. 50 ppm, 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm were used in this test. After it reached equilibrium stage, the tube was centrifuged at 1,000-2,000 revelations per minute (rpm) and the solution yielded was sent for analysis using Atomic Adsorption Spectrometer (AAS). The heavy metals left in the solution can be used to calculate the amount sorbed by the soils.

The sorption isotherms for all soil samples were plotted between the amounts of heavy metals species removed from nitrate solution per gram of soil sample, q in mg/g as a function of the equilibrium free ion concentration in the solution, C in mg/l. The values of q were calculated using the equation below (Griffin and Shimp, 1978):

$$q = \frac{(C_o - C) \cdot V}{(M \times 1000)} \qquad (1)$$

where q = the amount of contaminant removed from solution (mg/g).

C_o = the concentration of contaminant in the solution before mixing with soil (mg/l).

C = the equilibrium concentration of contaminant left in the solution after the experiment (mg/l).

V = volume of solution in the centrifuge tubes (40 ml).

M = mass of soil in the tubes (4 g).

RESULTS AND DISCUSSION

Figure 2 shows the sorption isotherms of samples AHQ, SSC, APS, TBL and SSL for the case of Pb. The sorption isotherms were plotted between the amounts of heavy metal species removed from nitrate solution per gram of soil sample (mg/g) against equilibrium concentration in mg/l. It shows very clearly that sample AHQ from Puchong has better sorption capability for Pb compared with other soil samples SSC, APS, TBL and SSL. Soil sample from Ampang Pechah (APS) shows the least adsorption capacity. This is due to the fact that AHQ contains more active clay component compared with APS, which is consists of mostly graphitic materials. It is interesting to note that all soils show an increasing amount of Pb sorption with an increasing of initial concentration of Pb. At maximum initial concentration of Pb (500 mg/l), about 20.7 mg/g (or 42.8%) was sorbed by the AHQ soil. While, in APS soil sample, at maximum initial Pb concentration, only 0.75 mg/g (or 15.4%) of Pb was sorbed. The sorption of Pb by soil samples can be ranked as follow; AHQ>SSC>SSL>TBL>APS.

The sorption of Cu from $Cu(NO_3)_2$ solution by AHQ, SSC, APS, TBL and SSL soil samples is presented by Figure 3. Soil AHQ shows the largest amount of Cu removed from copper nitrate solution, where at maximum initial concentration (500 mg/l), about 0.6 mg/g of Cu was removed (about 12.2%). For APS, at maximum initial concentration of 500 mg/l, about 0.18 mg/g of Cu has been removed (about 3.2%). The sorption capability of these soil samples can be ranked as AHQ>SSC>SSL>TBL>APS.

Figure 4 shows the amount of Zn removed from $Zn(NO_3)_2$ solution by various soils. The amount of Zn sorbed is increased with the increasing initial concentration of Zn in the solution. Sample AHQ shows the highest sorption capability compared, with other soil samples. Sample APS possess the lowest sorption capability with the amount removed from solution is quite constant after the initial concentration of 200 mg/l. At the highest initial concentration (500 mg/l), about 14% of Zn was adsorbed by soil AHQ, 10% SSC, 9% TBL, 13% SSL and 5% by soil APS. The sorption of Zn by these soil samples can be ranked as AHQ>SSL>SSC>TBL>APS.

Soil sample of weathered metasediment from Kenny Hill formation (AHQ) has a better potential to adsorb (sorb) heavy metals Pb, Cu and Zn compared with weathered Graphitic Schist from Terolak Formation in Ampang Pechah.

CONCLUSIONS

Batch equilibrium test is a useful and quickest method to assess the adsorption capability of soils on heavy metals. The study has revealed that different soils possess different capabilities to adsorb heavy metals, and this is very much affected by their physical and chemical properties. Soil sample from Air Hitam Landfill in Puchong prove to be effective to adsorb heavy metals and has a good potential to be used as liner material. Soil sample from Ampang Pechah in Kuala Kubu Bharu (APS) has a lowest sorption capability and it has a poor potential for landfill liner material. The capability of these soils to adsorb heavy metals can be simplified in Table 1.

Table 1. The capability of soils to adsorbed different types of heavy metals.

Pollutant species	Ranking
Pb	AHQ>SSC>SSL>TBL>APS
Cu	AHQ>SSC>SSL>TBL>APS
Zn	AHQ>SSL>SSC>TBL>APS

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