Research Article

Adsorption study on mixture material of granite residual soil – palm oil fuel ash (POFA)

Abstract

Granite residual soil mixed with up to 15% of palm oil fuel ash (POFA) by dry weight was investigated to ascertain its adsorption capacity with regards to its use as an adsorbent material for leachate. A batch equilibrium adsorption study was carried out in which the effect of dosage and pH on the adsorption capacity of granite residual soil – POFA mixture was determined. In general, the results showed that adsorbent dosage and pH had significant effect on the sorption capacity of the soil – POFA mixture. Such as example, Manganese ion which had the highest initial concentration of 18.23 mg/l in leachate, once gone through the shaking process, the amount which had been adsorbed by the admixture increased from 22.92 mg/g at 0% POFA content to 30.32 mg/g at 15% POFA. The increased pattern of adsorption capacity of the admixtures occurred with the increment of pH values. The optimum condition for the effectiveness sorption of contaminant for the mixture is 15% POFA content and pH values is 6. It can be concluded that the mixture granite residual soil–POFA is expected to be an economical adsorbent product for metal ion remediation in leachate.

Keywords: granite residual soil, palm oil fuel ash (POFA), leachate, optimum condition, sorption

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Abbreviations: USCS, unified soil classification system; OMC, optimum moisture; MDD, maximum dry density; CL, inorganic clay of low plasticity; CEC, cation exchange capacity

Introduction

Environmental pollution is caused mainly through improper solid waste disposal. The main problem associated with uncontrolled municipal and industrial solid waste disposal sites is the generation highly polluted leachate. This leachate has high concentration of heavy metals and organic pollutants which serves as a source of contamination to both soil and ground water body.[1–3] In order to curtail this problem, waste containment facilities must be equipped with a good lining and cover system. Conventionally, clay liner has been assessed on the basis of hydraulic conductivity to control adjective contaminant transport. However, previous works indicate that chemical compatibility and adsorption capacity is an important aspect that must be given due attenuation.[4,5]

Carbon adsorption, ion exchange, precipitation, membrane filtration, reverse osmosis, and solidification/stabilization are the available technologies for the removal of heavy metals in water and soil. Sorbent-based processes are probably the most used, although the cost of substrate materials and regeneration is a limiting factor. Thus, a lot of studies have being carried out to the sorption properties of alternative low-cost materials that range from natural sorbent phases to dead biomass Furthermore, the ability of natural soils or natural soils mixed with different types of waste to absorb heavy metals has been studied by many researchers. [6–9] Ijimdiya and Osinubi[10] investigated the potential of using black cotton soil treated with biogases ash for attenuation of cationic contaminant in municipal solid waste. In a similar study, compacted abandoned dumpsite and reddish brown tropical soils were used to assess the sorption of contaminant from municipal solid waste leachate.[6,7] Another research used residual soils as low – cost adsorbent for nickel and zinc contained in prepared nickel and zinc aqueous stock solution.[11] In both researches, batch studies were used to check the sorption of heavy metals present in various solutions.

Granite residual soil and palm oil fuel ash (POFA) intended for this study are readily available in Malaysia. Their availability in abundance makes the barrier material visible. Residual soils are formed in tropical areas, physically defined as the zone contained between 20oN (Tropic of Cancer) and 20oS (Tropic of Capricorn) of the equator, which includes Malaysia.[12] Three – quarter of the land area of Peninsular Malaysia is covered by residual soils[13] One of the by-products of the palm oil industry is the palm oil fuel ash (POFA) which is produced from the burning of palm fiber, shells and empty fruit bunches in a boiler at a temperature of 800 – 1000oC to produce steam. The steam produced serves as source of energy used in turbines to supply electricity during the milling operation.[14,15] The objective of this study is to investigate adsorption capacity of granite residual soil mixed at different percentages of palm oil fuel ash (POFA) to be used as an adsorbent for treating leachate in sanitary landfill.

Methodology

Materials

The location of soil sampling and preparing process for granite residual soil and waste material used in this study can be referred to Nik Daud and Mohammed.[16] Landfill leachate used in this study was collected from Jeram landfill sanitary, located in Kuala Selangor, Malaysia. Sample was collected directly from the pipes connected to the equalization lagoon and taken to the cold room in the laboratory for proper storage.

Batch equilibrium adsorption

Batch equilibrium adsorption tests (BEATs) were performed on the soil samples and the leachate to quantify the potential adsorption of some specified metal ions namely; Pb, Cr, Mn, Fe and Zn. The granite residual soil was mixed 5, 10 and 15% palm oil fuel ash (adsorbent)

by dry weight of the soil. The test was carried out in accordance with procedure described by Shackelford and Daniel. The 1:4 ratio was maintained by adding 50g of soil – POFA mixture and 200g of solution (leachate) into a conical flask and the mixtures were placed in a table shaker (HS 500 Janke and Kunker, Ika-Werk) at a speed of 30 hub/mins. After shaking, samples were centrifuged at 50 RPM for 10 minute (model Kubota 5200) by using fabricated small column before obtaining the supernatant and keep it in a plastic bottle Figure 1. The solutions were analyzed using Atomic Absorption Spectrophotometer (AAS), model UNICAM 969. The amount of adsorption at equilibrium qe (mg/g) was calculated using equation (1).
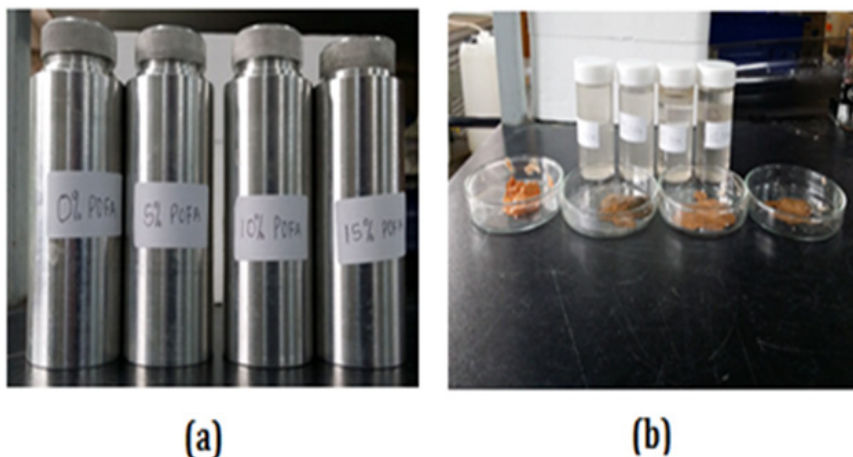
$$qe = (Co - Ce)mV$$

Figure 1 (a) Fabricated small column used in the centrifuge. (b) Supernatant and sludge sample produced after centrifuge process.

Where C_o(Eq. 1) and C_e (mg/l) are the initial and equilibrium concentration of metal ion solution, V is the volume of the solution in liters and m is the amount of mass of dry adsorbent used (g). Similarly, the percentage adsorption was determined by using Equation (2).

$$\% \ Adsorption = (Co - Ce)Co \times 100$$

Where C_o(Eq. 2) and C_e (mg/l) are the initial and equilibrium concentration of metal ion solution.

Results and discussion

Materials properties

The index properties of natural granite residual soil and mixture soil with 15% POFA have been tabulated in Table 1. Values for cation exchange capacity (CEC) showed and increment by adding the POFA material. The initial values of metal ions contented in raw leachate as follows: Zinc (Zn) is 2.32 mg/L, Lead (Pb) is 9.95, Manganese (Mn) is 18.23, Chromium (Cr) is 2.6 and Iron (Fe) is 7.25.

Table 1 Index properties of the soil and soil mixed pofa sample[16]

Properties	Units	Natural soil	Soil mixed POFA 5%
Moisture content	%	27.51	-
Specific Gravity	-	2.63	2.58
Liquid limit	%	50	48
Plastic limit	%	29.89	28.06
Plasticity index	%	20.11	19.94
Linear shrinkage	%	9.3	8.79
< No. 200 sieve	%	53.13	56.26
CEC	meq/ 100g	8.36	8.79
MDD	Mg/ m3	1.61	1.59
OMC	%	20.05	23
USCS	-	CL	CL

USCS, unified soil classification system; OMC, optimum moisture; MDD, maximum dry density; CL, inorganic clay of low plasticity; CEC, cation exchange capacity

Effect of adsorbent dose

The amount of palm oil fuel ash (POFA) used to remove various metal ions (Pb, Cr, Mn, Fe and Zn) was varied from 5, 10 and 15% POFA by dry weight of the soil. The results of the relationship between adsorbent dosage and metal ion removal performance are shown in Figure 2. From graph it can be seen that the amount of adsorption of the various metal ion is directly proportional to adsorbent (percentage of POFA) dosage. The more amount of adsorbent (percentage of POFA) used, the higher the uptake of various metal ions. Such example, Manganese ion had the highest initial concentration of 18.23 mg/l, the amount which had been absorbed by the admixture increased from 22.92 mg/g at 0% POFA content to 30.32 mg/g at 15% POFA. Similar pattern was observed for Zinc ion, which had an initial concentration of 2.23 mg/l, the amount which had been absorbed by the admixture from 0.2mg/g at 0% POFA content to 2.0 mg/g at 15% POFA content. The reason for such behavior may be attributed to greater surface area and large number of vacant bio-sorption sites thus favoring more amount of metal ion in the leachate solution.[17,18] From the study, adsorbent dosage (POFA) plays an important role in achieving metal ion removal as increased dosage leads to higher adsorption capacity. Similar findings behavior was reported by Saka C.[19]
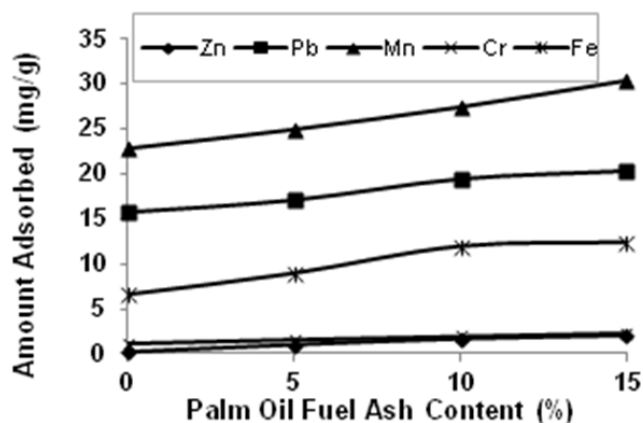
Figure 2 Effect of adsorbent dose on the uptake metal ions.

Effect of pH

pH of the solution has a significant impact on the uptake of heavy metals, since it determines the surface charge of the adsorbent, the degree of ionization and speciation of the adsorbent.[20] The effects of pH on metal ions adsorption have been studied by many researchers previously, and the results indicated that pH of solution exerts a great effect on uptake of metal ions.[21,9] In order to establish the effect of pH on the bio-sorption of the heavy metals, the highest adsorbent dosage (15% POFA) was used at a pH of 2-10 Figure 3. It was observed that the percentage removal was relatively lesser at low pH. However, there was an increases pattern in percentage removal with rise in pH, especially at pH 6 which showed the optimal removal rate for all the metal ions tested except for chromium ion. This was similar to the findings of other researchers.[22,23] The increase patterns may be due to the presence of negative charge on the surface of the adsorbent that may be responsible for metal binding. However, as the pH is lowered, the hydrogen ions compete with the metal ions for the sorption sites in the sorbent; the overall surface charge on the adsorbent becomes positive and hinds the binding of positively charged metal ions.[22]
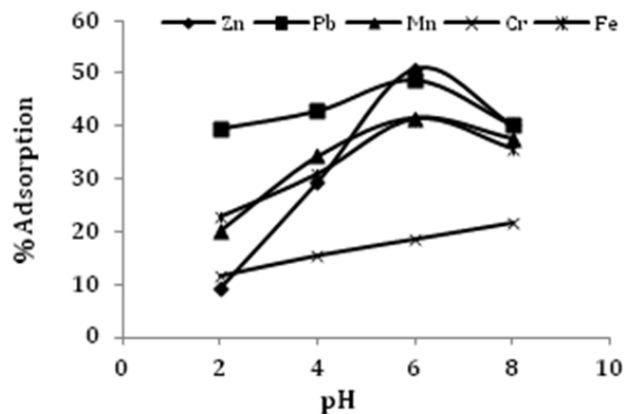
Figure 3 The effect of pH on the percentage removal of metal ion.

Conclusion

This study shows that granite residual soil mixed palm oil fuel ash (POFA) is an effective adsorbent for the removal heavy metals from leachate. It was found that higher amount of adsorbent lead to greater adsorption of heavy metals from the leachate tested.[24,25] It was also observed that pH influence on metal ion removal was high, and was more noticeable at pH values of 6 which gave the optimal percentage removal. Based on this study, the results show that adsorbents which have a very low economic value may be used effectively for removal of heavy metals from waste containment facilities for environmental protection purpose.

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Conflicts of interest

Author does not have any conflicts of interest.

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