

SORPTION CHARACTERISTICS OF CONTAMINANTS IN COMPACTED GRANITE RESIDUAL SOIL - PALM OIL FUEL ASH MIXTURE

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Abstract

Granite residual soil mixed with 0 to 15% palm oil fuel ash (POFA) by dry weight was investigated to ascertain its sorption characteristics with regards to its suitability as hydraulic barrier in sanitary landfill. A batch equilibrium adsorption test (BEAT) was carried out in which the effect of dosage and ionic concentration (pH) on the adsorption capacity of granite residual soil – POFA mixture was determined. The results showed that the highest percentage removal (15% POFA content) of the metals concentration with respect to the initial concentration were Zinc (22%) Lead (51%), Magnesium (41%), Chromium (22%), and Iron (43%). With lead having the highest percentage removal of 51%. Furthermore, the results showed adsorbent dosage and pH had significant effect on the sorption capacity of the soil – POFA mixture. The optimum POFA content and pH values were 15% and 6 respectively. It can be inferred that the adsorbent is an economical product for metal ion remediation from water and wastewater.

Keywords: Sorption, Contaminant, Granite residual soil, Fuel ash

1.0 Introduction

The main problem associated with uncontrolled municipal and industrial solid waste disposal sites is the generation of 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, 2, 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 advective contaminant transport. However, previous works indicated that chemical compatibility and adsorption capacity are important aspects that must be given due attention [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. The sorbent-based processes are probably the most widely used, though the cost of substrate materials and regeneration is a limiting factor. Quite a lot of studies have been carried out on the sorption properties of alternative low-cost materials that range from natural sorbent phases to dead biomass [6]. Furthermore, the ability of natural soils or natural soils mixed with different types of agricultural waste to absorb heavy metals has been studied by many researchers [7, 8].

The potential of using black cotton soil treated with bagasse ash for attenuation of cationic contaminant in municipal solid waste was investigated by [9]. Similarly, studies on compacted abandoned dumpsite and reddish brown tropical soils were used to assess the sorption of contaminant from municipal solid waste leachate (MSWL) [10, 8]. Residual soils were used as low – cost adsorbent for Nickel and Zinc contained in prepared Nickel and Zinc

aqueous stock solution [11]. In both researches, the batch studies were used to check the sorption of heavy metals present in various solutions.

Both the Granite residual soil and Palm oil Fuel ash intended for this study are abundantly available in Malaysia, for barrier application. Tropical residual soils are formed in tropical areas, physically defined as the zone contained between 20° N (Tropic of Cancer) and 20° S (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 fibre, shells and empty fruit bunches in a boiler at a temperature of 800 – 1000°C to produce steam. The steam produced serves as source of energy used in turning of turbines to supply electricity during the milling operation [14, 15]. The objective of this study is to investigate the adsorption capacity of granite residual soil mixed at varying proportions of POFA for the purpose of hydraulic barrier in landfill application.

2.0 MATERIALS AND METHODS

2.1 Materials

The granite residual soil used in this study was obtained from Hulu Langat, located in Selangor State of Malaysia (coordinates of 30 7' 0'' N 1010 49' 1''). The soil was collected at a depth of 1.5m and preserved in plastic bags to prevent loss of moisture content. This soil sample was then transported to the laboratory for subsequent tests. The palm oil fuel ash (POFA) sample for this study was obtained from Southern Malay Oil Palm factory in Johor, Malaysia. The POFA samples were oven dried for 24 hours at a temperature of 1100 °C to remove the moisture in it. It was then sieved through 300µm sieve size then kept in plastic bags.

The landfill leachate used in this study was collected from Jeram landfill sanitary, located in Kuala Selangor, Malaysia located at Lot No. 1595, 2958, 2959 in Jeram Town, Kuala Selangor District. The landfill leachate sample was collected directly from the pipes connected to the equalization lagoon and taken to the cold room in the laboratory for proper storage.

2.2 Methods

2.2.1 Batch Equilibrium Adsorption Tests

Batch equilibrium adsorption tests (BEATs) were performed on the soil samples and the leachate to quantify the potential adsorption of some specified cations namely, Pb, Cr, Mn, Fe and Zn. The granite residual soil was mixed with 5, 10 and 15% palm oil fuel ash by dry weight of the soil as the adsorbent. The test was carried out according to the procedure described by [16]. 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/min. After shaking, samples were centrifuged at 50 RPM for 10 minutes before obtaining the supernatant into plastic bottle. The solutions were analyzed using UNICAM 969 Atomic Absorption Spectrophotometer (AAS). The amount of adsorption at equilibrium q_e (mg/g) was then calculated using eq.1.

$$q_e = \frac{(C_o - C_e)}{m} V \tag{1}$$

Where, **C_o** and **C_e** (mg/l) are the initial and equilibrium concentration of metal ion solution,

V is the volume of the solution in litres and

m is the amount of mass of dry adsorbent used (g).

Similarly, the percentage adsorption was determined using eq.2.

$$\% \text{ Adsorption} = \frac{(C_o - C_e)}{C_o} \times 100 \tag{2}$$

Where, C_o and C_e (mg/l) are the initial and equilibrium concentrations of metal ion solution. The modified moulds used in the centrifuge are presented in plate 1.



Plate1: Modified moulds used in the centrifuge

3.0 Result and Discussion

3.1 Effect of adsorbent dose (POFA) on the amount of metal ion absorbed and Removal Rate

The amount of POFA used to absorb the various metal ions such as 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 (POFA), metal ion absorbed and removal rate with respect to the initial concentration are shown in Fig 1 (a) and (b)

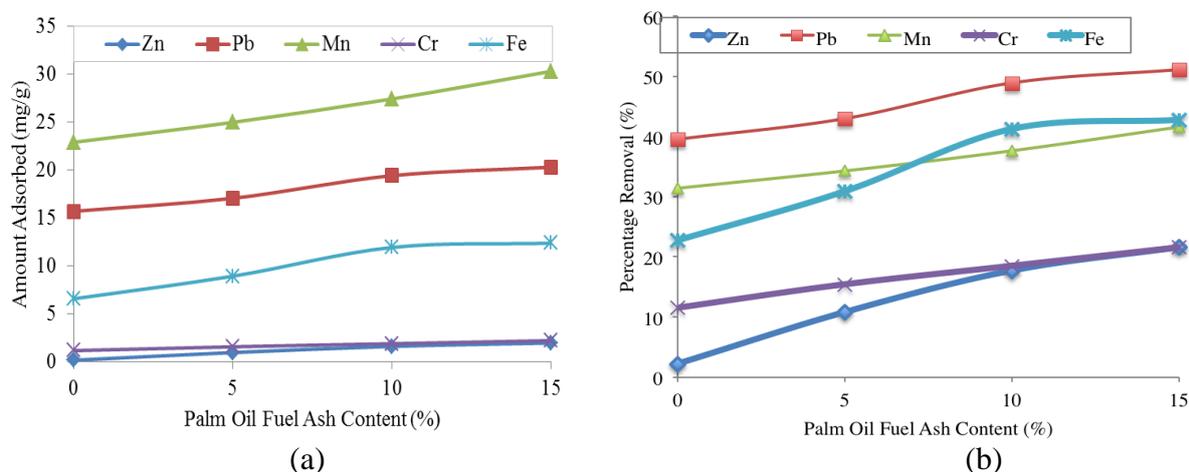


Fig. 1: (a) Variation of absorbed metal ion with Adsorbent Dose (POFA) (b) Variation of Removal rate with Adsorbent Dose (POFA).

It could be seen from Fig.1 (a) that the amount of adsorption of the various metal ion is directly proportional to adsorbent (POFA) dosage. The more the amount of adsorbent content (POFA) used, the higher the uptake of various metal ions. Manganese ion had the highest initial concentration of 18.23mg/l, the amount adsorbed increased from 22.92mg/g at 0% POFA content to 30.320 mg/g at 15% POFA. Similarly, Zinc ion had an initial

concentration of 2.23mg/l, but the amount adsorbed increased from 0.2mg/g at 0% POFA content to 2.0 mg/g at 15% POFA content. The reason for such behaviour may be attributed to greater surface area and large number of vacant bio sorption sites thus favouring greater amount of metal ion in the leachate solution [17, 18]. The adsorbent dosage (POFA) plays an important role in achieving metal ion removal, as increased dosage leads to higher adsorption capacity. Similar findings were reported by [19]. Similarly, Fig 1(b) shows that the highest percentage removal (15% POFA content) of the metals concentration with respect to the initial concentration was Zinc (22%) Lead (51%), Magnesium (41%), Chromium (22%), and Iron (43%).

3.2 Effect of pH on the percentage removal rate of different metals ions

The ionic concentration (pH) of the solution has a significant impact on the uptake of heavy metals, due to the surface charge of the adsorbent, degree of ionization and speciation of the adsorbent [20]. The effects of pH on metal ions adsorption have indicated that pH of solution exerts a great effect on uptake of metal ions [21, 22]. 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 as depicted in Fig. 2.

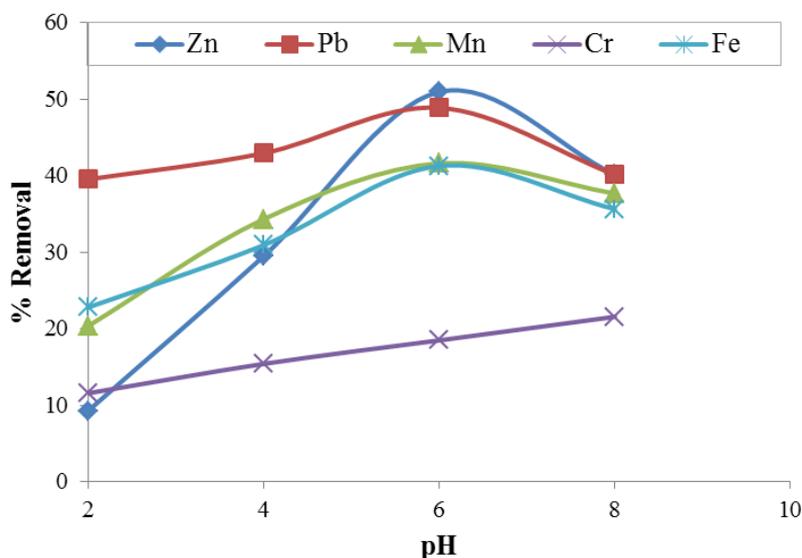


Fig. 2: Variation of percentage removal with pH

It was observed that the percentage removal was relatively lesser at low pH value. However, there was an increase in percentage removal with rise in pH value, especially at pH of 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 such as [23, 24]. This increase may be associated with 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 hides the binding of positively charged metal ions [23].

4.0 Conclusion

This study showed that granite residual soil mixed with POFA is an effective adsorbent for the removal of heavy metals from leachate. It was found out that the more the amount of adsorbent content (POFA) used, the higher the uptake of various metal ions. It was also observed that pH influenced metal ion removal very high, and was more noticeable at pH

values of 6 which gave the optimal percentage removal. It could be inferred that the adsorbents having very low economic value may be effectively used for the removal of heavy metals from waste containment facilities for environmental protection purpose.

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