Performance Evaluation of Adsorption Potential of Fly ash for Waste Containment Applications

MS. POLY BURAGOHAIN[1], DR. SREEDEEP S[2]

[1]Research Scholar, Department of Civil Engineering, IIT Guwahati,Guwahati-781039, INDIA ,
Email: poly@iitg.ac.in
[2]Associate Professor, Department of Civil Engineering, IIT Guwahati,Guwahati-781039, INDIA
Email: srees@iitg.ac.in

Abstract

Anthropogenic activities due to increased urbanization and industrialization has polluted the geoenvironment and ground water resources. A healthier environment therefore warrants efficient containment system that can effectively contain harmful waste for a long duration of time. Clay liners and its contaminant retention properties are the mandatory requirements of any waste containment facilities. However, for developing countries like India, high cost of clay liners (commercial soil) results in the diminished development of such facilities. The utilization of fly ash as a low-cost adsorbent for replacing a fraction of commercial available soil would considerably reduce the cost of waste containment facilities. For this purpose, it is essential to assess the contaminant retention capacity or sorption of the soil. Therefore, batch equilibrium test was conducted to evaluate the retention capacity of flyash a waste product from a coal- fired power generating station at Farakka, West Bengal, India with Copper as the model contaminant. The equilibrium sorption characteristics have been mathematically quantified by using the two popular Langmuir and Freundlich isotherms. It was observed that both the isotherms gave satisfactory fitting though the best fit was observed for langmuir isotherm. The initial concentration, played a pivotal role in the sorption mechanism and also on the removal efficiency. The study clearly demonstrates the utility of fly ash as an absorbent for copper.

Keywords: waste containment facility, clay liners, flyash, sorption capacity, isotherm.

Introduction

The past few decades have triggered a tremendous growth in energy sector due to rapid urbanization and industrialization. This along with population growth has generated indiscriminate production of huge volume of wastes that disturbs the ecological harmony and cause environmental degradation. These wastes are disposed off into surface dump yards, or engineered and non-engineered landfill sites. The waste, in the due course of time, interacts with water and produces leachates and gases which pollute the geo-hydrosphere (Selim and Iskandar,1999). Therefore, the problems related with their safe management and disposal has become a major challenge to environmentalists. The other related problem is the pressure on land, materials and resources to support the developmental activities, including infrastructure. Such a situation has necessitated efficient waste containment facilities to effectively contain the contaminants. The contaminant retention property of soil used in these waste management facility and those lying below the facility is of utmost importance for effective containment of waste and minimizing groundwater pollution. The retention property of soil is defined based on the sorption-desorption behaviour during soil-contaminant interaction (Sharma and Reddy, 2004). It plays a vital role in deciding the fate, transport and risk of disposed off pollutants in surface as well as subsurface environment. Therefore, its determination is of utmost importance in the design of waste containment liners (Rowe and Booker, 1985).

Clay liners are mandatory requirements for any waste containment facilities but India being a developing country the high cost of clay liners (commercial soil) results in the diminished development of such facilities. The use of locally available soil for replacing a fraction of commercially available soil would considerably reduce the cost of waste containment facilities. Fly ash is a particulate material generated from coal-fired power plants. Every year, there is a large amount of fly ash produced during combustion of coal all over the world, which requires large dumping sites for the safe disposal or investigation for reuse and recycling of those fly ash waste. This demand is more intense in current India. In India alone, more than 200 million tons of flyash every year has been generated but utilization rate is relatively low. "Use of remaining fly ash is a serious challenge as its disposal not only occupies the valuable land, but also creates environmental problems if not disposed off systematically," said head, fly ash unit, department of science and technology, government of India, Vimal Kumar. Thus as the amount of fly ash increases, there is a need to develop other avenues for the utilisation of the vast amounts as an alternative to costly adsorbents could benefit developing countries like India.

With this in view, flyash generated from coal- fired power generating station at Farakka, West Bengal, India is characterized for its potential use in containment facility by taking copper which is a major constituents in most solid waste landfill leachates as model contaminant. Fly ash is strong alkali material, and its pH value normally varied from 9 to 13 when added to water. Thereby, it can be expected that copper ions can be removed from aqueous solutions.

Materials and Methods

The fly ash (designated as FA) used in this study is a waste product from a coal- fired power generating station at Farakka, West Bengal, India. It is subjected to various physico-chemical tests such as specific gravity, particle size distribution, Atterberg limits etc. by following the guidelines provided in the literature (ASTM D 4.08). The total SSA was determined using ethylene glycol monoethyl ether and CEC was determined by ammonium replacement method (Horneck et al.1989). The mineralogical composition of the soil was determined by x-ray diffraction analysis (Bruker AXS D8 model, Canada) by using a graphite monochromatic and Cu-Ka radiation. A summary of these physical and chemical characterizations along with classifications are listed in Table 1. It can be noted that FA used in this study belongs to class F. The morphological and the chemical characterization of sample was carried out by scanning electron microscopy (SEM) by using a variable pressure digital scanning electron microscope (model LEO 1430VP) with EDX for elemental analysis. It can be noted that the major elements in percentage present in in FA are SiO_2 (47.5), Al_2O_3 (26.1),Fe_2O_3 (8.4), CaO (0.9), MnO(0.2) and MgO (0.3).

Copper Nitrate stock solution was prepared by dissolving Cu $(N0_3)_2$.2.5 H_20 (A.R. grade) in deionized water. Solutions at different concentrations were obtained by adding appropriate amounts of stock solution to deionized water to obtain ion range of concentrations varying from 10 mg/l to 1200 mg/l. Literature indicates that copper equilibrium in solution is largely pH dependent. The solution pH was adjusted using dilute hydrochloric acid or sodium hydroxide solutions. So for minimizing the precipitation effect we have taken a pH of 5. 5 g of air dried soil sample sieved through 2 mm sieve is weighed and transferred into a 125 ml glass container. It is then mixed with 50 ml of contaminant solution to maintain a solid to liquid ratio of 1:10. The container is then closed and placed in a shaker and subjected to shaking for 24 hrs (ASTM D 4646-03). After shaking, the soil-solution slurry was centrifuged for 20 min. at 3000 rpm and then the supernatant was filtered through 0.45 µm pore size membrane. The resulting solution is subjected to chemical analysis for determining the concentration of Cu^{+2} by using an ion Chromatograph (Metrohm, Switzerland). Each analysis was done three times to ensure repeatability and average of the data the results is used for plotting isotherm.

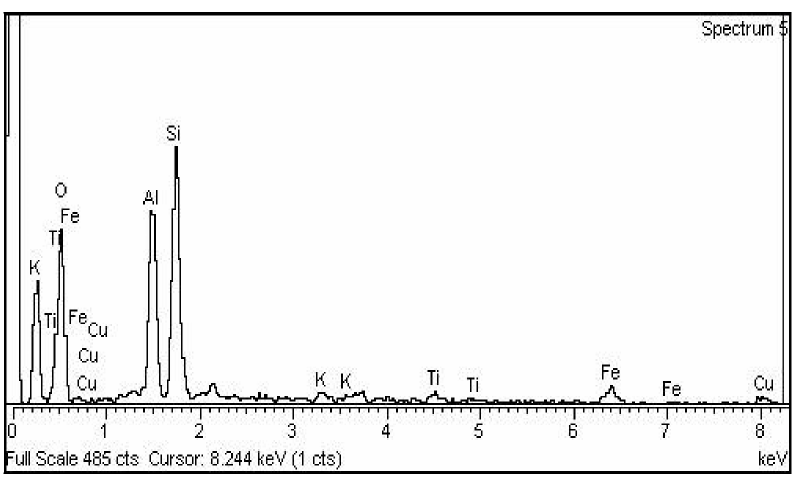

Figure 1 EDX pattern of FA

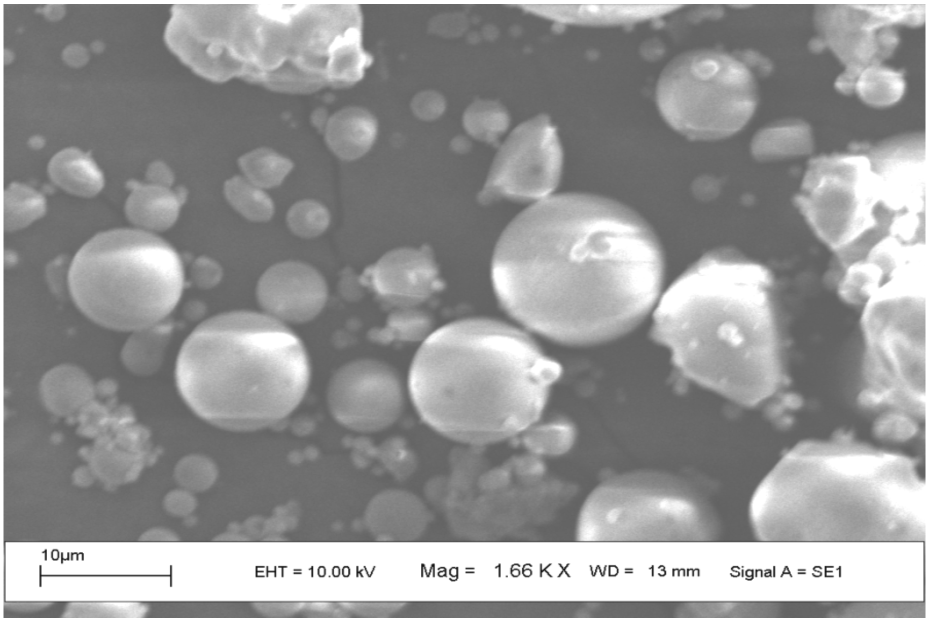

Figure 2 sem image of FA

Table 1 summary of physico-chemical properties of FA

Tests	Values
Specific gravity	2.071
Particle size (%)	
Sand (4.75–0.075 mm)	0
Coarse sand (4.75 –2 mm) 0	0
Medium sand (2–0.425 mm) 0	0
Fine sand (0.425–0.075 mm) 25	25
Silt size (0.075–0.002 mm) 75	75
Clay size (0.002 mm 0	0
Liquid limit (%)	
Plastic limit (%)	Non-
Plasticity index (%)	Plastic
CEC (meq./100g)	1.23
Total SSA (m^2/g)	1.53
Minerals Present	Quartz
pH	9.5

Results And Discussion

The results of the chemical analyses were used to develop linear, Freundlich and Langmuir sorption isotherms as given by Eq. 1, Eq. 2 (Sharma and Reddy, 2004). The isotherms represent relationship between adsorbed concentration (Q_e) versus equilibrium concentration (C_e) of solute species.

$Qe = K_F. C_e^N$ (1)

$Q_e = (QK_LC_e)/(1+K_LC_e)$ (2)

Where Kd is known as distribution or partition coefficient, K_F and N are Freundlich constants, K_L is the Langmuir adsorption constant related to the binding energy and Q is the maximum contaminant adsorbed by solid (mg/kg).The retention characteristics curves for copper contaminant solution is shown in Fig.3 .The shapes of isotherms are thought to reflect the type of sorption mechanism taking place .

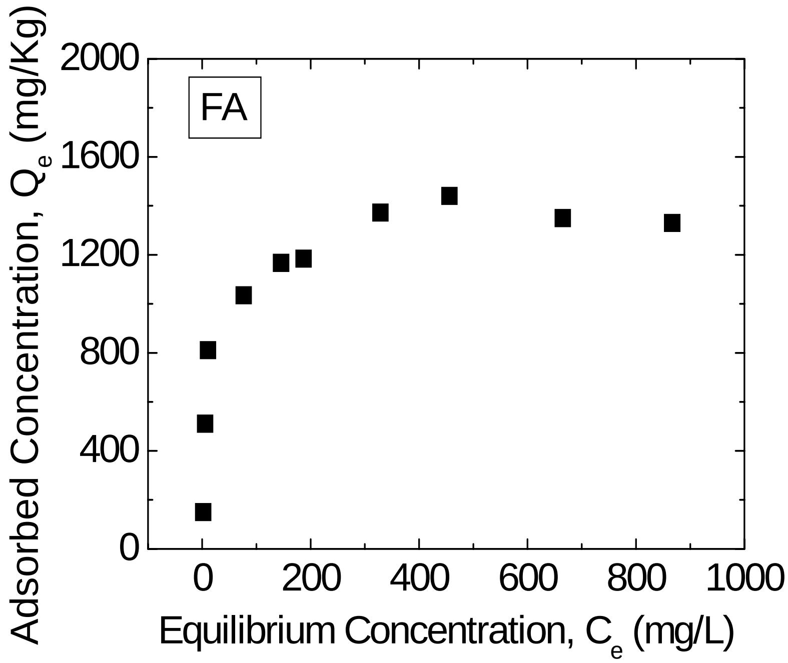

Figure 3 Retention characteristics of Cu^{+2} in FA.

From the research data it can be noted that the inclination of the adsorption curves show that the amount of Cu adsorbed by flyash increased with the increasing amount of Cu^{+2} used in the experiment, especially at lower concentration. This is in accord with the findings of McLaren *et al*. (1981) who stated that at low concentration the sorption of metals are essentially linear. This may be attributed to an increase in the driving force of the concentration gradient with the increase of Cu^{+2} to overcome the resistances to the mass transfer of Cu^{+2} between the aqueous and the solid phases. As the concentrations increased, the increase in the adsorption was less pronounced. The process of Cu^{+2} adsorption probably occurred in two stages, with the saturation of different adsorptive sites. With the increase in the metal concentration, more sites were filled and Cu^{+2} retention became more difficult (Petruzzelli et al., 1985). Similar results were obtained by Jordão et al. (2000), who demonstrated the occurrence of two phases in the adsorption curve. The initial phase of the adsorption curve corresponded to high bonding energy, although the soil had a low capacity for the adsorption of high quantities of the metal. In this case, although the soil adsorbed a lower quantity of copper, the energy which kept it adsorbed was sufficient for the metal not to be free in the system. In a second phase, higher quantities of Cu^{+2} are retained, although the retention energy is lower. Thus, each linear portion of the adsorption curve suggests different types of adsorption sites responsible for Cu^{+2} retention in the soil. When the sorption sites become saturated with Cu^{+2}, the sorption decreases with further increasing of Cu^{+2} in the solution. The curve show linear pattern at lower concentration, and become constant, i.e. reach the maximum adsorption (Q_m) with increasing concentration of Cu^{+2}.

Fig. 4 shows the Freundlich and Langmuir isotherms model fitting. It was observed from Table 2. that both the isotherms gave satisfactory fitting though the best fit was observed for Langmuir isotherm as evident from its R^2 value of 0.951. The results as depicted in Fig. 5. also show that an increase in the initial Cu^{+2} concentration led to a reduction in the percentage removal efficiency of Cu^{+2} ions from aqueous solution. The removal of Cu^{+2} ions decreased, showing the process to be highly dependent on the initial concentration, this may lead to a possible saturation of the mono-layer coverage on the surface of FA by the Cu^{+2} ions

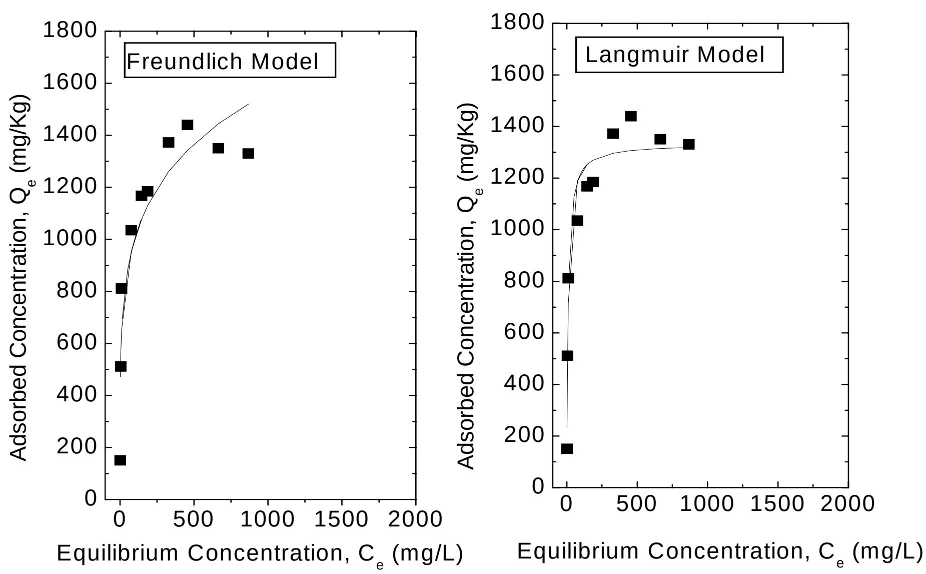

Figure.4. Freundlich and langmuir isotherm model used for evaluating cu^{+2} adsoption capacity.

TABLE 2:Adsorption isotherm parameters for Cu^{+2}

Isotherms	Freundlich	Langmuir
Parameters	K_F =412.817	K_L=0.10663
	N=0.192	Q_m=1333.238
	R^2=0.865	R^2=0.951

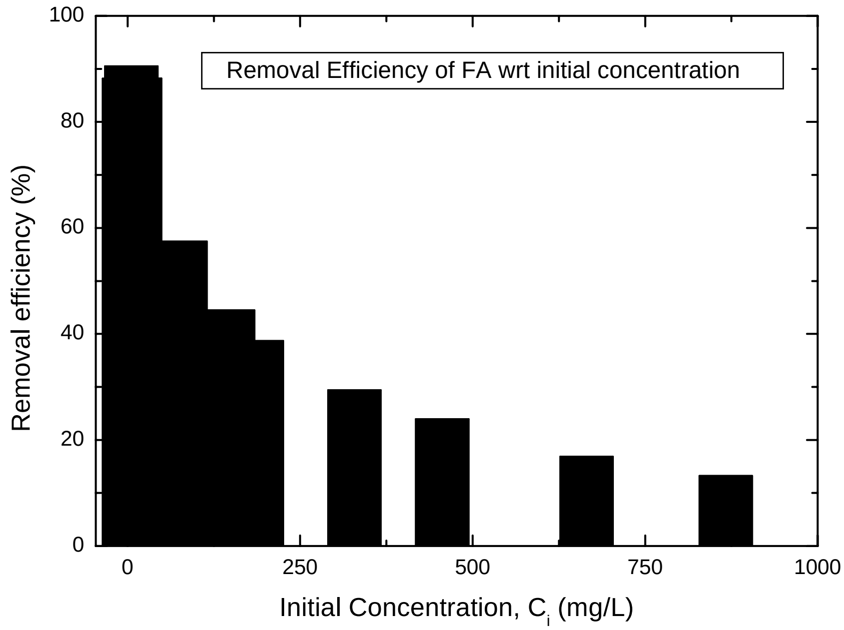

Figure.5. removal efficiency of cu^{+2} with respect to initial concentration

Conclusions

The study deals with the evaluation of sorption characteristics of flyash for its use in waste containment facilities. A non-linear trend is obtained for Cu^{+2} sorption and Langmuir isotherm gave the best fit isotherm. It was observed at low concentration demonstrates the utility of fly ash as a absorbent for Cu^{+2}. With proper discretion of its ranges of water content and dry unit weigh its addition would not only improve the strength and reduce the shrinkage behaviour of clay but also can contribute to its adsorption of heavy metals like Cu^{+2} in place of sand, which is advantageous from an environmental perspective.

Acknowledgement

The authors would like to acknowledge Department of Science and Technology, India project SR/FTP/ETA-21/2007 for funding this work.

References

1. ASTM D 4646-03 (2003). “Standard Test Method for 24-h Batch-Type Measurement of Contaminant Sorption by Soils and Sediments”. *Annual Book of ASTM Standards*, ASTM International, West Conshohocken, PA, USA..

2. ASTM 4.08-06 (2006). ASTM Book of Standards Volume 4.0 “Construction: Soil and Rock (I)**”** *Annual Book of ASTM Standards,* ASTM International, West Conshohocken, PA, USA.

3. Horneck, D.A., Hart, J.M., Topper, K. and Koespell, B. (1989). “Methods of soil analysis used in the soil testing laboratory at Oregon State University.”*Agric. Exp. Stn. S.M.* 89: 4

4. Jordão, C. P.; Alves, N. M.; Pereira, J. L. and Bellato, C. R. (2000)." Adsorção de íons Cu^{2+} em Latossolo Vermelho-Amarelo húmico." *Quím. Nova*, **23**, 5-11.

5. Petruzzelli, G.; Guidi, G. and Lubrano, L. (1985)."Ionic strength effect on heavy metal adsorption by soil." *Commun. Soil Sci. Plant Anal.*, **16**, 971-986.

6. Rowe, R.K. and Booker, J.R. (1987). "An Efficient Analysis of Pollutant Migration Through Soil", Chapter 2 in the Book *Numerical Methods in Transient and Coupled Systems* (Ed. Lewis, Hinton, Bettess & Schrefler), John Wiley & Sons, pp. 13-42.

7. Selim and Iskandar. (1999). "Fate and transport of heavy metals in the vadose zone." Lewis, London

8. Sharma and Reddy. (2004). "Geoenvironmental engineering: site remediation, waste containment, and emerging waste management technologies." John Wiley & Sons, Inc.