Effect of pH and Other Ions on Heavy Metal Adsorption by Zeolite of Na-P1 Synthesized from Fly Ash

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1. Introduction

A large amount of fly ash is generated annually from the combustion of coal in power plants. Most, however, has been disposed of by dumping, giving rise to serious environmental pollution. Only a small amount of fly ash is used as an additive to cement, mortar or used in soil stabilization[1]. Consequently the development of methods for the greater utilisation and the production of high value compounds from waste ash have been the objects of recent research world-wide.

The constituents of fly ash are mainly aluminosilicate glass, mullite and quartz, with a small amount of residual coal and ore minerals; the aluminosilicate glass is a readily available source of Si and Al for zeolite synthesis. The synthetic zeolites exhibit better adsorbent properties and selectivities compared to fly ash for substances such as heavy metal ions, other toxic solutes and gases.

Industrial effluents are likely to contain several different metals and metal binding components which may interfere with recovery of the metal of interest. The present work focuses on a method for the efficient utilisation of fly ash by synthesis of various zeolites, and evaluation of their potential for the removal of heavy metals. The effects of co-existing cations and anions on adsorption and pH of the solutions were investigated.

2. Experimental

The fly ash sample used in this work was obtained from a power plant. The sample used in all experiments was pretreated in a high gradient magnetic separator to remove Fe_2O_3 and TiO_2 which are known to be undesirable for zeolite synthesis.[2]

The chemical compositions of the synthetic zeolites were determined by using XRF (Multi-Channel X-Ray Fluorescence Spectrometer, Shimadzu model MXF-2100). The synthetic product was further characterized by thermogravimetry (Cahn TG121) with a heating rate of 8 K/min from room temperature to 500°C.

Batch experiments were carried out to investigate the adsorption properties of the zeolites for heavy metals. Analytical grades of $Pb(NO_3)_2$, $Cd(NO_3)_2$-$4H_2O$, $Cu(NO_3)_2$-H_2O, $Zn(NO_3)_2$- $6H_2O$ and $Fe(NO_3)_3$-H_2O were used to prepare stock solutions of 20 mM which were diluted for use. The metal ion concentrations were obtained by using atomic absorption spectroscopy (UNICAM 939 AA Spectrophotometer).

3. Result and discussion

3.1 Characteristics of synthetic zeolites

By use of a caustic solution the fly ash can be easily converted to the zeolite phase via hydrothermal reaction. The chemical composition of the untreated fly ash and synthesized products are compared. The synthetic product showed a higher loss on ignition (>10%) and higher Na2O content than fly ash. Thermogravimetric analysis also showed a high weight loss (ca. 10%) in the synthetic product.

3.2 Heavy metal removal characteristics

Raw fly ash showed a relatively small Pb^{2+} removal efficiency (~8%). Natural zeolites showed better removal efficiencies, depending on their source, eg., natural zeolites from Yongdong and Daesin gave removal efficiencies of 24% and 60%, respectively. The synthetic zeolite, Na-P1, showed the highest efficiency for lead removal (>98%).

The maximum lead uptake of fly ash is about 0.19 mmole/g and that of natural zeolite is 0.22-0.34 mmole/g, however, the maximum uptake of Na-Pl is about 1.3 mmole/g. Therefore, it is clear that the synthetic zeolite has a

much higher adsorption capacity compared with fly ash and natural zeolites.

3.3 Effect of pH on heavy metal uptake

In order to investigate the effect of pH on the adsorption capacity of metal ion, a constant pH for batch equilibrium sorption experiment was maintained at pH 2, 3, 4, 5 and 6, respectively. The amount of biosorbent 0.2 g/L and initial metal concentration of 0.1 mM at different pH values were used. The pH effect on heavy metals adsorption is shown in Fig. 1. It was observed that the adsorption of heavy metals increase with in solution pH. As shown in figure, a low pH of 2 resulted in a markedly lower metal biosorption and higher metal biosorption capacity were obtained in the range of pH 3.0-6.0

3.4 Effect of ionic strength

Indusrial effluents contain large amounts of light metal ions such as calcium, magnesium, sodium and potassium along with the heavy metal ions. These metal ions often reduce the binding capacity of commercial ion exchange resins. The effect of light metal ions on lead adsorption capacity of Na-Pl were studied and the results are shown in Fig. 2. The effect of Na^+ and K^+ on lead uptake was marginal at 20 mM concentration of these ions. Calcium and magnesium ions, at 10 mM concentration, reduced the removal efficiency by 20%.

4. Conclusions

Zeolite was produced by heating fly ash in sodium hydroxide solution. The synthetic zeolites showed a high affinity for metal ion and a better removal efficiency than raw fly ash and natural zeolites. Of the synthetic zeolites produced, Na-Pl exhibited the highest affinity for metal with a maximum removal of 1.3 mmole Pb/g, which corresponded to 98% removal efficiency, while raw fly ash gave less than 8% removal efficiency(0.19 mmole Pb/g removal), and natural zeolites from Yongdong and Daesin gave 24% and 60% respectively (0.22-0.34 mmole Pb/g removal).

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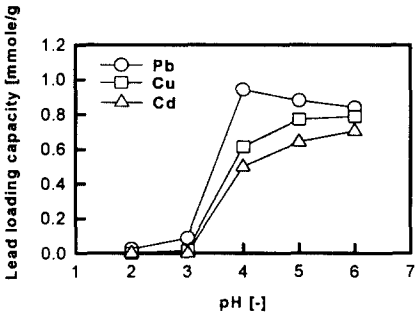

Fig. 1. Effect of pH on each metal ion uptake for Na-P1(adsorbent=0.2/L, metal concentration=0.1mM).

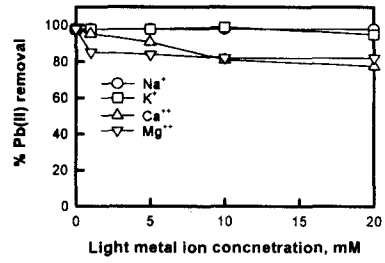

Fig. 2. Effect of light metal on Pb(II) adsorption by Na-P1(adsorbent=0.2/L, initial Pb(II) concentration=0.1mM, pH of solution=5.5)

5. Abstract

Fly ash obtained from a power generation plant was used for synthesizing zeolite. The synthetic zeolites had greater adsorption capacities for heavy metals than the original fly ash and natural zeolites. Na-P1 exhibited the highest adsorption capacity with a maximum value of about 1.3 mmole Pb/g and had a strong affinity for Pb^{2+} ion. The adsorption of heavy metals increase with in solution pH. The effect of Na^{+} and K^{+} on lead uptake was marginal at 20 mM concentration of these ions. Calcium and magnesium ions, at 10 mM concentration, reduced the removal efficiency by 20%.

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