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Zeolite as Adsorbent for the Removal of Nickel

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Abstract

Fly ash based zeolite was synthesized by a modification in the alkaline fusion. The potential of this zeolite as an adsorbent has been evaluated by carrying out batch experiments for the removal of nickel. Characterisation of zeolite was done. Adsorption efficiency was estimated by considering different parameters such as concentration, amount of zeolite, pH, contact time and temperature. The Freundlich and Langmuir isotherm model describes the equilibrium well.

Keywords: Adsorption, nickel, fly ash, zeolite, atomic absorption spectrophotometer.

Introduction

In the production of electricity, large quantities of fly ash are generated. Fly ash is mainly used for landfills which have represented an environmental problem in recent years[1]. Fly ash is defined as the fine residue resulting from the burning of ground or powdered coal in thermal power plants. In India, nearly 90 mt of fly ash is produced per year and is mainly responsible for environmental pollution[2]. Environmental problems arising out of such disposal has led researchers to conduct investigations into other alternatives such as conversion of this abundantly available waste into a higher level product by an economically viable method.

Various studies have been carried out on fly ash based zeolites as adsorbents for heavy metal ion removal. Zeolite synthesis requires Al and Si which is found in fly ash in major quantities. Zeolites with low Si / Al ratio are better adsorbents owing to their high cation exchange capacities and suitable pore size[3,4]. Heavy metals are generally considered to be those whose density exceeds 5 g per cubic centimetre. To clean the water contaminated with lead, sedimentation-floatation process was designed[5]. The zeolite synthesized from fly ash was applied in the removal of heavy metal ions Ni^{2+}, Cu^{2+}, Cd^{2+} and Pb^{2+} and described adsorption isotherms of Langmuir and Freundlich models[6]. Fly ash from coal burning was used in the removal of Cu (II) and Pb (II) ions[7].

Zeolite NaX was identified as an efficient adsorbent for use in the treatment of water contaminated with hexavalent chromium[8]. The adsorption capability of zeolite was analysed in the removal of Cu^{2+}, Cd^{2+}, Pb^{2+} and concluded that sorption capacity of zeolite was higher than that of fly ash[9]. The adsorption studies of SBA-15 for nickel adsorption and found out that the maximum percentage adsorption was 92.5 %[10]. The MCL standards for the toxicity of hazardous heavy metals established by USEPA describes the toxicity of Nickel in various ailments such as dermatitis, nausea, chronic asthma, coughing, human carcinogen etc[11].

Here in, we investigated the efficiency of the newly synthesized zeolite for the removal of nickel.

Material and Methods

All chemicals used were from E-Merck wherein the purity of Nickel ammonium sulphate is about 99.8%.

Zeolite Preparation: The main raw material, coal fly ash samples were collected from electrostatic precipitators from Khaperkheda Thermal Power Station (India) and stored in sealed plastic container with an airtight lid. The plastic containers were stored in a dark cool room and away from fluctuating temperatures[12].

The fly ash was initially screened to eliminate larger particles by using mechanical sieve shaker (filterwel test sieves) of mesh size 72 μ. Fly ash was subjected to pre-treatment with 8N HCl for 2 hours. The sample was fused with NaOH, Na_2CO_3 in a muffle furnace in the ratio of 1:1.5:0.5. The mixture was then heated at 700^0 C for 1 hr. Fused mass was cooled, milled and mixed thoroughly in distilled water with simultaneous addition of sodium aluminate solution. The slurry so obtained was then subjected to stirring and ageing for 8-10 hrs. It was then subjected to hydrothermal crystallisation in a closed container in an oven at 100^0C for 2-3hrs. After crystallisation the solid crystalline product was recovered by filtration using vacuum pump. It was washed with double distilled water and dried in oven[13].

The newly synthesized zeolite was used as adsorbent for the removal of nickel.

Nickel adsorption experiments: Nickel solutions was prepared by dissolving Ni $(NH_4)_2(SO_4)_2$ $6H_2O$ in distilled water The pH of the solution was found to be $\underline{+}$5. To know the effect of pH, contact time, weight of adsorbent on nickel adsorption, various series of batch experiment were carried out.

Nickel solutions were mixed with pre weighed amount of newly synthesized zeolite. The concentrations was varied between 100 to 500 mg/L, the time was varied between 60 to 360 min, whereas weight of zeolite was varied between 0.1 to 0.5 g/L. The stirring speed was maintained at 100 rpm for all the batch experiments and the experiments were carried out at room temp. The schedules of experiments conducted were: effect of weight of zeolite, initial concentration of adsorbate, effect of contact time and pH.

Results and Discussion

Effect of weight of zeolite on the removal of nickel: The experiments were carried out with 0.1, 0.2, 0.3, 0.4 and 0.5g of zeolite added to 50 ml of Ni^{2+} ion solution. The concentration of sorbed metal ion was analysed using Atomic Absorption Spectrophotometer (Model no. GBC 906 AA). The effect of weight of adsorbent of newly synthesized zeolite on the percent removal of Ni^{2+} ion is shown in figure-1. The maximum adsorption was given by 0.2 g of zeolite.

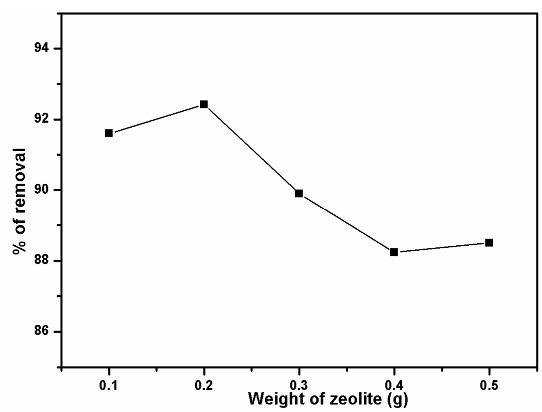

Figure-1
Effect of weight of zeolite on the removal of Nickel

Effect of initial concentration of adsorbate on the removal of nickel: This effect was studied by adding 0.2g of zeolite to a 50 ml of 100 mg/L, 200 mg/L, 300 mg/L, 400 mg/L, 500 mg/L Ni^{2+} ion solution at pH 5 for 5 hours. The maximum adsorption of Ni^{2+} ion solution was found to be 92.42 % at the concentration 212 mg/L. The results are shown in figure-2.

Effect of contact time on the removal of nickel: The adsorption of nickel was carried out with 0.2g of adsorbent to a 212 mg /L of Ni^{2+} ion solution as various contact time 1hr, 2hr, 3hr, 4hr and 5hr at pH 5. Results of studies on the effect of contact time on the maximum removal of nickel under investigation are illustrated in figure-3 Nickel shows higher adsorption at 5 hrs.

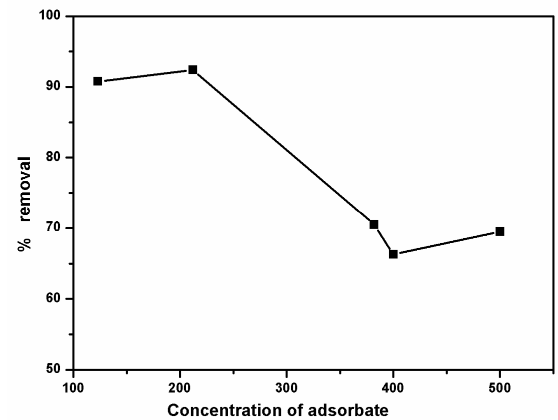

Figure-2
Effect of initial concentration of adsorbate on the removal of Nickel

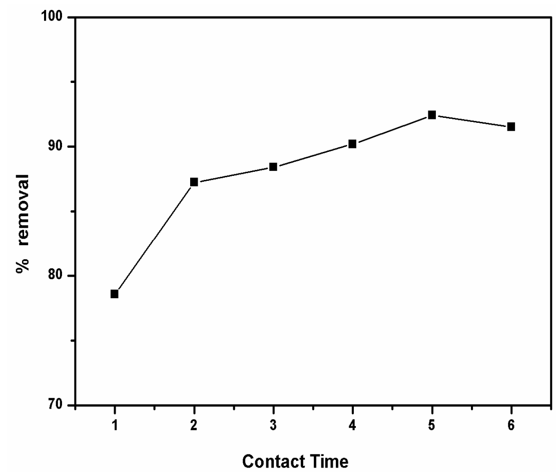

Figure-3
Effect of contact time on the removal of heavy metal ions

Effect of pH on the removal of nickel: The effect of pH on the removal of Nickel was studied by taking 0.2g of zeolite with 212 mg/L of adsorbate at various pH 1, 2, 3, 4, 5, 6 for 5hrs. Results present in figure-4 show that maximum removal takes place at pH 5.

Adsorption isotherms: The Langmuir isotherm model is the most common model used to quantify the amount of adsorbate adsorbed on an adsorbent figure-5. The Langmuir isotherm can be expressed in terms of a dimensionless constant R_L, is defined as

$$R_L = 1/\,(1 + K_A\,C_o)$$

Where: C_o is the initial concentration (mg/l), R_L is the Indicates the isotherm, K_A is the rate of adsorption. The values of R_L were found to be in between 0 to 1, which indicates favourable adsorption of metals under study onto the adsorbent[8].

The lineralized Freundlich model isotherm was applied for the adsorption of heavy metal ions figure-6 and is expressed as

$$Log(X/m) = Log\ K_F + 1/n\ (Log\ C_e)$$

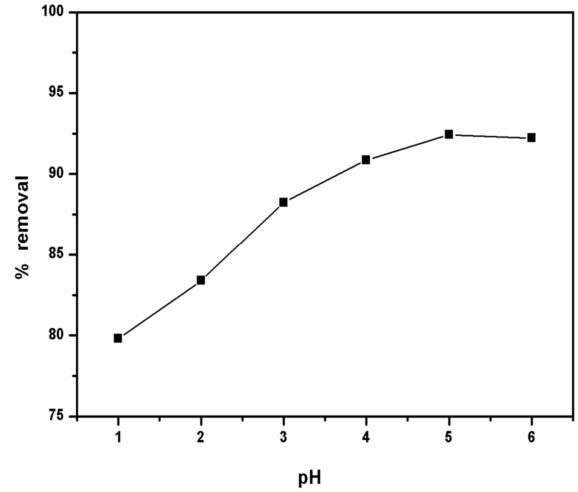

Figure-4
Effect of pH on the removal of nickel

Where, (x/m) is the amount of heavy metal ions adsorbed at equilibrium (mg/g), C_e is the equilibrium concentration of heavy metal ions (mg/l). K_F and n are the constants values calculated from the intercept and slope of the plot.

The regression coefficient R^2 for Langmuir and Freundlich values for Ni^{2+} adsorption were found to be between 0 to 1 indicating favourable adsorption of the metal ions onto the synthesized zeolite.

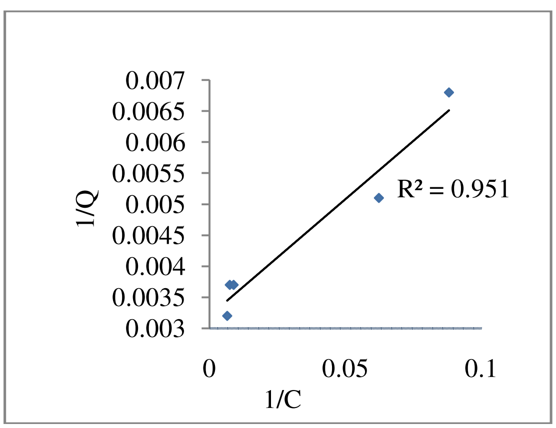

Figure-5
Langmuir curve for the adsorption of Ni^{2+} ion on zeolite

Conclusion

Based on the present investigation it could de concluded that the newly synthesized zeolite can be used effectively in the removal of heavy metal ion Ni^{2+} from aqueous solution. The removal of Ni^{2+} ion was found to be maximum under the conditions of 0.2 g of adsorbent, 212 mg/L of adsorbate, pH 5 and contact time of 5 hrs. Adsorption data was best fitted into Langmuir and Freundlich adsorption isotherm.

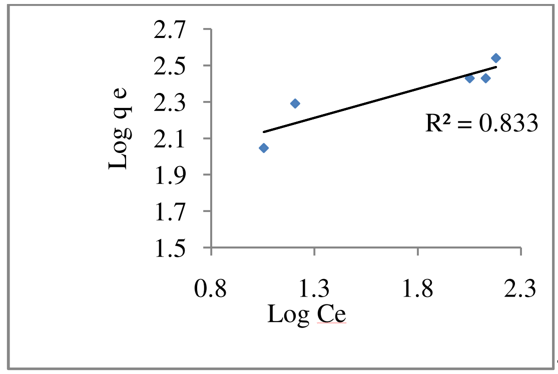

Figure-6
Freundlich curve for adsorption of Ni^{2+} ion on zeolite

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