Abstract

In this study, mesoporous silica SBA-15 material was synthesized, using Tetraethylorthosilicate (TEOS) as silica precursor and Pluronic (P123) as a template, and functionalized by post synthesis method with amino functional group (3-aminopropyltriethoxysilane) to investigate its potential use as an adsorbent for heavy metals removal from aqueous solution. Several characterization methods were used for identifying the material characteristics before and after functionalization, such as X-ray diffraction (XRD), scanning electron microscopy (SEM), BET surface area, Fourier transform infrared (FTIR) spectroscopy and thermal gravimetric analysis (TGA).

Batch adsorption experiments were conducted for single metal solutions. Several variables that affected the removal of heavy metals ions (Ni(II) and Co(II)) were studied, such as pH (1-6), contact time (0-150min), initial concentration (20-120mg/L) and NH_2–SBA-15 dose (0.025-0.3g). It was found that the amino-functional group was very effective in increasing the percentage removal of heavy metals ions (Ni(II) and Co(II)) as compared with non-functionalized SBA-15. The percentage removal of these ions were increased with increasing the pH (until 5), contact time and NH_2–SBA-15 dose, while the increase of the initial concentrations for these metal ions led to decrease in their percentage removal. Also, it was found that Ni(II) ions had a higher affinity for adsorption on NH_2-SBA-15 than Co(II) ions.

The temperature effect at Ni(II) adsorption on NH_2-SBA-15 was studied, and the results showed that the percentage removal of Ni(II) increased as the temperature was increased from 293 to 333K. The thermodynamic parameters were also investigated, and from their values, it was indicated that the overall process of Ni(II) adsorption on NH_2-SBA-15 was endothermic chemisorption process (ΔH^o = 93.8734kJ/mol) with a very little degree of disorder (ΔS^o = 0.38812kJ/mol.K) and whenever the temperature increased from 293 to 333k, the process became more spontaneous (ΔG^o= -19.098KJ/mol. K to -34.33KJ/mol. K).

The adsorption isotherms of Ni(II) on NH_2-SBA-15 at three varied temperatures were studied, and the equilibrium data were fitted with three linearized adsorption isotherm models (Langmuir, Freundlich and Temken), also the models parameters were calculated. It was found that the Langmuir adsorption isotherm model had the best fit with R^2=0.99, and the maximum capacity of monolayer adsorption increased from 64.52 to 90.1mg/g as the temperature was increased from 293 to 333K,respectively.

The kinetic data for Ni(II) adsorption on NH_2-SBA-15 were fitted to pseudo first and second order kinetic models, it was found that these data were fitted well with the pseudo-second-order kinetic model. A general predictive model was also developed for descrying the relationship between the Ni(II) adsorption rate along with solution temperature and initial concentration at any time. A good agreement between the experimental data and that predicted from the general model was obtained. The intraparticle adsorption model was also applied to the experimental data, and the results indicated that the intraparticle diffusion was not the only rate that controlled the adsorption process.

The adsorption of binary system consisting of Ni(II) and Co(II)on NH_2-SBA-15 was investigated, it was found that the percentage removal for Ni(II) ions in binary system was less than in single system by 64.67% which confirms the presence of competition between these ions, and the effect was much clearly in higher concentrations.

The competitive adsorption for six metals ions on NH_2-SBA-15 was studied, and it was obtained that the adsorbent had an affinity for metal ions in decreasing order as follows: Pb^{+2}> Cr^{+3}> Cu^{+2}> Cd^{+2}> Ni^{+2}> Co^{+2} which show that Pb was the most adsorbed metal at NH_2–SBA-15. It was also found that the Ni^{+2} removal efficiency obtained from the single-metal solutions (99%)was higher than in multi-metals solutions (42%),confirming the existence of competition between the metallic elements for adsorption by amine groups.