Removal of mercury from aqueous media using polypyrrole/ SBA-15 nanocomposite

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Abstract

Santa Barbara Amorphous (SBA-15) is significant mesoporous silica with exclusive and important properties of highly ordered mesopores, hydrothermally stable and thick wall, profusely large surface area and huge pore volume which render it as sorbent for wide applications such as heavy metals removal. In this study, synthesis and preparation of SBA-15 and its nanocomposite containing polypyrrole (Ppy) was discussed, and their capability to removal of mercury (Hg) from aqueous solution was studied. Polypyrrole was prepared by chemical oxidative polymerization of pyrrole using $FeCl_3$ as an oxidant and coated on SBA-15 (prepared with sol-gel method). The removal of Hg was investigated using Ppy, and Ppy/SBA-15 nanocomposite, respectively. The products were investigated in terms of morphology and chemical structure with transmission electron microscopy (TEM) and BET test, respectively. Batch studies were performed to evaluate the influence of various experimental parameters like pH, adsorbent dosage and contact time. Optimum conditions for Hg removal were found to be pH= 8, adsorbent dosage of 1 g/L and equilibrium time 60 min.

Keywords: Polypyrrole, SBA-15, Nanocomposite, Mercury, Removal.

Introduction

Mercury (Hg) is a heavy metal with extremely toxic effects in high enough doses that causes irreversible neurological damage to humans [1]. The World Health Organization (WHO) recommends the maximum Hg uptake by human of 0.3 mg per week and the maximum acceptable concentration of 1 µg/L in drinking water [2]. Conventional treatments to remove Hg from aqueous solutions include chemical precipitation, adsorption by activated carbon, ion exchange resins and electro-chemical recovery [3]. However, these processes can be ineffective at low metal concentrations (1–20 mg/L), or expensive due to toxic sludge disposal, chemical reagents for metal recovery, sorbent regeneration and high-energy requirements. Therefore, more effective low-cost alternatives are urgently required. Conductive polymers such as polyacetylene, polyaniline, polypyrrole (Ppy) and polythiophene have attracted so much research interest in wide range applications such as rechargeable batteries [4], electromagnetic interference (EMI) shielding [5], antistatic coatings [6], gas sensors [7], optical devices [8] and removal of heavy metals [9,10]. The main purpose of this paper is synthesis of SBA-15 and its composite with Ppy and the removal of mercury ion by using adsorption and determining the ability of Ppy/SBA-15 nanocomposite to remove of mercury ion from aqueous solution. Also effects of pH, adsorbent dosage and contact time have been investigated.

Experimental

Materials and equipment

A magnetic mixer (Helmer model MK20, Germany), digital scale (Helmer model FR 200, Germany), transmission electron microscope (TEM) Philips, CM120, Netherlands), oven (Binder model FD 23, USA) and an atomic fluorescence spectrophotometer (Perkin-Elmer Corp. model 2380, USA). The specific surface area of synthetised SBA-15 was measured by the BET method using a Quantachrome, chem BET 3000 TPR/TPD, USA. The BET results show that the specific surface is 743.45 m^2/g for SBA-15. Synthesis of SBA-15 with sol-gel method makes easier the incorporation of heteroatoms into a siliceous structure but disturb the hexagonal ordering of the pores leading to a wormhole-like material. This fact can be confirmed by means of transmission electron microscopy (TEM) Philips, CM120, Netherlands). Figure 1 show TEM micrographs of synthesized SBA-15. As observed, SBA-15 exhibits a well-organized hexagonal mesoporous structure .

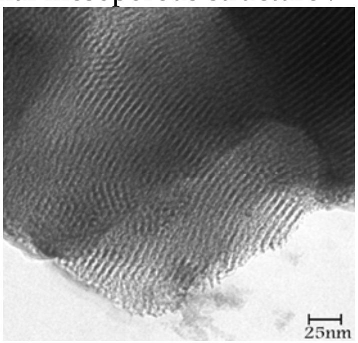

Figure 1: TEM image of synthesized SBA-15.

All reagents were used without further purification, unless stated otherwise. Distilled deionized water was used throughout this work. The 100 mg/L of stock solution of mercury was prepared by dissolving $Hg(NO_3)_2$ in double distilled water. Pyrrole was purified by simple distillation. Other materials were $FeCl_3$, NaOH, HCl and sulphuric acid from Merck.

Preparation of polypyrrole/SBA-15 nanocomposite

5.4 g of $FeCl_3$ was added to a aqueous solution (100 mL distilled water) and stirred. After 20 min, 1 mL of pyrrole monomer and 1g of SBA-15 were added to the stirred solution. After 5 h, the Ppy/SBA-15 nanocomposite was collected by filtration, and in order to separate the oligomers and impurities, the product was washed several times with deionized water. It was then dried at room temperature.

Batch adsorption experiment

Batch experiments were conducted to investigate the parametric effects of adsorbent dose, adsorption time and pH for Hg adsorption on the Ppy/SBA-15 nanocomposite. Hg samples were prepared by dissolving a known quantity in distilled water and used as a stock solution and diluted to the required initial concentration. 100 ml of Hg solution of known concentration (C_o) was taken in a 250 ml conical flask with a required amount of adsorbent and was shacked for different time duration in a Stirrer at different pH and Temperature. The solution was then centrifuged. The pH of the solution was adjusted by using either 0.1 N NaOH or 0.1 N H_2SO_4.

Results and Discussion

Effect of pH

The pH value of the aqueous solution is an important controlling parameter in the adsorption process. These pH values affect the surface charge of adsorbent during adsorption. In order to evaluate the influence of this parameter on the adsorption, the experiments were carried out at different initial pH ranging from 2 to 12. The experiment was performed by Ppy/SBA-15 nanocomposite, with an initial concentration of 40 mg/L, at room temperature with contact time of 60 min. The results are shown in Figure 2. Maximum value removal of Hg was reached at an equilibrium pH of around 8, as can be seen in Figure 2.

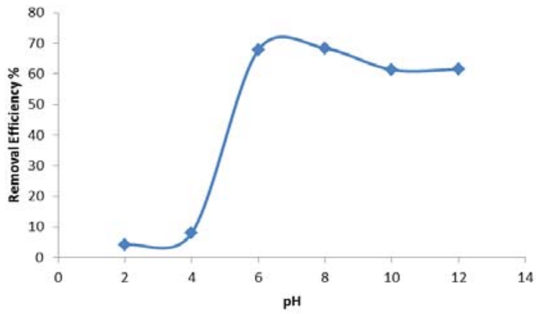

Figure 2: The effect of pH on the removal efficiency with: Ppy/SBA-15 (The initial concentration, contact time, volume of solution and amount of adsorbent was 40 mg/L, 60 min, 100 mL and 0.1 g, respectively).

Influence of sorbent dosage

The removal percentage of Hg was studied by varying the adsorbent (Ppy/SBA-15) dose between 100 and 2000 mg/L at Hg concentration of 40 mg/L. Results are presented in Figure 3. The Hg removal efficiency increases up to an optimum dosage beyond which the removal efficiency does not significantly change. This result was anticipated because for a fixed initial solute concentration, increasing adsorbent doses provides greater surface area and more adsorption sites, whereas the adsorbed Hg quantity per unit weight of the sorbent decreased by increasing the magnetic beads quantity. At very low adsorbent, the absorbent surfaces become saturated with the Hg and the residual Hg concentration in the solution was high.

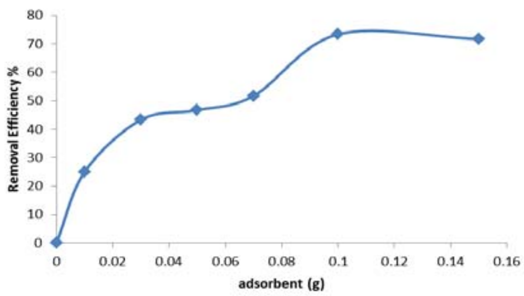

Figure 3: The effect of adsorbent dosage on the removal efficiency with: Ppy/SBA-15 (the initial concentration, pH, contact time and volume of solution was 40 mg/L, 8, 60 min and 100 mL, respectively).

Effect of contact time

Figure 4 shows the effect of contact time on sorption of Hg by Ppy/SBA-15. For these cases, initial Hg concentration was 40 mg/L and pH of 8 was used for Hg solution. Also Ppy/SBA-15 dose of 0.1 g in 100 mL were used. For Hg sorption rate reaches up to 73 by Ppy/SBA-15, when contact time was 60 min, and then little change of sorption rate was observed. This result revealed that adsorption of Hg was fast at first (until 45 min) and the equilibrium was achieved after 60 min of contact time. Taking into account these results, a contact time of 60 min was chosen for further experiments.

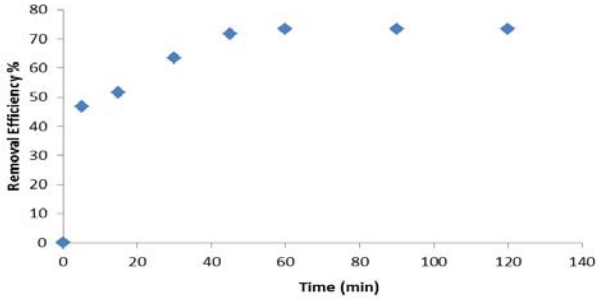

Figure 4: The effect of contact time on the removal efficiency with: Ppy/SBA-15 (the initial concentration, pH, volume of solution and amount of adsorbent was 40 mg/L, 8, 100 mL and 0.1 g, respectively).

Conclusions

In this research, Ppy/SBA-15 nanocomposite was prepared by coating the SBA-15 substrate with pyrrole using the chemical oxidative polymerization method and its ability in the removal of Hg from aqueous solution was investigated. The results indicate that the Ppy/SBA-15 nanocomposite has a considerable potential for the removal of Hg from aqueous solution. Optimum conditions for mercury removal were found to be pH=8, adsorbent dosage of 1 g/L and equilibrium time 60 min.

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