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Removal of Arsenic in Water Using Polypyrrole and its Composites

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Abstract: In this research various adsorbents such as bentonite, activated carbon, conductive electroactive polypyrrole composites were employed. The conductive polypyrrole composites were prepared using different surfactants such as sodium dodecylbenzenesulfonate, hydroxypropylcellulose, poly(vinyl alcohol) and poly(ethylene glycol) in the presence of $FeCl_3$ as an oxidant respectively. The results indicate that the type of adsorbents and surfactants have a great effect on the removal of arsenic.

Key words: Heavy metal removal · conductive polymeric composites · surfactant · surface morphology · adsorbent

INTRODUCTION

All over the world industry is forced to diminish down to acceptable level contents of heavy metal in water and industrial waste waters. Conventional methods like precipitation are a favorable especially when dealing with large volume of matter which contains heavy metal ions in low concentration. Typically these ions are precipitated as hydrated metal oxides or hydroxides using calcium oxide. Precipitation is accompanied by flocculation or coagulation, and one major problem is the formation of large amounts of sediments containing heavy metal ions. In recent years, considerable attention has been devoted to fine new adsorbents. One of the suitable methods for removing heavy metals from water and waste water is using surface adsorption process.

Heavy metals removal from industrial waste streams by the use of natural zeolites has long been applied in medium and large scale installations with variable success [1]. By ion exchange undesirable ions are replaced by others which don′t contributes to contamination of the environment. The method is technologically simple and enables efficient removal of even traces of impurities from solutions [2]. Mercury is one of the most hazardous contaminant in natural environment because it spreads easily and will be accumulated in living organisms. To remove mercury compounds mainly reduction, precipitation, extraction and ion exchange methods are applied. It is possible to remove Hg(II) ions from water and industrial waste waters on various types of ion exchangers [3-6].

Removal of Cr(III,VI) from waste waters is essential due to their toxicity. A main source of water contamination with chromium ions are industrial waste waters from the surface metal treatment plants and from tannery. Activated carbon may be regarded as a unique class of ion-exchange adsorbents [7]. Various techniques such as, chemical sedimentation, surface absorption, ion-exchanger and reverse osmosis can be used for the removal of chromium from waste water [8]. Activated carbon with low polar properties is typical adsorbents and is commonly used for removal of non-polar organic material in water and waste water [9]. Bentonite is used widely for adsorption of particles due to its high activated surface and their tendency to adsorb water in the inter-layer sites [10]. Conductive electroactive polymers such as polypyrrole and polyaniline can be used for the removal of heavy metals from water and waste waters [11, 12].

In this study various adsorbents such as bentonite, activated carbon, and conductive electroactive polypyrrole composites prepared chemically using various surface active agents were employed to the removal of arsenic from water.

MATERIALS AND METHODS

Instrumentation: Magnetic mixer MK20, digital scale FR200, atomic absorption device perkin-elmer 2380, pH meter, and scanning electron microscope (SEM) model XL30, inductively coupled plasma (ICP) model vista-pro were employed.

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Reagents and Standard Solutions: All reagents were used as received without further purification, unless stated otherwise. Distilled deionized water was used throughout this work. Monomer of pyrrole was purified by simple distillation. Materials used in this work were bentonite, activated carbon, pyrrole(Aldrich), sodium dodecylbenzenesulfonate (DBSNa) from Loba chemie, hydroxypropylcellulose (HPC, $M_w=10^6$) from Aldrich, poly(vinyl alcohol) (PVA, M_w=72000, 15000), poly(ethylene glycol) (PEG, M_w=35000, 4000), and $FeCl_3$ were obtained from Merck.

Polypyrrole Composite Preparation: $FeCl_3$ was used as the oxidant, with HPC, DBSNa, PVA and PEG as surfactants. The reaction was carried out in an aqueous media at room temperature for 4 hours. In a typical experiment, 1 mL of pyrrole was added to a stirred aqueous solution 100 mL containing 0.1-0.2 g of one of the surfactants. After 4 h polymer composite was filtered and to separate the oligomers and impurities, product was washed several times with deionized water and dried at room temperature.

Heavy Metal Removal Method: For determining the amount of heavy metal removal by different adsorbents such as polypyrrole composites, activated carbon and bentonite, 50 mL of arsenic solution was mixed with 0.25 g powder of adsorbents and then stirred using magnetic mixer for 30 min and then was filtered respectively. The concentration of arsenic from the resultant solution was determined using ICP test.

RESULTS AND DISCUSSION

The chemical method can be a general and useful procedure to prepare conductive polymer and its composites. PPy composites were prepared chemically using different stabilizers. The different concentrations of As(III), was used as inlet solutions. The results indicate that the removal of arsenic from the solutions is dependent on the ability of surface absorption.

The effect of various adsorbents to the removal of arsenic is shown in Table 1. As can be seen in table the removal of arsenic related to type of adsorbents. HPC, DBSNa, PEG and PVA are stabilizing agents and could affect the size, morphology and homogeneity of particles [13, 14], because the additives are adsorbed physically or chemically by the growing polymer. By using composites of PPy with PEG and composite of PAn with PVA, the percentage of mercury and chromium removal from the water and waste water solutions reaches 97.9 and 73.9%, respectively [11, 12].

Table 1: The results of ICP test for removal of arsenic using polypyrrole and its composites

Type of sample	Arsenic concentration (10^{-3} g L^{-1})	Arsenic concentration after removal (10^{-3} g L^{-1})	Removal percentage (wt %)
Polypyrrole	3	2.80	6.66
	5	4.63	7.40
Composite of PPy with PVA (M_w = 15000, 1.5 g L^{-1})	25	17.56	29.76
Composite of PPy with PVA (M_w = 72000, 1.5 g L^{-1})	25	14.06	43.76
	5	2.81	43.80
	3	1.06	64.66
Composite of PPy with PEG (M_w = 4000, 1.5 g L^{-1})	25	14.7	41.20
	5	1.24	75.20
	3	0.50	83.33
Composite of PPy with PEG (M_w = 35000, 1.5 g L^{-1})	25	22.86	8.56
	5	4.69	6.20
Composite of PPy with activated carbon	25	23.39	6.44
	3	2.90	3.33
Composite of PPy with bentonite	5	0.44	91.20
	3	0.08	97.33
Activated carbon	25	22.83	8.68
	5	4.21	15.80
	3	2.74	8.66
Bentonite	5	0.26	94.80
	3	0.15	95.00

Fig. 1: Scanning electron micrograph of pure PPy. Reaction conditions: ($FeCl_3$=48 g L^{-1}, pyrrole monomer 14.4×10^{-2} mol L^{-1}, volume of solution 100 mL, reaction time 4 hours at room temperature)

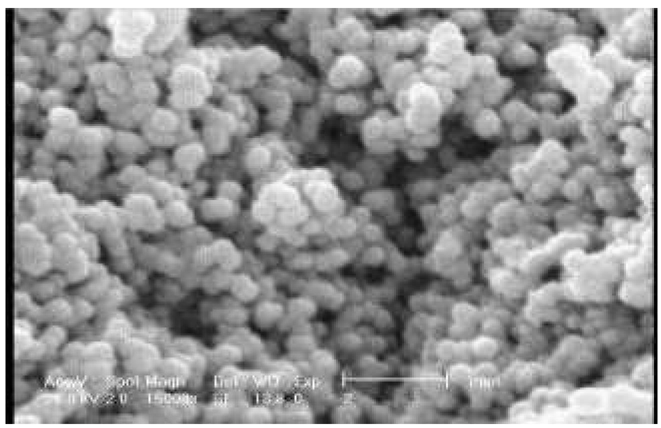

Fig. 2: Scanning electron micrograph of PPy composite in an aqueous media. Reaction conditions: ($FeCl_3$=48 g L^{-1}, pyrrole monomer=14.4×10^{-2} mol L^{-1}, poly(vinyl alcohol)(M_w=72000, 1.0 g L^{-1}), volume of solution 100 mL, reaction time 4 hours at room temperature)

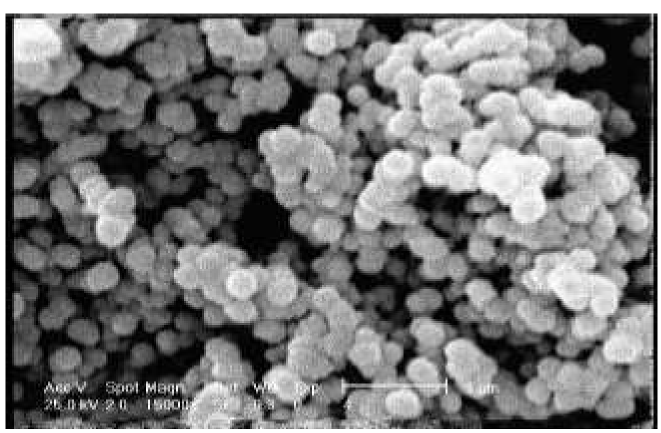

Fig. 3: Scanning electron micrograph of PPy composite in an aqueous media. Reaction conditions: ($FeCl_3$=48 g L^{-1}, pyrrole monomer=14.4×10^{-2} mol L^{-1}, hydroxypropylcellulose=2 g L^{-1}, volume of solution 100 mL, reaction time 4 hours at room temperature).

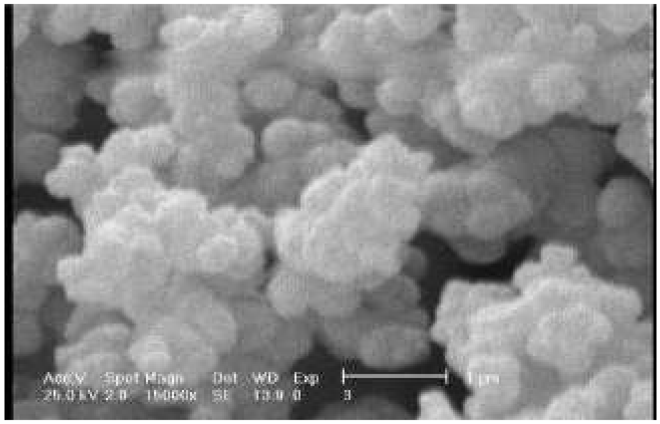

Fig. 4: Scanning electron micrograph of PPy. Reaction conditions: ($FeCl_3$=48 g L^{-1}, DBSNa=2 g L^{-1}, pyrrole monomer 14.4×10^{-2} mol L^{-1}, volume of solution 100 mL, reaction time 4 hours at room temperature)

The SEM micrographs of the PPy composites are shown in Fig. 1-4. As can be seen the size and homogeneity of particles are dependent on the type of surfactant. By comparison between Fig. 1 and Fig. 2 & 3, it is clear that good spherical nanoparticles were obtained using PVA and HPC as surfactant.

CONCLUSIONS

The effect of various adsorbents on the removal of arsenic from water was investigated. The results indicate that the percentage of removal related to the type of adsorbent. Also type concentration and molecular weight of surface active agents were used for the preparation of PPy composites have a great effect on the removal of heavy metal from the solution. As it can be seen in the SEM micrographs, PVA and HPC play a major role on the surface morphology of products because the total surface area increases as the particle size decreases.

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