Efficient removal of ion chromium (VI) from aqueous solutions using functionalized acrylic fibers

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Abstract

Hexavalent chromium (Cr(VI)) ions are toxic and carcinogenic. Their presence in environmental media such as soil, groundwater, sediment, or surface water, leads to negative impacts on the human health and the environment. Therefore, environmental remediation, consisting in the removal of the chromium ions from aquatic environmental media, is of paramount importance. The present work deals with highlighting the efficient removal of ion chromium (VI) from aqueous solutions using chelating acrylic fibers. Thus, polyacrylonitrile fibers (PAN) were amidoximated, and then used as adsorbent in batch experiments to remove chromium ions from water. Prior to batch adsorption experiments, preliminary FTIR spectroscopy and Scanning Electron Microscopy (SEM) investigations have shown that chemical structure and morphological modifications of the PAN occur as resulting from the fiber amidoximation. Further, the ability of fibers as adsorbent to eliminate Cr (VI) ions from aqueous solutions was assessed by UV-visible spectroscopy.

The adsorption data indicate that, under optimal experimental conditions, the use of amidoximated PAN allows removal of up to 90% of chromium ions initially present in the polluted water. Moreover, various parameters were studied, such as the aqueous phase pH, the agitation time, the temperature, and the amidoximated PAN concentration, and were found to affect the chromium ions amount removed from water. Finally, in order to elucidate the adsorption mechanism of the chromium ions from water onto amidoximated PAN, and to predict its adsorption behavior, the experimental data were compared to Freundlich and Langmuir theoretical models.

Introduction

In the recent years, the increase of the industrial activities is considered to be the main cause of the increase in toxic metals concentrations in various environmental media. Wastewater containing heavy metals pose serious threat to both the ecosystems and public health due to their non-biodegradability, their toxicity beyond a certain concentration limit, and their tendency to accumulate in living organisms, Abu-Saied *et al* (2015). In water, chromium exists in two oxidations state trivalent chromium Cr (III) and hexavalent chromium Cr(VI). The later appears in many wastes resulting from industrial activities such as electroplating, paints, dyes, paper industries, etc. Hexavalent chromium is more toxic than trivalent chromium; it is a carcinogen, pose liver damage and pulmonary congestion, Vetriselvi *et al* (2015). Several methods including chemical precipitation, osmosis, membrane filtration, electrochemical treatment, ion exchange and adsorption, were used in the removal process of heavy metals from wastewater. However, the adsorption method, used in the present work, has been found to be the most efficient and low cost technology, due to its easy handling and to the little needs of the chemical products, Morillo Martin *et al* (2017). Further, the use of chelating fibers, as adsorbent for the metallic depollution of wastewater, was found to have several advantages over conventional supports. Hence, the fiber is easy to handle, has high adaptability, high adsorption and desorption rates, and better retention capacity. Since the polyacrylonitrile, is bearing on its surface nitrile groups, it can be easily transformed to chelating fibers, Bhunia *et al* (2017). The objectives of this study is first to synthesize chelating acrylic fibers by using hydroxylamine hydrochloride as reactant, and second to use the amidoximated PAN as adsorbent for chromium removal from wastewater, and finally to examine the effects of various parameters, such as the pH, the agitation time, the temperature and the fiber concentration, that may affect on the efficiency of the metallic ions removal.

Materials and methods

Commercial acrylic fibers was supplied from Sigma Aldrich and were used as a raw material. Hydroxylamine hydrochloride, potassium dichromate and sodium hydroxide was purchased from Scharlab, Riedel-de-Haen and Sigma Aldrich. All the products were used without any purification.

-A synthetic chromium solution was prepared by dissolving potassium dichromate in distillated water at room temperature. Chemical functionalities of the fibers before and after modification were characterized by Thermo Scientific™ Nicolet™ iS™10 FTIR spectrometer. The surface morphology was analyzed by Scanning Electron Microscopy. The metal adsorption capacities of fibers were measured by Evolution™ 300 Uv-Vis spectrophotometer at room temperature.

Results and discussions

Fig 1 shows the FTIR spectra of the pristine and modified fibers samples. As can seen in this figure, the PAN surface nitrile group absorption peak decreased due to the conversion of nitrile group into amidoxime, as resulting from the PAN amidoximation reaction. By investigating the effect of the aqueous phase pH on the chromium ions removal from water by the amidoximated PAN fiber, a maximum chromium adsorption amount was reached at a pH=3, as depicted in Fig 2. Regarding the temperature effect, the chromium adsorption from water onto amidoximated PAN fiber was found to increase by increasing the temperature indicating that the adsorption process is endothermic. Finally, the SEM analysis showed that the modified PAN has rougher surface when compared to the pristine PAN as observed in Fig 3.

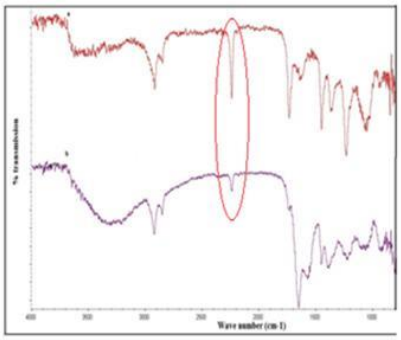

Figure 1: FTIR spectra of the raw acrylic fiber (a) and the modified acrylic fiber (b)

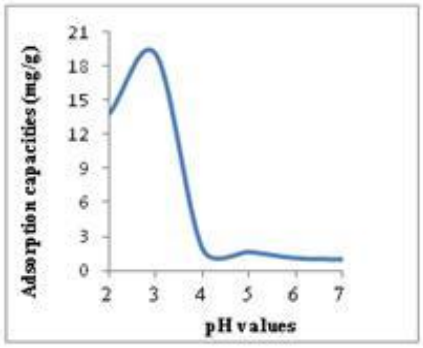

Figure 2: Effect of pH values on chromium adsorption capacity

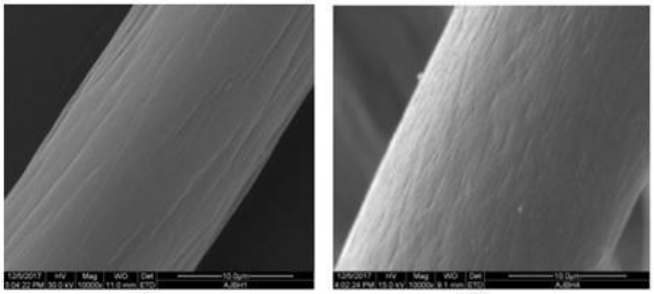

Figure 3: Scanning electron microscope photographs of the fibers before (a) and after modification (b)

Conclusions

The present work, the nitrile groups on the raw acrylic fibers were converted to amidoxime groups using hydroxylamine hydrochloride. The resulting amidoximated PAN fibers when used as adsorbent were found to remove up to 90% of the hexavalent chromium ions initially present in wastewater. The adsorption capacity was found to depend on the aqueous phase pH and the temperature of the medium.

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