Histidine-Functionalised Polypyrrole Hybrid Nanocomposite for Adsorption of Toxic Hexavalent Chromium from Water

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Abstract

Chromium(VI) is one of the most toxic metal ions as it can bioaccumulate and its excessive assimilation may result in anaemia, nervous system failure, kidney damage, cancers of the digestive tract and lungs. In this study a polypyrrole (PPy) modified with histidine (His) by in situ polymerisation technique was investigated for the removal of Cr(VI) from aqueous and characterised by means of Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction (XRD), field emission scanning electron microscopy/energy dispersive X-ray spectroscopy (FE-SEM/EDS), high resolution-transmission electron microscopy (HR-TEM) and X-ray photoelectron spectroscopy (XPS).The influence of solution pH, adsorption time, initial adsorption concentration, temperature and coexisting ions on its adsorption were investigated. The results showed that the optimum adsorption pH was 2.0 with the adsorption being endothermic and chemisorption in nature. Mono-layer adsorption was witnessed as the Langmuir isotherm best described the process with a maximum adsorption capacity 274.73 mg g−1 at 25 °C. Although the removal of Cr(VI) was the primary drive, the reduction of Cr(VI) to Cr(III) during treatment turned out to be very significant to avoid secondary pollution. The adsorption mechanisms were mainly ion exchange, electrostatic attractions, complexation, chelation reactions with protonated histidine sites and reduction. Remarkably, the His-PPy nanocomposite exhibited an exceptional removal for Cr(VI) ions after three cycles of adsorption–desorption (over 99%) suggesting the adsorbent's exceptional recyclability. The adsorption equilibrium was attained from 60 to 150 min and best described by pseudo-second-order kinetics. The high adsorption efficiency, stability and selectivity makes the His-PPy nanocomposite adsorbent potentially suitable for large-scale Cr(VI) ions removal from water.