Abstract

A study on oxy-hydroxide compound mediated fluorometric detection and removal of hexavalent chromium from wastewater and its application in energy harvesting

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Nowadays, unplanned urbanization and rapid industrialization due to the increasing population are causing irreparable damage to the ecosystem. Water is one of the most vulnerable media that introduces such pollution into the environment and leads to severe damage to the ecosystem. Heavy metal contamination into the water and water bodies is considered to be one of the crucial issues to be paid immediate attention because of their high toxicity. The detection and removal of such toxic contaminants from wastewater need immediate attention. Among various heavy metals, hexavalent chromium (Cr(VI)) is contaminating our water bodies rapidly causing numerous carcinogenic diseases. In recent years, the fluorometric detection of heavy metals has gained immense popularity due to their high selectivity, rapid detection and sensitivity. Additionally, adsorption-based removal is found to be an efficient strategy to remove such heavy metals from wastewater. But, a very limited amount of interest has been paid to the field of simultaneous detection and removal of heavy metals from wastewater. Herein, metallic oxy-hydroxide compounds could be a promising candidate having excellent physicochemical properties, such as high adsorption efficacies, biocompatibility, low cost and prominent fluorescence activities. In fact, oxy-hydroxide compounds are having promising energy harvesting properties due to their structural alignment. In the past few decades, substantial efforts have been assigned on the synthesis of these nanostructures that result in various morphologies, such as nanoparticles, nanoflowers, nanofibers and nano-petals. However, a very limited amount of interest has been shown to understand their multifunctional sensing and energy storage properties. This study will be directed towards the investigation of the simultaneous sensing and adsorption of hexavalent chromium in wastewater by using aluminum oxy-hydroxide (boehmite) and its modified forms. Additionally, the bio-sensing of Cr(VI) is performed using these nanostructures to estimate the sensing efficacy in living systems. The fluorometric sensing mechanisms have been substantiated using density functional theory (DFT) and molecular docking simulation, besides several other theoretical techniques. In reality, polymeric boehmite nanocomposite is successfully achieved during this work, which finally leads to a portable device, `Kavach'. This device can efficiently detect Cr(VI) in nanomolar accuracy in real-life wastewater samples and Cr(VI) contaminated living cells. Moreover, Cr(VI) has been successfully removed from wastewater (up to 85%) using boehmite-based nanostructures showing the multifunctional aspects of these materials. The Cr(VI) adsorbed boehmite also shows enhancement in energy storage, which adds another dimension to this study. Henceforth, this work may propel the unlocking of new avenues, which could enlighten the area of application of these novel nanostructures.

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