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A facile one-pot synthesis of phyto-conjugate superparamagnetic magnetite nanoparticles for the rapid removal of hexavalent chromium from water bodies

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ABSTRACT

Sustainable and economical strategies for producing efficacious adsorbent systems for the rapid removal of hazardous Cr(VI) have recently gained research attention. This study employs the aqueous extract of *Chromolaena odorata* flowers as a green reductant and capping agent for the synthesis of Chromolaena odorata-derived magnetite nanoparticles (CMNs). The method yielded relatively monodispersed and small superparamagnetic magnetite nanoparticles with an average particle size of 3.14±0.25 nm. At an optimum pH of 2, CMNs enabled rapid removal of Cr(VI) and its subsequent reduction to Cr(III) in under 10 minutes. The maximum adsorption capacity recorded was 173.12 mg g^{-1}. The adsorption conformed to Langmuir adsorption isotherm and followed pseudo first order kinetics. The strong magnetic nature of the adsorbent facilitated easy separation and recycling after adsorption. The present work provides insights into the use of aggressive weeds for the phytogenic development of eco-compatible adsorbents for rapid chromium reduction and removal.

1. Introduction

Chromium exists in its trivalent and hexavalent state in nature. Cr (III) is considered an essential human dietary element whereas Cr(VI) is highly toxic and acts as carcinogens, mutagens, and teratogens in biological systems. It is well established that the toxicity of Cr(VI), is higher than that of Cr(III), due to the increased solubility of Cr(VI) species compared to Cr(III), and easy absorption and accumulation in kidneys, stomach, and liver [1]. Extensive use of hexavalent chromium in various industries including electroplating, leather tanning, metal fabrication, and finishing has exacerbated Cr(VI) contamination in water bodies [2]. Existing literature indicates the presence of unacceptable quantities of Cr(VI) in drinking water, soil, and plants [3–6] which demands immediate and effective remediation strategies.

Assorted techniques such as membrane filtration, ion exchange, reverse osmosis, electrochemical treatment, solvent extraction, photocatalysis and adsorption/biosorption have been developed for the removal of chromium from industrial sewage. Researchers have fabricated various materials including surface engineered metal oxide nanosystems and polymer nanocomposites for efficient removal of chromium [6–10]. Among these, adsorptive techniques play pivotal role owing to their effortless execution, appreciable efficiency, and economic viability [11,12]. Numerous reports on strategic development of adsorbent systems including modified GO [13,14] supports the efficacy of the technique. Different forms of iron oxides and hydroxides are reported as efficient adsorbents for heavy metal ions from water [15–17] and various physical, chemical and biological methods have been reported for the synthesis of iron oxide nanoparticles (IONPs) as well [18]. Additionally, the magnetic properties of IONPs facilitate easy separation of the exhausted adsorbents, making IONPs more desirable. Recently tailor-made IONPs were synthesized via co-precipitation, hydrothermal and sol-gel techniques coupled with the aid of constrained environments or molecular cages (e. g., microemulsions, micelles, dendrimers, cyclodextrins) [19], acoustic cavitation [20] and microwave irradiation [21]. Iron oxides are also extensively used to magnetize carbonaceous adsorbent systems [22,23]. However, most of these methods use separate stabilizing and templating agents to attain precise control over the nanoparticle size and morphology, as well as to prevention of

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