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Application of phytogenic zerovalent iron nanoparticles in the adsorption of hexavalent chromium

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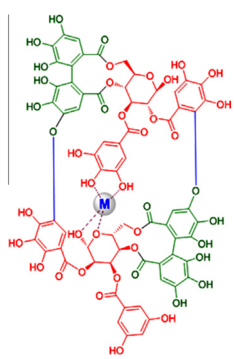
HIGHLIGHTS

- The present study emphasis on the green synthesis of zerovalent iron nanoparticles (ZVNI).
- The prepared ZVNI were stable for a long time.
- ZVNI showed high efficiency towards the reduction of chromium (Cr (VI)).
- The Cr (VI) adsorption efficiency was interpreted by response and contour surface plots.

GRAPHICAL ABSTRACT

Oenothein B – ZVNI complexation.



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ABSTRACT

Zerovalent iron nanoparticles (ZVNI) were synthesized using a rapid, single step and completely green synthetic method from the leaf extracts of *Eucalyptus globules* and were characterized using the techniques Scanning Electron Microscopy (SEM), UV–Vis Spectroscopy, Fourier Transform-Infrared Spectroscopy (FT-IR), X-ray Diffraction (XRD) and Zeta potential measurement. The FT-IR analysis reveals that the polyphenolic compounds present in the leaf extract may be responsible for the reduction and stabilization of the ZVNI. These nanoparticles were utilized for the adsorption of hexavalent chromium (Cr (VI)) and the concentration of Cr (VI) was determined using UV–Vis spectrometer after treating with ZVNI. Response and surface contour plots were drawn with the help of Mini-tab software to explain the adsorption of Cr (VI). The adsorption efficiency of Cr (VI) reaches to the highest value (98.1%) when the reaction time was about 30 min. and the ZVNI dosage was 0.8 g/L. The effective parameters such as adsorbent (ZVNI) dosage, initial Cr (VI) concentration and the kinetics were also examined.

Introduction

One of the major environmental problems faced by the world today is the contamination of soil, water, and air by toxic chemicals. With the industrialization and the extensive use of pesticides in agriculture, the pollution of the environment with manmade compounds has become a serious problem. In addition, increasing contamination of groundwater by toxic metal ions poses significant environmental hazard as they are non degradable and can accumulate in living tissues to become concentrated throughout the food chain which leads to various diseases and disorders [1–3]. Among the metals hazardous in nature, hexavalent chromium (Cr (VI)) is a potential carcinogen to humans and animals

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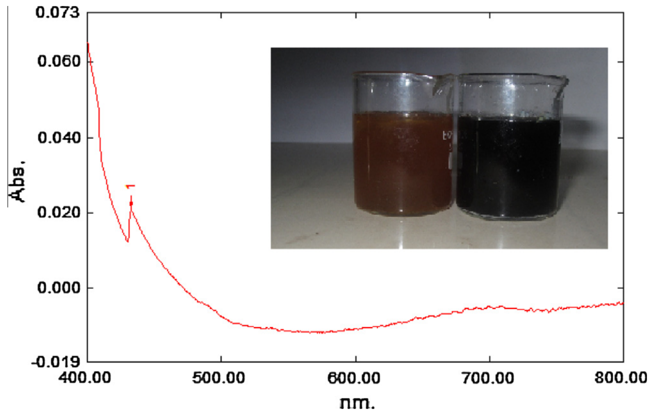

Fig. 1. UV spectra of reaction product of FeSO4 and *E. globulus* extract. Inset shows the photographic image of the reaction.

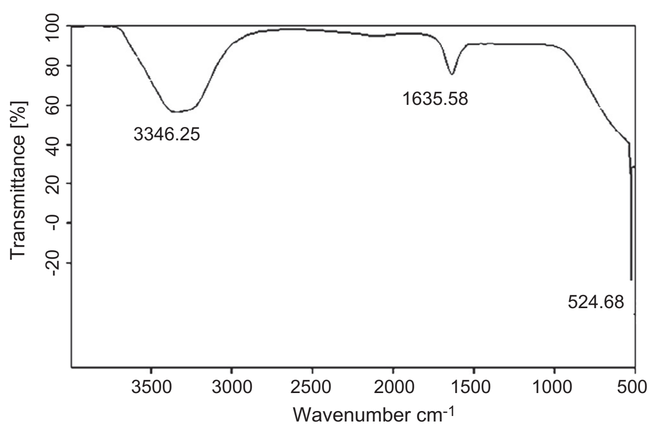

Fig. 2. Representative FT-IR spectra of iron nanoparticles synthesized using *E. globulus* extract.

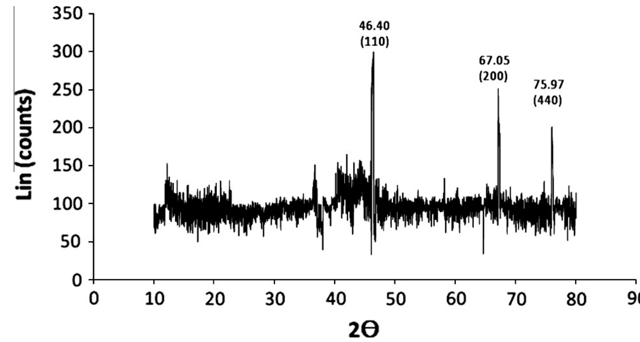

Fig. 4. Representative XRD pattern of phytogenic stabilized ZVNI particles.

and causes dermatitis, rhinitis and lung cancer and is on the top priority list of toxic pollutants defined by USEPA [4]. In recent years nanoscale zerovalent iron (ZVNI) has received much attention for its potential applications in the effective remediation of contaminated soils and water. Since various technologies were available to remove heavy metal from water, the nanoscale zerovalent iron is reported as an ideal candidate for *in situ* remediation because of its large active surface area and high heavy metal adsorption capacity [5,6].

Different methods were employed to prepare ZVNI particles including sodium borohydride ($NaBH_4$), ethylene glycol and carbothermal synthesis. The nanoparticles prepared using these conventional methods would agglomerate rapidly in clusters [7] or react quickly with the reactive oxidisable media (e.g., dissolved oxygen or water) [8], resulting in the formation of large particles and reduce their rapid reactivity rendering them undeliverable to the targeted contaminant locations. As a consequence, new processes are being investigated to prepare stable nanoparticles using stabilizers such as a soluble polymer or surfactant onto the nanoparticles [9]. Several studies have been carried out in order to obtain stabilized ZVNI, and different stabilizing agents have been used to prevent agglomeration of ZVNI, including resin [10], Fe_3O_4 particles [11], starch [12], carboxymethyl cellulose (CMC) [13], and chitosan [14]. Biosynthesis of metallic nanoparticles is useful not only because of its reduced environmental impact [15] compared with some of the physicochemical production methods, but also because it can be used to produce large quantities of nanoparticles that are free of contamination and have a well-defined size and morphology [16]. The better defined size and morphology of biosynthetic nanoparticles than some of the physicochemical methods of production are reported [17]. Plant extracts may act both as reducing agents and stabilizing agents in the synthesis of nanoparticles [18]. Typically, a plant extract-mediated bio-reduction involves mixing the aqueous extract with an aqueous solution of the relevant metal salt. The reaction occurs at room temperature and is generally complete within a few minutes. An additional advantage of this nanoiron green synthesis process is that it

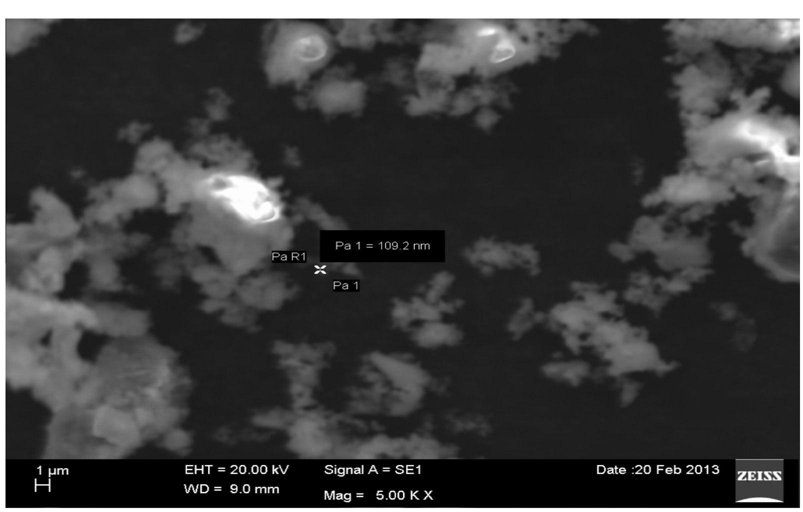

Fig. 3. Representative SEM image of iron nanoparticles synthesized using *E. globulus* extract.