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Synthesis and application of biocompatible nontoxic nanoparticles for reclamation of Ce^{3+} from synthetic wastewater: Toxicity assessment, kinetic, isotherm and thermodynamic study

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Abstract

The aim of present study is to synthesize forsterite nanoparticles (FRST) for the reclamation of cerium ions (Ce^{3+}) from synthetic wastewater. The aim to synthesize FRST nanoparticles is due to its biocompatible and nontoxic nature. The formation of nanoparticles with average diameter of 58 nm was confirmed by TEM analysis. SEM images of bare FRST nanoparticles show a heterogeneous surface with porous nature. BET surface area of FRST nanoparticles is calculated to be 33.69 m^2/g. The significant uptake of Ce^{3+} ions can be obtained for all the selected concentrations (25–150 mg/L) within 2 h of adsorbent-adsorbate interaction. The pH study shows that by increasing pH from acidic to alkaline range, higher removal can be achieved. Temperature study demonstrates the endothermic nature of Ce^{3+} adsorption. The value of sticking probability suggests very high sticking probability of Ce^{3+} ion for FRST nanoparticles. Ce^{3+} uptake is favored by higher temperature and with the increase in temperature from 298 to 328K, Langmuir adsorption capacity increases from 36.45 to 42.99 m^2/g. Applicability of FRST nanoparticles was also investigated for other light and heavy rare earth elements in single solute and multisolute systems. FRST nanoparticles show the significant removal of divalent metallic pollutants as well. The assessment of chemical toxicity of treated wastewater was carried out with the bioluminescent photobacterium (*Vibrio fischeri*) and decreased toxicity was observed in treated water samples. The outcome of present study suggests that the FRST nanoparticles can be efficiently utilized for the removal of Ce^{3+} ions and a wide range of other pollutant species as well.

Keywords: Forsterite; Rare earth elements; Isotherm model; Cerium; Metallic pollutants.

1. Introduction

Due to rapid industrialization, large amounts of metallic pollutants and other contaminants are being released into water streams. Lanthanides are widely used in various fields due to their peculiar properties and used in several fields such as electronics, functional materials, magnetism, semiconductor industry, laser, metallurgy, phosphors, glass, catalysts, fiber optics/superconductors, ceramic, medicine and some fertilizers in agriculture, battery alloys, etc.[1–7] Due to variety of applications and the development of new technologies, there is an increasing demand for rare earth elements(REEs).[8-11]

Due to anthropogenic activities, metallic pollutants end up in the environment due to lack of efficient technologies and resulting variety of environmental threats and health issues due to their accumulation in the environment. To reduce negative impact of pollutants on environment, wastewater should be properly treated prior to their discharge into the environment. Several treatment methods have been developed for reclamation of lanthanides viz. ion exchange, solid-phase extraction, liquid-liquid extraction separations, adsorption, co-precipitation, solid–liquid extraction, ion-exchange, and precipitation.[1,8,12,13] Conventional separation methods such as solvent extraction and precipitation have complicated operation, lack of selectivity etc.[1] It is the demand of present time to develop efficient cost effective techniques for the remediation of metal contaminated wastewater. Among different available techniques, adsorption is a quite promising and suitable technique due to its simplicity in operation. Possibility of utilization of low-cost materials as an adsorbent material, further make this process cost-