The Surface Modification on the Surface of magnetic Nanocrystals for Biological and Environmental Applications

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Abstract

superparamagnetic Fe_3O_4 nanocrystals synthesized by a chemical co-precipitation technique were modified with humic acid containing carboxylic acid, phenolic hydroxyl and quinone functional groups. The as-synthesized products were high soluble in water and used as magnetic resonance imaging (MRI) contrast agents and adsorbents for removal of cationic organic dye Methylene blue (MB) from neutral water.

Introduction

Superparamagnetic iron oxide nanoparticles with appropriate surface moiety have recently attracted a great deal of attention due to their potential biological applications[1], such as, bioseparation, biosensor, biocatalysis, hyperthermia, MRI image contrasting and specific cell labeling and tracking. Meanwhile, their applications in wastewater treatment have aroused more and more concerns, because magnetic separation techniques are generally superior to filtering or centrifugation based purification techniques, as magnetic nanoparticles could be easily extracted from the solution with high selectivity and efficiency by applying an external magnetic field [2]. In this presentation, we prepared superparamagnetic Fe_3O_4 nanocrystals coated with humic acid and used them as magnetic resonance imaging (MRI) contrast agents and adsorbents for removal of cationic organic dye Methylene blue (MB) from neutral water.

Experiments

The superparamagnetic nanocrystals were synthesized by the chemical co-precipitation of ferrous and ferric salts in a basic aqueous solution with humic acid as coating agents. Animals study was performed using adult male Wistar rats (about 180 g). Nanoparticles were applied in a concentration of 0.6 mg of Fe/kg of rat body weight in 1mL of 0.9% NaCl solution through intravenous injection into a tail vein and the liver was scanned using a 1.5T-MR scanner before injection and at 5 minutes after injection. A common cationic organic dye Methylene blue (MB) applied in various industries was used as a model sample of organic pollutant to investigate the adsorption property of the as-synthesized products as well as bare Fe_3O_4 nanoparticles, humic acid powders and activated carbon particles. The concentration of MB in the solution was determined by measuring the absorbance by UV-visible spectrophotometry at 665 nm.

Results and discussion

T2WI images of a live rat obtained by magnetic resonance tomography are shown in figure 1. Only 5 minutes after injection, the liver was found to be significantly darker (figure 1b) than that before injection (figure 1a) corresponding to the increased contrast signal. The as-synthesized samples can increase the sensitivity and differentiation between normal and pathologic tissue in the liver.

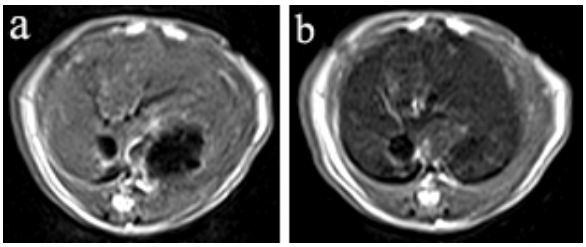

Figure 1. Images of a live rat obtained by magnetic resonance tomography. a. T2WI image before injection and b. T2WI image at 5 minutes after injection

Figure 2 displays the adsorption rate of MB at 25℃ on 50 mg of Fe_3O_4 nanoparticles, humic acid powders, activated carbon particles and humic coated Fe_3O_4 nanoparticles. The humic coated Fe_3O_4 nanoparticles could remove over 96% of MB within only 5 min and 99% in 30 min as shown by curve d of figure 2. We estimate that 1g humic acid coated Fe_3O_4 nanoparticles can remove about 100 mg MB.

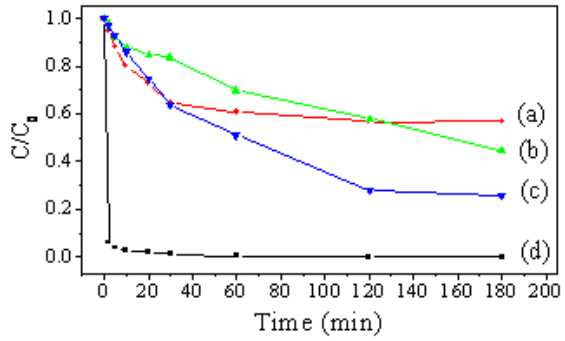

Figure 2. Adsorption rate of MB on 50mg of (a) Fe_3O_4, (b) HA, (c) AC, d) humic coated Fe_3O_4 nanoparticles . Conditions: 50mL 100mg/L of aqueous MB solution without pH adjustment

However, within 2 h, the bare Fe_3O_4 nanoparticles can only remove 43% of MB with removal capacity of 43 mg MB/g Fe_3O_4 (curve a of figure 2) and humic acid powders can remove 55.4% of MB with removal capacity of 55.4 mg MB/g humic acid (curve b of figure 2). It is clear that both the adsorption rate and removal capacity of humic acid coated Fe_3O_4 nanoparticles are extremely better than bare Fe_3O_4 nanoparticles and humic acid powders, even activated carbon particles (removal capacity of 74 mg MB/g activated carbon, curve c of figure 2). These may be attributed to the presence of large numbers of functional groups on the surface of humic acid coated Fe_3O_4 nanocrystals. Moreover, the MB desorption could be easily completed using a methanol solution containing 10% acetic acid. Both the adsorption and desorption rates were quite rapid for minor internal diffusion resistance. The recovery and reuse of adsorbents and dyes were also simple and high efficient.

Summary

The humic acid coated superparamagnetic Fe_3O_4 nanocrystals with large numbers of functional groups have potential applications in Biological and Environmental science.

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