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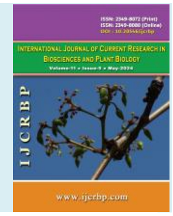

Original Research Article

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Arsenic evacuation from industrial wastewater through magnetite nanoparticles

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Abstract

Many biological and medical fields, including enzyme and protein immobilization, genes, magnetic resonance imaging (MRI), diagnostics, RNA and DNA purification, and magnetic cell separation and purification, use magnetic particles extensively. This study examined the role of magnetite nanoparticles in the extraction of arsenic from groundwater and industrial sources. The creation of a sustainable water treatment system and the adsorption of As onto magnetic nanoparticles that are free of surfactants and soluble in water are the main objectives of the work. A straightforward precipitation method was tried to create magnetite (Fe3O4) nanoparticles with a regulated size without the need for a high-temperature calcination phase. In order to remove bacteria and heavy metals from water, this study develops a flexible water treatment system using magnetic nanoparticles. Magnetite nanoparticles were synthesized by sol-gel method and characterized by SEM images. Magnetite nanoparticles with a diameter of 15 nm have been applied to enforce the sedimentation of the solid waste to absorb the arsenic ions in water in the area of water purification. The arsenic removal capacity was evaluated for the synthesized nanoparticle.

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Introduction

Synthesis of magnetite (Fe_3O_4) nanoparticles has long been of great interest because of their immense technological applications especially in the form of ferrofluids. A ferrofluid is a colloidal suspension of suitably coated magnetite particles in a liquid medium having unusual properties due to the simultaneous fluid mechanic effects and magnetic effects (Enzel et al., 1999). Its widespread applications are in the form of seals to protect high speed CD drives, as rotary shaft seals, for improving performance of audio speakers, in oscillation damping and position sensing (Moses and Zurek, 2008). The reveal so promising future biomedical applications of ferrofluids. Nanoparticles with super-paramagnetic properties have great potential to achieve such desirable properties. Various methods have been developed to synthesize Fe_3O_4 particles in nanometer size range (Enzel et al., 1999). However, the magnetic properties of magnetite based nanoparticles or films highly depend upon the synthesis procedure (Margulies et al., 1996; Sena et al., 1997; Voogt et al., 1998). Here we report a novel and simple chemical route to produce magnetite (Fe_3O_4) nanoparticles in a size range of 5 nm to100 nm without calcination at high temperatures. Size effect studies conducted on these nanoparticles help to optimize the size of Fe_3O_4 particles suitable for ferro fluid formation and some other applications.

Nanoparticle (or nano powder or nanocluster or nanocrystal) is a microscopic particle with at least one dimension less than 100 nm. Nanoparticle research is currently an area of intense scientific research, due to a wide variety of potential applications in biomedical, optical, and electronic fields. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. Iron oxide nanoparticles are iron oxide particles with diameters between about 1 and 100 nanometers. The two main forms are magnetite (Fe_3O_4) and its oxidized form maghemite (γ-Fe_2O_3). They have attracted extensive interest due to their superparamagnetic properties and their potential applications in many fields (although Co and Niare also highly magnetic materials, they are toxic and easily oxidized). The magnetite particles thus produced were then characterized by various techniques. X-ray diffractometer (XRD) was used for structural phase identification. Coherently diffracting domain size (dxrd)was calculated from the width of the XRD peak under the Scherrer approximation (which assumes the small crystallite size to be the cause of line broadening) after correcting for instrumental broadening. Scanning electron microscope (SEM) was used to find out morphology of the nano- many other oxide systems oxygen deficiencies with reduction in size has been observed(Voogt et al., 1998; Palkar *et al*., 1993).

Magnetic transition temperature (TM) was determined using differential thermal analyzer (DTA). The saturation magnetization (MS) was measured using a SQUID magnetometer. Environmental pollution in certain areas of the world is becoming more and more severe. Water is one of the basic necessities required for sustaining life. With the process of industrialization and urbanization, global water utilization has doubled every 15 years. According to the data of the World Health Organization (WHO), the scarcity of water resources has created challenges for over 40% of the world population, i.e., more than 2 billion people have no access to enough or clean water. Meanwhile, industrial and urban activities have led to increasing concentrations of a wide range of pollutants in groundwater and wastewater, affecting the health of millions of people worldwide. So ground water remediation and waste water treatment are of critical importance. Arsenic is a heavy metal contamination in water which should be removed by special adsorbing techniques. Magnetite nanoparticles have been applied widely to remove the arsenic molecules from water. The size of the nanoparticle also plays a role in adsorbing capacity of the particle. The size of the particle was evaluated by SEM.

Materials and methods

Chemicals and reagents

The chemicals used in this study were mostly reagent as received (Merck Co) without further treatment. The chemicals used were NaAs, $FeCl_2$, $FeCl_3$, ammonia solution and NaOH. All chemicals solution were prepared with deaerated deionized water with 99.9% nitrogen for 2hour. In the laboratory, magnetite nanoparticles was prepared by developing the existing sol-gel method.

Synthesis of magnetite nanoparticles

First, 200 ml^{-1} of purified, deoxygenated water (resistivity of 18MΏ) will be bubbled by nitrogen gas for 30 min. Then 5.2 g $FeCl_3$ and 2 g $FeCl_2$ will be dissolved in the above mixture with mechanical stirring. Under the protection of nitrogen gas, 1.5 mol l-1 NH_4OH solution will be added dropwise into the above mixture under vigorous stirring. After an initial brown precipitate, a black precipitate will be formed.

Characterization of magnetite nanoparticles

When pH reached 8, the stirrer was turned off and magnetite settled gradually. The black precipitate formed will be isolated by an external magnetic field and the supernatant decanted. This will be characterized for further structural analysis.

Arsenic removal using nanoparticles

The arsenic contaminated water sample was used to study the adsorption ability of NPs. The adsorption process occurred when 0.25 l was used (1.5 g of nanoparticles were stirred in 1 l of the arsenic solution) for a time period from 1 min to 60 min; then, the nanoparticles were collected by using an external magnet. The remaining solution was subjected to atomic absorption spectroscopy (AAS) to determine the arsenic concentration remaining in the solution.

SEM analysis

The size of the nanoparticles was evaluated by SEM. Slides were prepared with the nanoparticles and the SEM images were taken. SEM Make: Hitachi, Model: S-3400N *Essential Features:* Resolution upto: 3nm@30kV HV mode; 10nm @3 kV HV mode *Detectors:* Secondary Electron; Semiconductor BSE (Quad type), *Magnification:* 5x to 300,000x; *Vacuum System:* TMP & Rotary: 1.5 x 10 -3 Pa

Collection of arsenic contaminant water samples

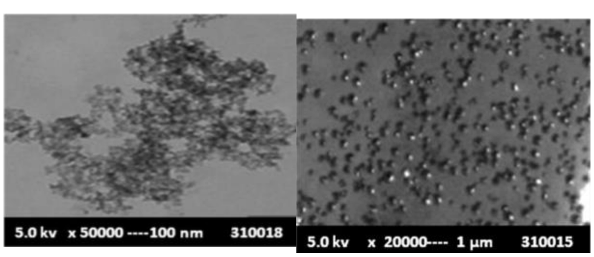
The water sample was collected from Neyveli Lignite Corporation, Neyveli Tamil Nadu. The collected samples were (1 l) evaluated for arsenic level using Atomic absorption spectrophotometry in Pharma analytical laboratory Pondicherry. It is used for arsenic removal experiments.

Results

Characterization

Nanoparticles:

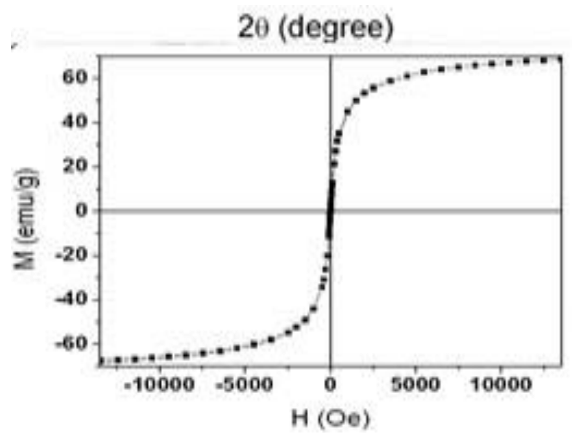
SEM images of magnetite nanoparticles



The SEM images revealed that the nanoparticles are spherical in shape with size varying from10-15nm.The particle mean size was 10.8nm.The melting temperature was 535ºC and the saturation magnetization was 2.6 μBfu^{-1}.

Magnetization curve of magnetite nanoparticles

The field dependence of the magnetization of the magnetite nanoparticles showed that the samples were superparamagnetic at room temperature.



Arsenic removal

The removal of arsenic from contaminated water was done with increasing time interval from 0min to 60 min. As the time increases the arsenic concentration in the water decreases which is the evidence of magnetite nanoparticles to remove the As from contaminated water.

Time and Concentration of Arsenic removal

Time (min)	As concentration (µM)
0	50
5	45
10	42
30	30
60	10

Discussion

Magnetic nanoparticles are useful in biological and environmental applications. A combination of magnetic nanoparticles and a traditional way of water treatment helped to foster the sedimentation of the solid waste in water and to adsorb arsenic ions. The magnetic behavior of the nanoparticles makes possible their separation from the sample solution after the treatment. The study demonstrated that ultra small NPs are a good candidate material for efficient removal of As in water. Itis feasible to synthesize a composite of larger size to retain its magnetic characteristics, adsorption capacity removal of As exhibiting fast kinetics. They serve as a very promising alternative to removing As from contaminated groundwater or drinking water due to their high compatibility with current water treatment technologies.

Conclusions

The nanoparticles were spherical and the mean size was 10 nm. The magnetite nanoparticle synthesized by sol-gel method was a promising tool to remove the arsenic contamination from water.

Conflict of interest statement

Authors declare that they have no conflict of interest.

Acknowledgement

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