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Short Communication

Effect of magnetic iron oxide nanoparticles in surface water treatment: Trace minerals and microbes

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HIGHLIGHTS

- ▶ Protein-functionalized and magnetic iron oxide nanoparticles for surface water treatment.
- ▶ No significant difference in mineral ion concentration.
- ▶ Effective reduction of microbial content and turbidity levels.
- ▶ The application of nanoparticles, could be a complement to the existing treatment process.

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ABSTRACT

The existing water treatment process often uses chemicals, which is of high health and environmental concern. The present study focused on the efficiency of microemulsion prepared magnetic iron oxide nanoparticles (ME-MIONs) and protein-functionalized nanoparticles (MOCP + ME-MIONs) in water treatment. Their influence on mineral ions and microorganisms present in the surface water from lake Brunnsviken and Örlången, Sweden were investigated. Ion analysis of water samples before and after treatment with nanoparticles was performed. Microbial content was analyzed by colony forming units (CFU/ml). The results impart that ME-MIONs could reduce the water turbidity even in low turbid water samples. Reduction of microbial content (98%) was observed at 37 °C and more than 90% reduction was seen at RT and 30 °C when compared to untreated samples from lake Örlången. The investigated surface water treatment method with ME-MIONs was not significantly affecting the mineral ion composition, which implies their potential complement in the existing treatment process.

1. Introduction

Surface water and ground water are being used as a source for water treatment for human consumption. Potable water should be free from biological contaminants (bacteria, viruses, parasites), trace minerals (boron, calcium, chloride, copper, molybdenum, potassium, zinc, magnesium, manganese etc.); and nutrients (phosphate, ammonia, nitrate) (Othman and Abdullah, 2010). Microbial population in fresh water is mostly dependent upon biomass, pH, nutrient composition, temperature and water flow which often leads to the distribution of bacterial taxa (Lindström et al., 2005). Therefore the water treatment process is critical and varies depending on the water quality that enters the treatment plant.

In surface water, most particles including microbes have a negative charge hence they repel each other rather than forming aggregates. Aluminum or ferric ions are usually employed as coagulant agent in water treatment process. However, the presence of aluminum residues in treated water has health and environmental concerns like neurotoxicity and possibly Alzheimer's disease (Rondeau et al., 2001). Besides, the removal of microorganisms is more focused on microbial ecology distribution systems by adding chlorine or ozone or UV treatment that will enhance safety and high quality drinking water (Berry et al., 2006). Nevertheless, the disinfectant by-products are of health concern and the cost of ozone or UV treatment takes away the benefits of the treatment process.

Currently, advances in nanoscale science and engineering suggest that nanomaterials have great potential to improve water quality in a cost-effective way whilst, with increased reduction in the level of water contaminants (Debrassi et al., 2012). Magnetic iron oxide nanoparticles are good candidates for the development of high-capacity sorbents linked with surface modification to enhance their selectivity/affinity for the reduction or removal of chemical ions and microbes in waters (Theron and Walker, 2008). Conversely, adsorption with magnetic iron oxide nanoparticles is considered as

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fast and cost-effective approach to remove water contaminants (Pang et al., 2011).

In order to develop a suitable environmental friendly material for water treatment, magnetic iron oxide nanoparticles were synthesized and characterized by different techniques. The interaction of nanoparticles with natural coagulant protein was also established (Okoli et al., 2012a). Further, study reveals the efficiency of protein-functionalized microemulsion prepared magnetic iron oxide nanoparticles (MOCP + ME-MIONs) in removing water turbidity at high and low initial turbid waters whilst, implying potential application in water treatment (Okoli et al., 2012b) Therefore, it is vital to investigate the stability of the microemulsion prepared magnetic iron oxide nanoparticles and their influence on other mineral ions and suspended particles in surface water.

The aim of the present investigation is to emphasize a novel approach in the use of microemulsion-prepared magnetic iron oxide nanoparticles (ME-MIONs) or functionalized ME-MIONs with *Moringa oleifera* coagulant protein (MOCP + ME-MIONs) in surface water treatment. The influence of ME-MIONs or MOCP + ME-MIONs on the treated waters particularly microbial reduction and other mineral ions were investigated and reported.

2. Methods

The surface water samples were collected from two lakes; Örlången and Brunnsviken in Stockholm, Sweden for the analysis of trace minerals and microbial content.

2.1. Synthesis of magnetic nanoparticles and protein binding

ME-MIONs was prepared in *w/o* microemulsion system using the single-step mode of preparation (Okoli et al., 2011). Briefly, a precursor solution containing 2:1 M ratio of iron salts was dissolved in Milli-Q water. The addition of precursor solution to the mixture of CTAB/1-butanol/n-octane will result in the formation of a microemulsion. Magnetic nanoparticles were formed by the addition of a precipitating agent (aqueous NH_3) drop wise to the microemulsion containing the precursor upon vigorous stirring. The resultant ME-MIONs were washed and suspended in Milli-Q water until further use.

Protein binding was achieved by equilibrating the microemulsion prepared magnetic nanoparticles (6–10 nm size) with 10 mM ammonium acetate buffer, pH 6.7. Protein-functionalized magnetic nanoparticles (MOCP + ME-MIONs) were prepared as described earlier (Okoli et al., 2012a). The developed MOCP + ME-MIONs was suspended in ammonium acetate buffer and kept at 4 °C or freeze-dried prior to use.

2.2. Water treatment with magnetic nanoparticles

The surface water samples (100 ml) were mixed with nanoparticles (100 mg/L) at a slow speed using a rotator (25 rpm) in order to achieve maximum adsorption of the ions onto the ME-MIONs or MOCP + ME-MIONs. The samples were incubated for 1 h and the nanoparticles was separated from water samples using an external magnet. All the analyses were performed in duplicates and the results were analyzed. Turbidity of all the samples was also measured in NTU (Nephelometric Turbidity Unit) using Hach 2100Q IS Portable tubidimeter.

2.3. Ion analysis

Chemical analysis (17 compounds – nitrate, nitrogen, phosphorous, potassium, magnesium, calcium, sulfur, sodium, chloride, manganese, boron, copper, iron, zinc, molybdenum, silicon and aluminum), pH and conductivity of the treated and untreated water sample were carried out. The untreated water sample was used as a control in order to determine the efficiency of the nanoparticles (ME-MIONs) in water treatment. A 50 ml of each sample and control were sent to LMI (Lennart Månsson International) AB, Helsingborg, Sweden for the ion analysis.

A stock solution of potassium phosphate and copper sulfate (100 mg/l) was prepared using Milli-Q water. The nanoparticles were mixed with simulated water containing phosphate and copper at a concentration of 10 and 1 mg/l and the experiment was performed as mentioned in Section 2.2. The phosphate concentration was measured using Hach method (Phosver® 3 phosphate reagent, Hach Powder Pillow) and copper using Merck Spectraquant.

2.4. Microbial analysis

The microbial content (Colony Forming Units; CFU/ml) was analyzed by plating untreated and ME-MIONs treated water samples on Nutrient Agar (NA) plates. The CFU was obtained for 7 days after incubation at different conditions (Room Temperature (RT), 30 and 37 °C). The number of colonies representing Gram negative and Gram-positive organisms, the water sample was plated on NA; MacConkey; Phenyl ethyl Agar and colonies were observed after 48 h.

3. Results and discussion

3.1. Synthesis of magnetic nanoparticles

Magnetic nanoparticles has been synthesized by water in oil *(w/o)* microemulsion system with single-step preparation and characterized with XRD (X-ray Diffraction), FT-IR (Fourier Transform Infrared Spectroscopy, TEM (Transmission Electron Microscope) and VSM (Vibrating Sample Magnetometer). Using the above techniques, size, morphology, agglomeration and diffraction patterns were obtained for ME-MIONs. The magnetic property determined by VSM studies reveals that the saturation magnetization susceptibility was 25 emu/g. Detailed characterization of nanoparticles has been reported in our previous studies (Okoli et al., 2012a).

3.2. Water treatment with magnetic nanoparticles

The treatment of lake waters was performed using synthesized ME-MIONs. The magnetic property of ME-MIONs helps in fastening the separation time and facile recovery of nanoparticles using an external magnetic field. The complete process was performed in 1 h and the results are further discussed.

Lake water samples from Brunnsviken and Örlången were treated with ME-MIONs. The treated water samples showed more than 50% reduction in turbidity even at low levels of NTU (Initial 6 to final <2 NTU). Earlier studies reported that MOCP + ME-MIONs were efficient in removing suspended particles both in high and low turbid water as compared to that of aluminum sulfate (alum) (Okoli et al., 2012b).

3.3. Ion analysis

The effect of ME-MIONs on mineral ion composition of the surface water was investigated. The water sample from lake Brunnsviken was treated with ME-MIONs and the mineral ion concentration before and after treatment was shown in Table 1. The pH and conductivity values were similar before and after treatment in the water from lake Brunnsviken. All the 17 investigated trace mineral ions were at very low concentration in the lake water.