

Magnetic Charcoal Supporting Silver as a Water Disinfectant

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We investigated the magnetic behavior of charcoal composite with incorporated magnetite and silver ions. The magnetization curve measured at 282 K showed saturation magnetization of 8 emu/g. By benefiting from a mechanical process, the magnetic activated carbon, supporting silver ions (MCAG), acts as a magnetic filter uptaking the bacteria. This idea was confirmed by the DGGE analysis in which the bacterial DNA was detectable in the sediment after the treatment.

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1. Introduction

Materials that contain nanomagnets have shown great potential for use in advanced applications because of their exceptional properties [1]. Of special interest are those materials that exhibit superparamagnetic behavior at room temperature. In groundwater treatment applications, the development of superparamagnetic composites has gained a considerable attention due to possible simplification of the separation process that normally involves complex and expensive procedures such as filtration or centrifugation. The possibility of low-cost production drives the scientific interest to this subject.

We introduced a novel procedure for the preparation of activated carbon (charcoal) composite in which magnetite nanoparticles are incorporated inside the pores of an activated carbon using a modified version of the approach which has been previously described in Ref. 2. This material (denoted as MC) was then surface-modified with silver ions to bear antimicrobial properties for advanced applications, particularly the disinfection of surface water. Here we report combined properties of such final composites.

2. General information

The magnetite incorporated charcoals (MC) were prepared as reported previously [3]. The following batch adsorption of silver ions onto the MC was performed using a precise volume of silver nitrate solution as we published previously [3].

The magnetic properties of the MCAG were recorded at 282 K using a SQUID magnetometer (Quantum Design MpMS 5XL). The saturation magnetization was obtained from the magnetization curve registered in applied magnetic field of up to 6 T.

The magnetic activated carbon, supporting silver ions (MCAG) was tested for the efficacy of removing bacteria from the river water samples along with water disinfection tests [3]. The total bacterial DNAs from river water samples and magnetic sediments were extracted using the Ultra CleanTM Soil DNA kit (Mobio). The potential DNAs from magnetic supernatants were isolated by ethanol precipitation. All PCR reactions were carried as described previously [4]. The obtained 16S rDNA fragments were subsequently used as templates for the second round of PCR, using specific bacterial primers GC-clamp-968f and 1401r. The cycling conditions were applied as already mentioned [4]. PCR products generated with GC-968f and 1401r primers were subjected to DGGE analysis performed by using DCodeTM Universal Mutation Detection System (Bio-Rad). The total volume of 45 μ l samples were loaded onto 8% (w/v) polyacrylamide gel (40% Acrylamide-Bis 37.5:1) in 1 \times TAE (40 mM Tris, 20 mM acetate, 1 mM EDTA) containing a linear denaturing gradient ranging from 30-60% denaturant (100% denaturant solution consists of 7 M urea and 40% formamide). Electrophoresis was run for 17 h at a constant voltage of 50 V and the temperature of 60 °C. After the electrophoresis, the gel was incubated for 20 min in ethidium bromide (0.5 μ g/ml), rinsed for 20 min in distilled water, and photographed with UV transillumination using Gel Logic Imaging System.

3. Results and discussion

The activated carbon with incorporated magnetite composites (MC) are excellent adsorbents. Their adsorptivity is high, thus allowing progressive binding of silver ions [3]. The resulting MCAG composite possess stability against Ag⁺ leaching [3] and can be adopted for further studies. We assumed previously that the MCAG bearing 20% sorbed AgNO₃ (w/w) is stable, non-toxic [3] and thus is applicable for the following studies.

In order to prove the magnetic behavior of MCAG composites, the measurement of magnetization versus applied magnetic field was performed at room temperature.

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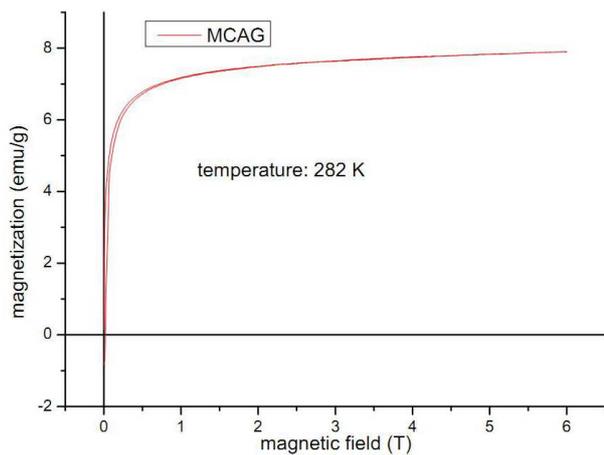


Fig. 1. Magnetization vs. applied field curve at 282 K for the magnetite incorporated onto charcoals bearing silver ions (MCAG).

The obtained magnetization curve, presented in Fig. 1, is dependent on the magnitude of the applied field. The saturation magnetization obtained from this dependence is 8 emu/g at 282 K and 6 T. The saturated shape of the curve reflects the superparamagnetic-like behavior of MCAG. The obtained value of saturation magnetization is less than that 34 emu/g for bare magnetite nanoparticles with ultrafine nature [5], prepared in a same manner as for MCAG [3]. A smaller magnetization value is comparable to that published previously by Fuertes group [1]. A decrease of magnetic susceptibility has previously been attributed to residing of major magnetite nanoparticles inside the pores [1].

The antimicrobial capabilities of the prepared MCAG were previously [3] examined using water disinfection test. The bacterial counts in the river water samples (1×10^3 to 1×10^5) which were treated for 30 min using $1 \text{ g} \cdot \text{l}^{-1}$ of MCAG at room temperature, were reduced by five orders of magnitude. Thus, the removal of all bacteria from the surface water samples is a consequence of suggested mechanical process, in which positively charged surfaces of MCAG were able to attract negatively charged bacteria with subsequent disruption of bacterial membrane [3]. The unambiguous destruction of bacterial cells by MCAG was confirmed by DGGE analysis of the whole microbial community of river water including unculturable bacteria. The spectrum of the PCR amplified DNA fragments from the river water, treated supernatant and magnetic sediment samples is shown in the Fig. 2. A part of bacteria is lysed already during the 30 min treatment period (Fig. 2, line 3 - supernatant). Many species were eliminated. On the other hand, the spectrum of 16S rRNA genes in the magnetic sediment indicates that sediment of treated water sample

involved huge DNAs, probably from live and died bacteria (Fig. 2, line 2 - magnetic sediment). This method documented the efficiency of MCAG treatment of the surface river water, despite the presence in water of a complex microbial community.

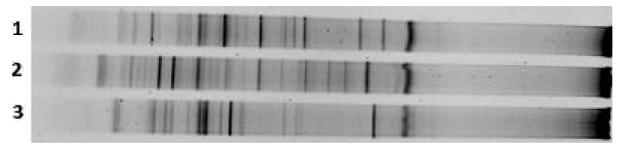


Fig. 2. DGGE patterns of 16S rRNA gene fragments amplified with the primers 1401r/968f-GC from DNA templates, extracted from bacterial species presented in river water sample (1), sediment (2) and supernatant (3) after 30 min. treatment with MCAG.

4. Conclusions

The activated carbon with incorporated magnetite and silver ions (MCAG) exhibited superparamagnetic properties. These allow MCAG to be separated easily with a permanent magnet from the water after the bactericidal effect has occurred, thus avoiding any adverse environmental effects. The combination of magnetic character and biocidal efficiency introduces MCAG as an excellent candidate for the simple ambulatory disinfection of surface water.

Acknowledgments

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