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Effect of microbes on Ni(II) diffusion onto sepiolite

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ABSTRACT

The effect of *Paecilomyces cateniannulatus* (*P. cateniannulatus*) on Ni(II) diffusion onto sepiolite was investigated by batch adsorption and their interaction mechanisms were determined by surface complexation modeling. At low pH, the diffusion of Ni(II) on sepiocite and sepiocite + *P. cateniannulatus* systems is primarily cation exchange and inner-sphere surface complexation, respectively. *P. cateniannulatus* facilitated the Ni(II) diffusion on sepiocite at pH < 5.0, whereas the inhibited diffusion was observed at pH > 5.0. According to surface complexation modeling, the diffusion of Ni(II) on sepiolite can be satisfactorily fitted by diffuse layer model with single amphoteric sorption sites (SOH) and ion exchange sites (XH), whereas the three type sites (strong sites (SsOH), weak sites (SwOH) and ion exchange sites (XH)) are assumed for sepiocite + *P. cateniannulatus* systems. The findings presented in this study are of great importance towards the investigation on Ni(II) diffusion at the water–mineral interface in the presence of bacteria.

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1. Introduction

Nickel (Ni(II)), a toxic heavy metal, has been extensively used in coinage batteries, electroplating and pesticides [1–3]. The excess discharge of Ni(II) into environments could cause illness such as hepatitis, anemia and diarrhea [4]. Therefore, it is mandatory to decrease the concentration of Ni(II) below its permissible limit (0.02 mg/L) according to WHO drinking water quality standards [5]. The diffusion of Ni(II) at water–mineral interfaces is correlated with the fate and transformation of Ni(II) in sub-environments. In recent years, there are plenty of literatures regarding the diffusion of Ni(II) on clay minerals such as kaolinite [6–8], montmorillonite [9–13] and illite [14–18]. Bradbury and Baeyens simulated the sorption of Ni(II) on illite very well by surface complexation modeling [17].

Sepiolite is one of the traditional 2:1 type phyllosilicate, which consists of one Al^{3+} octahedral sheet between two Si^{4+} tetrahedral sheets in a unit layer [46,47]. The main chemical component of sepiolite is $Si_{12}Mg_8O_{30}(OH)_6(OH_2)_4 \cdot 8H_2O$ [45], and a schematic diagram of the sepiolite structure was shown in Schematic 1. Sepiolite has been proved to be good candidate as sorbent for the removal of heavy metal ions such as Cd (II), Co(II) and Zn(II) owing to its high theoretical surface area (900 m^2/g), good chemical stability, and the micro-fibrous structure [48–50]. However, to the authors' knowledge, the reports on diffusion of Ni(II) on sepiolite are still scarce.

Microbes as an inherent part of groundwater play a vital role in the fate and transport of Ni(II) in sub-surface environments. The bioadsorption of Ni(II) has been observed by various microbes such as ureolytic mixed culture [19], *Litchi chinensis* [20], algal cells [21], fungi [22], and *Sargassum filipendula* [23]. *Paecilomyces cateniannulatus*, carnivorous fungi specialized in trapping and digesting nematodes, has beenextensively used for controlling nematodes. *P. cateniannulatus* can kill harmful nematodes by pathogenesis. It is demonstrated that *P. cateniannulatus* can be used as a promising adsorbent to remove heavy metals such as As(V) [24], Co(II) [25], Cr(VI) [26,27], Ni(II) [28, 29] and Pb(II) [30]. However, to the author's knowledge, little information on the effect of *P. cateniannulatus* on Ni(II) adsorption onto sepiolite is available.

The aims of this study are to investigate the effect of *P. cateniannulatus* on the diffusion of Ni(II) on sepiolite under a series of environmental parameters such as pH, ionic strength and initial Ni(II) concentration. This paper highlights the diffusion of heavy metals at water–mineral interface in the presence of microbes, which play an initial role in the fate and transport of heavy metals at sub-surface environments.

2. Materials and methods

2.1. Materials

The sepiolite sample from Guangming mining plant was purified with 0.1 mol/L HCl under continuous stirring conditions overnight. The stock solution of Ni(II) (1.0 mmol/L) was prepared from $Ni(NO_3)_2$ (99.9% purity) in 0.01 mol/L HNO_3 solution. *P. cateniannulatus* strain was provided from the School of Life Science and Environmental Science, Huangshan University. *P. cateniannulatus* cells were cultured in

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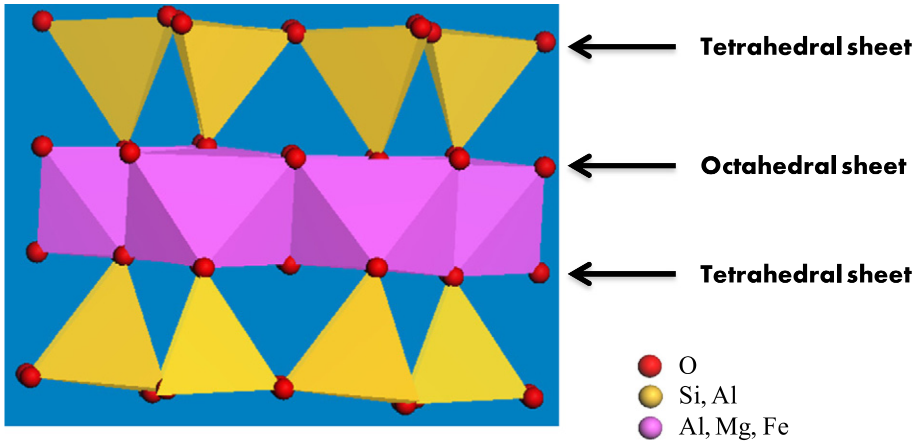

Schematic 1. Schematic structure of sepiolite.

the 10.0 g/L glucose solution with various salt solution such as 2.0 g/L KH_2PO_4, 1.0 g/L NaH_2PO_4, 1.0 g/L NH_4Cl, 0.2 g/L $MgSO_4 \cdot 7H_2O$, 0.01 g/L and $FeSO_4 \cdot 7H_2O$ at 303 K overnight [25]. Then the cells were harvested by centrifugation (3000 ×g, 10 min) during the logarithmic phase and were washed three times using Milli-Q water. All other chemicals used in this work were of analytical grade and were prepared using Milli-Q water. All solutions were sterilized at 120 °C for 30 min.

2.2. Characterization

The morphologies of sepiolite and *P. cateniannulatus* were performed by SEM (JOEL, Japan). FTIR spectra were conducted on JASCO FTIR 410 spectrophotometer in KBr pellet. Briefly, 2.0 mg of sample and 0.2 g KBr were ground, and then pressed into a disc. The spectrum was recorded from 399 to 3999 cm^{-1}. The mineralogy of sepiolite and

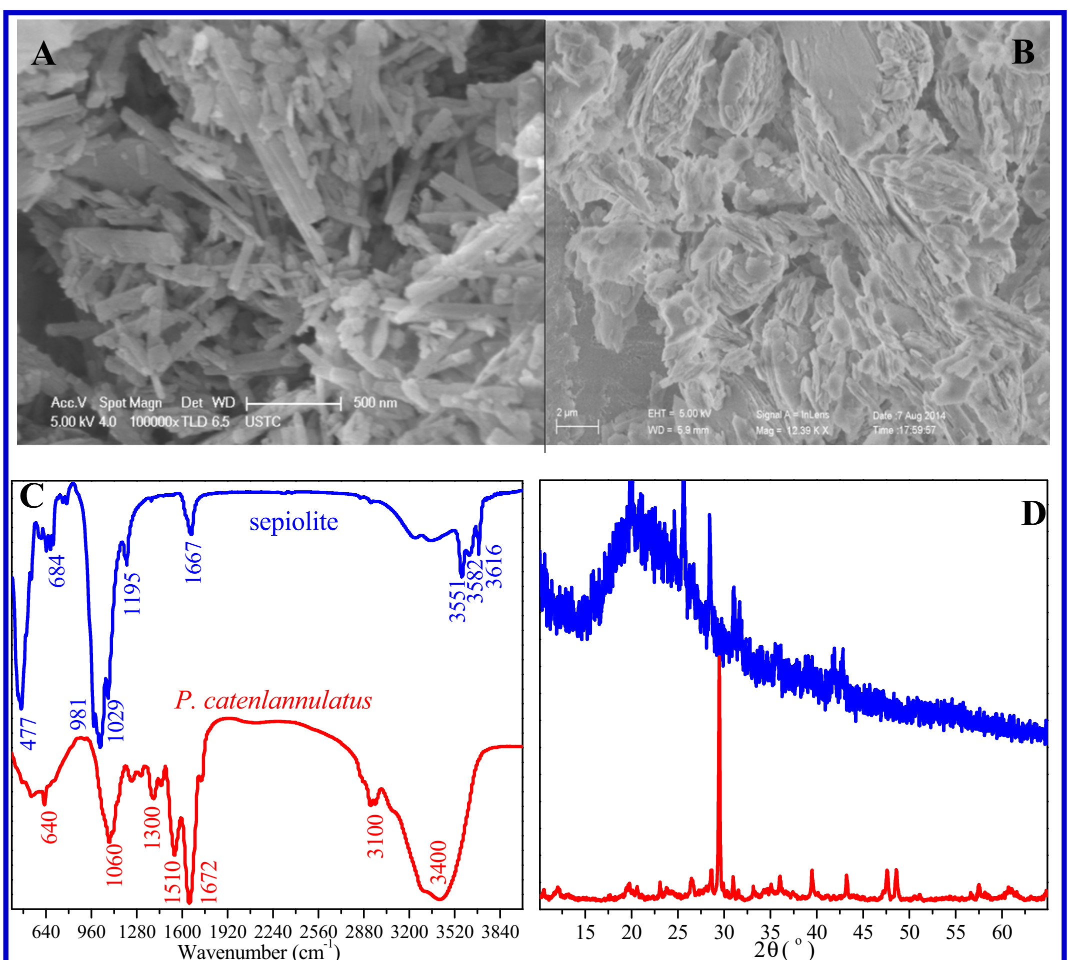

Fig. 1. The characterization of sepiolite and *P. cateniannulatus* used in this study. (A) and (B): SEM images of sepiolite and *P. cateniannulatus*; (C): FT-IR spectra; (D): XRD patterns.

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