Effects of sediment properties and organic matter on biomobilization of arsenic from aquifer sediments in microcosms

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ABSTRACT: In this study, the reducing capacity of the strain *Bacillus cereus* in the two sediments from Datong Basin and Jiangnan Plain was investigated by examining the concentrations of As and Fe and the changes of pH and Eh. Results showed that glucose contributed to the mobilization of As and Fe, and As in the sediment from Jiangnan Plain was released more easily. It was found that *Bacillus cereus* changed the pH and Eh in the surroundings, and promoted the reductive dissolution of As(V) and Fe(III) in the sediments to enhance As in groundwater.

1 INTRODUCTION

Arsenic (As) is an important element for human carcinogen. More and more people are suffering arsenism for long-term drinking arsenic-contaminated groundwater. Mobilization and enrichment of arsenic in groundwater were affected by several environmental factors.

The objectives of this study were to evaluate the influences of sediment properties and organic matter on bacterial migration of arsenic.

2 MATERIALS AND METHODS

2.1 Bacterial culture

The strain *Bacillus cereus* (*B. cereus*) was isolated from the aquifer sediment. The bacterial strain was cultured in modified minimal salt medium (MSM) in an incubator in dark at 25°C for 4 d. Salts supplied per liter of MSM were: 0.14 g KH_2PO_4 , 0.50 g KCl, 1.00 g NaCl, 0.13 g CaCl_2 and 0.62 g $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$. The bacterial cells were harvested by centrifugation at 4000 rpm for 20 min at 4°C. The cell pellets were resuspended and cultured in the fresh MSM for the next experiments.

2.2 Sediment characterization

Total organic C (TOC), As, Fe, pH and mineral size distribution of sediment particles were determined as the methods described in Simmler *et al.* (2016).

2.3 Microcosm experiments

Two sediment samples were collected from high arsenic aquifers at Datong Basin and in Jiangnan Plain. The two samples were named as SDB and SJP, respectively. The microcosms were prepared in 500 mL Erlenmeyer flasks with rubber stoppers. In N_2 -filled glove box, 10 mL of the bacterium in exponential growth phase were incubated in the Erlenmeyer flask

with 0.4 g glucose or 0.5 g fulvic acid, 20 g sieved sediment and 200 mL deionized water. Sediment, Erlenmeyer flask and deionized water were autoclaved prior to use. All the Erlenmeyer flasks were incubated in nitrogen atmosphere, in dark at 25°C. The control groups without organic matter or bacterium were run under the same conditions.

2.4 Chemical analyses of the aqueous phase

Before collecting the samples, pH and Eh were measured directly in the water-sediment system in the N_2 -filled glove box. Dissolved As(III), As(V), Fe(II) and Fe(III) in the solutions from the microcosms were determined. At regular time intervals, 5 mL of sample were removed from each reaction vessel and centrifuged. As(III) and As(V) were separated from the supernatant by a strong anion exchange column and measured by hydride generation-atomic fluorescence spectrometry. Fe(II) and Fe(III) were determined according to the method of Han *et al.* (2011).

3 RESULTS AND DISCUSSION

3.1 Sediment characterization

The content of sand in the two samples was high as shown in Table 1. Nevertheless, sand in SJH had higher percentage. The pH values of SDB and SJP were in slightly alkaline. The contents of TOC in sediments had obvious difference. In addition, the contents of As and Fe in SDB exceeded in SJH. The results indicated that the two sediment samples had different characterization.

3.2 Speciation and mobilization of As and Fe

The concentrations of dissolved As(V), As(III), Fe(III) and Fe(II) in aqueous phase in the microcosm were presented in Figure 1. From the figure, we can see that all the concentrations increased over time under the condition of bacterial activities. The concentrations of

Figure 1. Dissolved As(V), As(III), Fe(III) and Fe(II) in aqueous phase in the microcosm. a) As(V); b) As(III); c) Fe(III); d) Fe(II).

Table 1. Physicochemical characteristics of sediment samples.

	SDB	SJH
pH	7.9	7.6
TOC (%)	0.19	0.56
As (mg kg ⁻¹)	13.3	9.8
Fe ₂ O ₃ (%)	2.89	2.23
Sand (50–2000 µm) (%)	61.7	76.8
Silt (2–50 µm) (%)	27.7	18.3
Clay (<2 µm) (%)	10.6	4.9

As(III) and Fe(II) exceed those of As(V) and Fe(III) at the same sampling time. Additionally, the concentrations except As(V) in SJH microcosm were higher than in SDB microcosm. Glucose contributes to the mobilization of As and Fe. The results suggested that *B. cereus* promoted the reductive dissolution of As(V) and Fe(III) in the sediments.

Figure 2. Change of pH and Eh. a) pH; b) Eh.

3.3 Change of Eh and pH

It was shown that *B. cereus* affected the pH and Eh of the microcosms (Fig. 2). The change of pH and Eh contributed to mobilization of As and Fe.

4 CONCLUSIONS

From this study, it was found that the strain *Bacillus cereus* changed the environment factors and promoted the reductive dissolution of As(V) and Fe(III) in the sediments. Then, As and Fe were released into groundwater from sediments.

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