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Microbial Transformation of Arsenic and Its Transport

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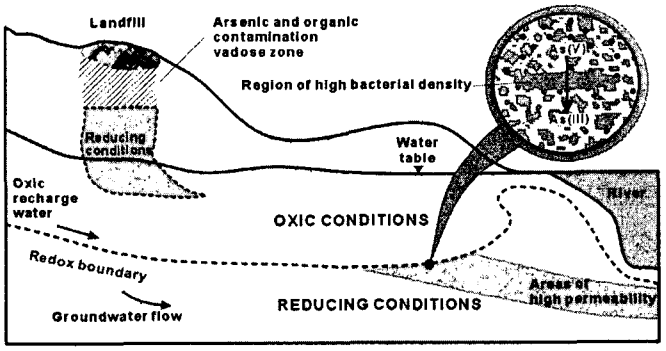
ABSTRACT

Toxic metalloids of abandoned mines, such as arsenic, emerge as a major contaminant. Arsenic occurs in natural waters as arsenite (As^{3+}) or arsenate (As^{5+}). Arsenite is more soluble and toxic than arsenate. Under oxidizing conditions, the predominant form of inorganic arsenic is arsenate, and arsenite prevails under reducing conditions (Figure 1). It is known that microorganisms play a critical role in both the direct reduction and oxidation of the arsenic species. The biogeochemical redox processes and transport behavior need to be coupled with a reactive transport model to predict concentrations of the toxic inorganic arsenic in aqueous phase. The new reaction module describing the fate and transport of inorganic arsenic species was developed and incorporated into the RT3D (Reactive Transport in 3-Dimensions) code.



$$\frac{\partial[CH_2O]}{\partial t} = r_1 = k \cdot [CH_2O] \cdot \left(\frac{[As^{5+}]}{K_{As^{5+}} + [As^{5+}]}\right) \left(\frac{k_{i,O_2}}{k_{i,O_2} + [O_2]}\right) \cdot \left(\frac{k_{i,NO_3^-}}{k_{i,NO_3^-} + [NO_3^-]}\right) \cdot \left(\frac{k_{i,Fe^{3+}}}{k_{i,Fe^{3+}} + [Fe^{3+}]}\right)$$

$$\frac{\partial[As^{5+}]}{\partial t} = r_2 = Y_{As^{5+}/CH_2O} \frac{\partial[CH_2O]}{\partial t}$$

$$\frac{\partial[As^{3+}]}{\partial t} = r_3 = Y_{As^{3+}/CH_2O} \frac{\partial[CH_2O]}{\partial t}$$

Figure 1. Conceptual and mathematical model of microbial As(V)-reduction in a subsurface aquifer (after J. A. Davis et al., 2004, EOS, 85)

To validate the model, laboratory batch and column experiments were conducted (Figure 2). The arsenic transport results obtained from the numerical model were

compared with the experimental results. In the result, the simulated arsenic transport patterns gave a good match with that of experimentally observed arsenic transport (Figure 3).

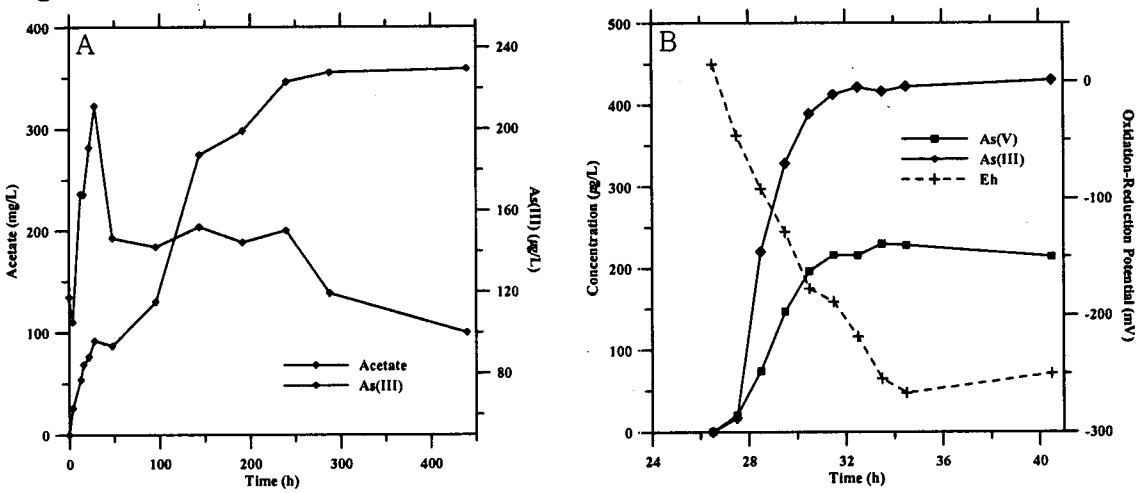


Figure 2. Experimental results of (A) microbial batch and (B) column tests.

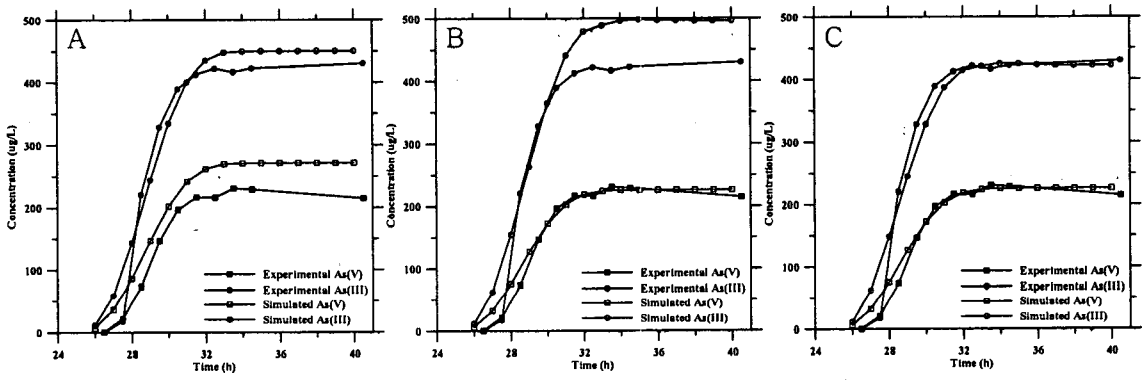


Figure 3. Comparison of experimental results with simulated results for the cases of (A) conservative tracer (Br^-), (B) microbial As(V)-reduction, and (C) microbial As(V)-reduction and precipitation.

The validated transport model of arsenic may be useful to predict the mobilization of arsenic, the evolution of its contaminant plumes, and the fate and transport of arsenic species in groundwater systems.

Key words: Arsenic, Microbial Transformation, Biogeochemical Process, RT3D

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