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Bacterial co-reduction of As(V) and hydrous Fe(III) oxide: Experiments and numerical simulations

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Existing models of inorganic contaminants transfer are mainly based on physico-chemical and geochemical functions. However, it is now accepted that mobility of metals and metalloids in sub-surface also depends on microbial processes, among which, the bacterial reductive dissolution of iron oxides is as key pathway. In this context, the effect of bacterial reduction of synthetic As-spiked 2-Lines ferrihydrite (As-HFO) on the release of As was investigated. On the basis of these batch-reactors experiments, a kinetic model has been developed and tested.

Biotic and abiotic experiments were carried out under anoxic controlled laboratory conditions during 60 days. Suspensions of As-HFO in a modified Fe-reducing growth medium were inoculated with an anaerobic community "FR" of Dissimilatory Iron Reductive Bacteria (DIRB), isolated from a natural soil. At the start of As-HFO incubations, about 15% of the initially adsorbed As(V) exchanged with aqueous PO_4^{3-} that was present in the culture medium. During the first 30 days of incubation, bacteria reduced Fe(III) to Fe(II) which is released at a maximal rate ranged between 1.8 and 2.3 mg Fe(II) (g As-HFO)$^{-1}$day^{-1} normalized with the initial As-HFO amount. No release of arsenic was observed during this phase. In contrast, during the last 30 days, Fe(II) concentration remained constant or decreased whereas As(III) concentration increased in solution with a maximal rate ranged between 0.96 to 1.1 mg As(III) (g As-HFO)$^{-1}$day^{-1}. Mineral analyses (XRD, TEM, XANES) indicated that after 60 days some samples contained vivianite $Fe^{(II)}_3(PO_4)_2.8H_2O$ and magnetite $Fe^{(II)}Fe^{(III)}{}_2O_4$, which formed from the reactions of released aqueous Fe(II) with PO_4^{3-} and ferrihydrite, respectively.

Other experiments with pure strains isolated from "FR" indicated that they are all DIRB and that, at least, one of them reduced also As(V) in solution.

Based on these results, we assumed that As-HFO dissolution is partially due to bacterial co-reduction of As(V) and solid Fe(III) and a numerical model using four kinetics has been developed : (1) reduction of bioavailable Fe(III) oxide surface sites according to a Monod formulation; (2) reduction of As(V) according to biomass; (3) production of biomass coupled to Fe(III) and As(V) reduction; (4) precipitation of magnetite and vivianite. The biogeochemical modeling enabled an evaluation of the effects of each mechanism on the rate of release of arsenic.

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Iron isotopic fractionation during microbial and abiotic oxydation

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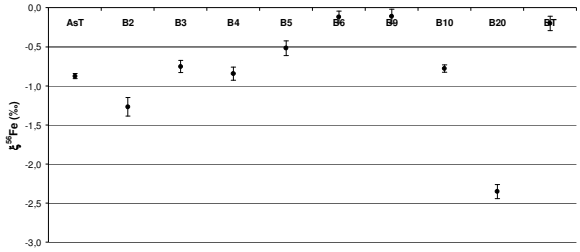
There is now a strong evidence to suggest a mass-dependent isotopic variability for Iron [1] though the extent of the isotopic fractionation, its origin (abiotic *vs*. biotic) and the fractionation mechanism (equilibrium *vs*. kinetic) in natural systems are still under debate as little is yet known about the controls of Iron isotopic fractionation. As surface (im)mobilisation processes for Iron are greatly controlled by microorganisms, there has been a lot of interest in the direct isotopic fractionation by Iron bacteria, either by reduction or oxidation reactions, the micro-organisms using preferentially lighter isotopes. Early work showed that the δ^{56}Fe of bacterially-reduced Fe(II) is 1.3 ‰ lower than the Fe(III) substrate [2]. Further laboratory studies with microbial cultures reveal that Iron oxidizing or reducing bacteria do fractionate Iron isotopically [1, 3]. However much less is know for Iron oxidizing bacteria.

Fe oxidizing bacteria were extracted from a former mining environment, individual strains were separated and Fe II oxidization experiments with the sterilized acid mine drainage



water were carried out with the total population and the individual strains. The extent of isotopic fractionation and its kinetics were dependent on the individual strains. Collectively, the results suggest that the extent of isotopic fractionation during the microbially mediated Iron oxidation is related to the biological activity itself *i.e.* to the oxidizing capability of a given species.

References

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