

Direct and indirect microbiological effects on uranium reduction in natural systems

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In natural systems, the extent and rate of the redox transformations of U are determined by the intricate interplay among biological and abiological processes. There seem to be two major pathways through which U is being reduced in environmental settings: abiological reduction of U by a neutral surface complex (FeIII₂OFeII(OH)) as a reductant, which forms in the coexistence of aqueous Fe(II) species and Fe(III)-bearing minerals. The other pathway is enzymatic reduction of U by Fe(III)-reducing and/or sulfate-reducing microorganisms. Redox potentials of electron acceptors for microbial respiration are generally considered to constrain the order of terminal electron-acceptors utilized by complex microbial communities. In principle, the oxidation of an electron donor coupled to the reduction of an electron acceptor with a higher redox potential is favorable for microbial energy production in comparison to the counterpart with a lower redox potential. As consistent with this principle, the supply of O₂ first promotes the growth of aerobic microorganisms in natural systems. According to the redox ladder, nitrate is the next electron acceptor for microbial metabolism. In the case of Fe(III), the chemical form of Fe(III) has a great influence on the redox potential. For instance, hydrous ferric oxide has a redox potential much higher than that of other solid Fe(III) minerals, and magnetite, hematite and goethite have a redox potential approaching to, or even lower than, that of sulfate. The persistence of some Fe(III) minerals from abiological and biological reduction likely leads to the coexistence of aqueous Fe(II) species and Fe(III) minerals, which appears to promote abiological reduction of U(VI). The occurrence of microbial sulfate reduction depends upon the form of Fe(III) accessible to microbial respiration. H₂S produced by sulfate-reducing microorganisms has inhibitory effects on abiological U(VI) reduction due to the precipitation of iron sulfide minerals, which dramatically decreases the level of aqueous Fe(II) species. Abiological reduction of Fe(III), and the precipitation of iron sulfide, at the surface of Fe(III) oxide minerals by H₂S also make the surface reduction of U(VI) less efficient. Under highly sulfidogenic conditions, enzymatic U(VI) reduction could be the only known mechanism by which U(VI) is actively being reduced. Although sulfate-reducing microorganisms are affiliated to phylogenetically diverse groups, only the members of the genera *Desulfovibrio* are known to mediate enzymatic reduction of U(VI), except for two species of spore-forming sulfate-reducing bacteria. However, these ongoing processes are contrary to the economic geological observations that U accumulation is associated with iron sulfide minerals in the sedimentary U ore deposits. Future researches are needed particularly for addressing differences in pathway through which U is being reduced and preserved for a geological period.