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Anaerobic biodegradation and biotransformation of Ni-citrate complexes at alkaline pH

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Nickel is a significant contaminant in Low- and Intermediate-Level radioactive wastes (LLW/ILW), as both a neutron capture product and from its use in corrosion resistant alloys. The environmental mobility of Ni may be affected by organic ligands, such as citrate, which are also present in wastes. Citrate is expected to increase Ni solubility via complexation, even under alkaline pH levels expected in cementitious repositories for L/ILW [1,2]. Accordingly, understanding the fate of Ni in the presence of citrate informs radioactive waste management practices. The biodegradation/biotransformation of Ni-citrate complexes has been studied previously under neutral pH and/or aerobic conditions [3,4]. To date, there has been little focus on the biogeochemical behaviour of Ni-citrate under alkaline conditions representative of expected L/ILW waste disposal conditions. Here, enrichment experiments were used to explore Ni-citrate biodegradation/biotransformation under nitrate- and sulfate-reducing conditions at pH 9. In both systems, 1 mM citrate was added as both a complexant and electron donor, and, three concentrations of Ni were tested: 0.01, 0.1 or 1 mM. Nitrate- or sulfate-reducing cultures enriched from natural, alkaline sediments were used to inoculate experiments; sterile controls were also included. The aqueous geochemistry was monitored by pH, IC, ICP-MS, and ESI-MS analysis and the solids by SEM/TEM (with EDS/SAED). Microbial communities were examined using 16s rRNA sequencing. In inoculated 0.01 mM Ni incubations, Ni-citrate was biodegraded under nitrate- and sulfate-reducing conditions. In the nitrate-reducing incubations Ni remained in solution over 160 days, even after citrate was removed from solution, suggesting biotransformation of the soluble complex may have occurred. In the sulfate-reducing experiment, 50 % of aqueous Ni was removed from solution over 100 days and black precipitates formed; electron microscopy suggested this was a nickel sulfide phase. Microbial community analysis identified both nitrate- and sulfate-reducing bacteria in the relevant systems. Overall, findings suggest Ni-citrate complexes may be biodegraded/biotransformed in the repository near-field; depending on conditions. Indeed, Ni liberated from complexes following biodegradation may only be immobilised when appropriate anions, such as sulfide, are available for precipitation.

References

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