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Enhanced strontium removal through microbially induced carbonate precipitation by indigenous ureolytic bacteria

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The prospective *in-situ* bioremediation of radionuclide-impacted subsurface environments has received increased academic scrutiny in recent decades, potentially offering a cheaper and safer alternative to current *ex-situ* techniques. Such ‘non-invasive’ technologies would typically involve injecting bioavailable reagents through boreholes, in order to instigate beneficial metabolic activity amongst the bacteria indigenous to soils and sediments.

Strontium-90 (half life = 28.8 years) comprises a significant portion of the radioactivity associated with waste from nuclear fission. In nature, ^{90}Sr persists as Sr^{2+} and exhibits similar biogeochemical distributions to Ca^{2+}. The partitioning of Sr^{2+} into $CaCO_3$ minerals occurs within several environmentally-relevant polymorphs of $CaCO_3$ and is a naturally-occurring process [1]. Microbial urea hydrolysis (ureolysis) generates ammonium and Dissolved Inorganic Carbon that elevate the pH and alkalinity of an aqueous system respectively, yielding geochemical conditions conducive to carbonate precipitation. Microbially Induced Calcite Precipitation (MICP) by ureolysis has shown great promise for the remediation of Sr^{2+}-contaminated groundwater under environmentally-relevant conditions [2].

Here, we investigated the potential for bacteria indigenous to Sellafield sediments to utilise urea in order to remediate aqueous Sr^{2+} contamination in static sediment microcosm studies. In the presence of urea only, most of the sediment lithologies concomitantly degraded urea and enhancing Sr removal from Sellafield-representative groundwater, coinciding with a significant pH increase. Additional biostimulants accelerated both urea decomposition and the rise in pH, increasing Sr and Ca removal compared with control microcosms containing no or only urea. Solid-phase analyses was conducted on sediments selected from two of the urea-bearing experiments. Environmental Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy revealed a strong correlation between Sr and Ca in these samples as well as Sr/Ca-bearing precipitates with varying morphologies. Sr *K*-edge X-ray Absorption Spectroscopy supported suggestions that differing Sr-rich $CaCO_3$ polymorphs were precipitated in the two incubations. Ureolytic bacteria of the genus *Sporosarcina* were identified in these samples using 16S rRNA analysis. The results indicated that ureolysis and MICP may be suitable for the *in-situ* immobilisation of aqueous ^{90}Sr impacting the Sellafield subsurface.

[1] Ferris (1995), *Geomicrobiol. J.* 13, 57-67.

[2] Fujita, Redden, Ingram, Cortez, Ferris & Smith (2004), *Geochim. Cosmochim. Acta* 68:3261-3270.