Radium Retention by Cynobacteria Forming Intracellular Carbonates

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Radium (Ra) forms naturally from the decay of uranium (U) and thorium (Th), elements that are ubiquitous within most rocks, soils and sediments. Although retained by numerous minerals, Ra is nevertheless often the dominant soluble radioactive element present within porewater. This is particularly true within deep saline aquifers, where Ra accounts for most of the "naturally occuring radioactive materials" (NORM), which is a problematic constituent of "produced water" generated during unconventional gas extraction. For example, Ra activity in produced water ranges from hundreds to thousands of picocuries per liter (pCi L^{-1}), with a median of 5350 pCi L^{-1}, far above the industrial effluent regulatory limit is 60 pCi L^{-1}. Long-term exposure to Ra increases the risk of cancer and therefore represents a potential threat to public and ecological health. The human-ecological health risks and challenges associated with Ra may be alleviated by understanding processes which could potentially immobilize Ra from soils-sediments-aquifers. Here, role of biomineralization on radium uptake from solution by the cynobacteria species *Candidatus gleomargarita lithophora* was investigated. This organism is of particular interest, because of its ability to form intracellular bio-minerals, implying that bio-minerals are retained within the cell, rather than "shed" during growth. *G.Lithophora* grew normally for 30 days within growth media initially amended with 450 Bq Ra, and accumulated 70% of the total Ra over this time period. Furthermore *G.Lithophora* exhibited an apparent selectivity with respect to other group II elements, first accumulating Ba and Ra, then Sr and finally Ca. Active growth was also observed within a sample of produced water collected hydrofracturing well pads located in Pennsylvania, with concomitant removal of Ra (20% of the initial concentration) over a span of 12 days. Our findings suggest that under appropriate conditions, biomineralization of Ra could be used to develop *in-situ* bioremediation schemes for removal of radium in groundwater and Ra contamianted effluent streams.