2D and 3D X-ray Fluorescence Microscopy of Strontium Uptake and Mineralization in Green Algae

M. Krejci[1], C. Tester[1], L. Gordon[1], I. McNulty[2], D. Legnini[2], S.-C. Gleber[2], S. Vogt[2], and D. Joester[1]

[1]Department of Materials Science and Engineering, Northwestern University, 2220 Campus Drive, Evanston, IL 60208
[2]X-Ray Science Division, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439

The removal of ^{90}Sr from radioactive waste is complicated by the chemical similarity of Ca^{2+}, Sr^{2+}, and Ba^{2+} cations, which also leads to indiscriminate transport of these ions by most organisms. However, desmid green algae of the genus *Closterium* have the ability to selectively precipitate $(Ba,Sr)SO_4$ crystals within vacuoles, indicating that they possess a rare mechanism for selectivity of Sr and Ba vs. Ca. We use synchrotron x-ray fluorescence (SXRF) microscopy to investigate this mechanism, with the hopes of enabling new methods for ^{90}Sr cleanup.

Using SXRF at beamline 2-ID-E, we have quantified the uptake and sequestration of Ba and Sr into crystals; by modifying culture conditions, we have shown that the incorporation of Sr into crystals can be increased to up to 45 mol%. We have also observed time-dependent changes in intracellular Sr concentrations - the kinetics of uptake and efflux of Sr appear to be dependent on external Ca concentrations, and Sr and Ca show similar cellular localization. We conclude from this that selectivity for Sr versus Ca does not occur at the whole cell level. Instead, high sulfur levels detected in the vacuole suggest a selective precipitation mechanism. Sulfur micro-XANES performed at beamline 2-ID-B reveals that most of the sulfur in the vacuole is present in the form of sulfate. We thus propose a “sulfate trap” model of selectivity, in which high sulfate levels in the vacuole leads to preferential precipitation of $(Ba,Sr)SO_4$ solid solutions due to their low solubilities relative to $CaSO_4$.

In an attempt to verify the sulfate trap model and gain further insight into the intracellular localization of Sr, Ba, Ca, and S in *Closterium*, we have recently performed a trial of the developing technique of x-ray fluorescence tomography at beamline 2-ID-E, acquiring a tilt series with a range of nearly 180°. Reconstruction of this dataset will result in a three-dimensional model of elemental concentrations and distributions in these cells, allowing for more precise determination of organelle volume concentrations and correlation of elemental content with cell structure. An elucidation of the mechanisms of selectivity in these organisms will enable and inspire innovation of chemical and bioremediation approaches to ^{90}Sr cleanup operations.