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Using iron biominerals for sustainable rare earth element recovery from acid mine drainage

DANIELLE RUSHWORTH AND **CLARA CHAN**
University of Delaware
Presenting Author: cschan@udel.edu

Rare earth elements (REEs) are widely used in green energy, consumer electronics, and defense technologies. With supply chains vulnerable to disruption, it is vital that we pursue domestic REE sources and develop more sustainable extraction methods to meet increasing demands. Acid mine drainage (AMD) is a promising source of REEs, however, economically feasible ways to concentrate and recover REEs in AMD must be developed. We propose using Fe biominerals naturally produced by microbial Fe oxidizers in AMD and remediation sites. Fe biominerals are highly reactive sorbents that concentrate REEs by surface sorption and coprecipitation. By optimizing adsorption and desorption steps, we aim to develop a cost-effective recovery method.

In this study we investigated the REE-enrichment potential of Fe biominerals and tested sustainable recovery methods such as mild acid leaching (pH 3-4) and thermal mineral transformation. Fe biominerals were collected from microbial Fe mats at an AMD site in Pennsylvania. The morphology, surface chemistry, and elemental composition of Fe biominerals were characterized using scanning electron microscopy (SEM), attenuated total reflectance-Fourier transform infrared spectroscopy and inductively coupled plasma mass spectrometry. The dominant mineral phase was confirmed as ferrihydrite and goethite using a combination of techniques including X-ray diffraction analysis.

Adsorption isotherms generated using dysprosium (Dy) showed that Fe biominerals adsorb 4.5 times more Dy than synthetic ferrihydrite despite having similar surface areas. Modeling results using PHREEQ-N-AMD Treat+REYs predicted that chemical constituents in AMD (e.g. sulfate) affect REE adsorption to Fe oxyhydroxide minerals, e.g. through the formation of ternary sulfate-REE complexes. Experiments in which Fe biominerals were suspended in synthetic AMD containing a multi-REE mix showed that Fe biominerals had a high affinity for all REEs at pH 6, regardless of the matrix. Additionally, the adsorption solution (synthetic AMD) did not inhibit REE recovery as approximately 100% of adsorbed REEs were recovered using a mild acid leachate (pH 3). Our results indicate that Fe biominerals can concentrate REEs, furthermore, these REEs can be recovered from Fe biominerals using minimal chemicals. This work may form the basis for a new sustainable technology to generate REE enriched fluids from the otherwise low-grade waste source, AMD.