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The Role of Dissolved Organic Matter in Critical Mineral Recovery from Coal Mine Drainages

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Coal mining has led to the generation of high-volume, often acidic discharges or coal mine drainages (CMD) that are rich in critical minerals such as nickel, cobalt, and rare earth elements (REEs) (100s-1000s of ppb) released from pyritic source rocks. These waste streams are currently an underutilized potential critical mineral resource. Dissolved organic matter (DOM) plays a vital role in the speciation, solubility, and mobility of metals in water. In CMD systems, dissolved organic carbon concentrations are typically low (<10 mg/L), due in part to the adsorption of organic carbon to mine waste precipitates, and as such, DOM-metal interactions have not been extensively investigated in these systems. To optimize the extraction and processing of critical minerals from CMD sources, the geochemical relationships between DOM and critical minerals, both dissolved and in mine waste precipitates, warrant detailed characterization.

We examined DOM and dissolved critical mineral concentrations (<0.45 µm) in eight CMD systems over multiple seasons using fluorescence spectroscopy and high-resolution mass spectrometry. Dissolved metal concentrations were inversely correlated with humification index, a ratio of fluorescent intensities at 300-480 nm, and these indices were typically higher in the spring. Humification is the conversion of low molecular weight organic compounds to more condensed, higher molecular weight compounds primarily by microbial synthesis. These more condensed compounds may not be as relevant for metal binding and the abundance of these substances could be changing seasonally as a result of microbial activity. Understanding how DOM-metal relationships could be shifting seasonally would allow optimization of extraction techniques.

Mine precipitates in a passive treatment system had decreasing water extractable carbon content and total percent solid carbon throughout the system. Conversely, near total concentrations (by 4-acid digestion) of Co, Ni, Mn, and Zn increased throughout the system. This inverse relationship between carbon and metal content may indicate metals are outcompeting carbon for adsorption sites, but more molecular characterization is required to assess if there are key functional groups involved with metal adsorption. By examining and quantifying these fundamental geochemical relationships, improved critical mineral processing methods can be developed, potentially strengthening CMD as a critical mineral resource.