Multiple methods of characterizing Zn and Cd secondary minerals associated with mine drainage from Keno Hill, Yukon, Canada

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Circumneutral drainage from the abandoned No Cash mine in the Keno Hill silver district contains 10 mg/L dissolved Zn and 0.14 mg/L Cd where it discharges into No Cash Creek. Along the 3 km reach of the stream, *ca*. 99% of the dissolved Zn and Cd is removed through natural attenuation on sediments. Identification of the Zn- and Cd-bearing secondary minerals and estimation of their relative proportions are important for assessment of the long-term stability of these sediments. The relatively low total metal concentrations in sediments (<4% Zn, <0.05% Cd) distributed in multiple phases, including amorphous material, means that conventional XRD is not applicable. Bulk XANES can identify phases hosting a specific element and also provides estimate of relative proportions. In this case, Zn XANES was very useful, but spectral similarities in the XANES profiles of different Cd-bearing model phases limited the utility of Cd XANES. SEM was used locate metal-bearing phases and provides high spatial resolution for textural examination, however, eye-catching features may introduce a bias, and secondary precipitates with low Zn and Cd concentrations can easily be missed. Synchrotron-based microXRF element mapping is highly sensitive and provided useful element correlations to guide microXRD, which captures nanocrystalline phases but misses truly amorphous material. LA-ICP-MS has low detection limits but the spatial resolution was not adequate for finely intergrown secondary precipitates. Automated mineralogy techniques (e.g. SEM coupled with Mineral Liberation Analysis) that characterize 100,000's grains promise an evaluation of the relative proportions of all mineral constituents, providing an appropriate reference library has been established. Based on the application of all these techniques, we have determined that the principal hosts of Zn and Cd in the No Cash sediments are (hydro)hetaerolite, birnessite and Zn sorbed or co-precipitated with ferrihydrite and goethite. Natural attenuation has been a stable, ongoing process for at least 20 years at No Cash creek.