Mineralogical diversity of Bi and W evolution in human-impacted environments over time

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ABSTRACT

Currently, achieving mineral resource self-sufficiency is a critical strategic priority for nations seeking to secure supply chains and reduce vulnerability to dominant economic powers. While the historical mining industry left a legacy of millions of tons of tailings and extensive environmental contamination, these sites now present an opportunity. France is currently considering the resumption of mining operations, which necessitates the transformation of mining waste from an environmental liability into a valuable secondary resource. In this context, the use of X-ray spectroscopy is essential to unravel the geochemical cycling of Bismuth (Bi) and Tungsten (W) in anthropogenically impacted environments.

Moving beyond total concentration analysis, REXEL project[1] focuses on solid-phase speciation and temporal evolution within mining materials. The research is structured around two core objectives: first, mapping the alteration pathways from primary sulfides to secondary Fe-oxides; and second, identifying the crystallographic properties of neo-formed mineral phases. These phases - including iron oxides[1], phosphates[2,3], sulfates[4]- act as efficient sinks for Bi and W. Understanding these retention mechanisms is key to developing natural attenuation strategies and optimizing the recovery of these metals for industrial valorization.

The project employs a high-resolution analytical framework, combining laboratory and synchrotron-based XRF and XAS to achieve sub-micrometer spatial resolution for chemical mapping and phase speciation. By determining the local coordination environments and oxidation states of Bi and W, we can assess their stability and recombination potential within alteration products. Furthermore, the synthesis of representative mineralogical phases allows for a comparative analysis between synthetic and natural samples. This dual approach is designed to isolate the most stable phases responsible for metal sequestration, thereby preventing environmental leaching while identifying pathways for the economic recovery of these critical elements.

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