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Mineral-centric approach for the ultimate characterization of arsenic in geologic materials: implications for mine tailings safety

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Mine tailings are complex waste materials, with an estimated annual production of 13 billion tonnes globally [1]. In these tailings, metal(loid)s can occur as major or trace components in some minerals with various levels of susceptibility to leaching. When occurring at trace levels, conventional analyses alone (XRD, EPMA, ICP-MS, SEM-EDS) are insufficient to identify their mineralogical hosts [2]. However, determining the distribution (i.e., deportment) and speciation of metal(loid)s is crucial, as these factors govern their availability and mobility, both factors controlling the environmental safety of mine tailings.

We studied tailings from the world-class lithium Beauvoir deposit (Massif Central, France) through a mineral-centric approach combining for the first time automated mineralogy [3] and X-ray absorption spectroscopy (XAS). Arsenic (As), which showed low concentration in the tailings [4], was chosen as the target element due to its high hazard potential.

A comparison between As deportment using LA-ICP-MS and automated mineralogy with solid-phase speciation using XAS is shown in Figure 1. Both methods align with the predominance of goethite and feldspars in the As budget. While deportment calculations provide detailed insights into the distribution of metal(loid)s within minerals (goethite, K-feldspars, albite, phosphates, cassiterite and other minerals such as columbite, microlite, and micas), certain mineral hosts such as arsenopyrite may be overlooked due to sample heterogeneities and textural complexities. On the other hand, XAS is highly sensitive for quantifying the proportion of minerals with distinct As redox states (As(-I, III, V)), characterized by distinct environmental mobility. However, the latter presents challenges in distinguishing between minerals in low proportions with identical oxidation states (e.g., As(V)-bearing goethite, cassiterite, and phosphates). This study highlights the complementarity of these techniques, demonstrating that their combined use offers a powerful approach for characterizing As in mine tailings but also any metal(loid)s in geological materials, which is essential for evaluating the environmental and human health impacts.

[1] Hudson-Edwards et al. (2024), Nature reviews earth & environment 5(9), 612-630. [2] Bollaert et al., (2023), Geochimica et Cosmochima Acta 353, 142-157. [3] Dehaine et al., (2019) Ore Geology Reviews, 104, 384-402. [4] Bollaert et al., Under review, Science of the Total Environment.