Natural attenuation processes in AMD context by mineralogical control: iron oxyhydroxides, oxyhydroxysulfates, and efflorescent sulfates

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Abstract

Acid mine drainage (AMD) is a common problem associated with the weathering of metal sulfide wastes in abandoned mining areas, which can be rich in toxic metals and metalloids. Oxidative dissolution of these minerals may negatively affect the soils and water reservoirs nearby. The formation of secondary mineral phases such as iron oxyhydroxides, oxyhydroxysulfates, and efflorescent sulfates may be a natural attenuation process in these areas because these minerals can scavenge potentially toxic elements. Typically formed by the evaporation (efflorescent salts) or precipitation (ochreous iron-rich oxyhydroxides) these minerals are highly soluble and reactive. Therefore, their characterization and inventory are particularly important for predicting the cycles of retention/contamination or accumulation zones of potential toxic elements (PTE) and acidity in mining contaminated systems.

The abandoned mines of Valdarcas and São Domingos were selected for the present study due to their AMD signature and occurrence of some of these secondary minerals. Valdarcas (north of Portugal) is a W-mine associated with a skarn deposit with sulfides that has already been rehabilitated. However, the AMD problems remain in the watercourse that receives leachates from the waste dumps. São Domingos is a Cu-mine composed of massive sulfide deposits that belong to the Iberian Pyrite Belt (south of Portugal). This mining area, which is presently under remediation process, is highly contaminated and AMD is a long-lasting problem. The samples collected in these mining areas were characterized by their morphology, size, mineralogy, and chemical composition using different techniques: binocular microscopy, SEM-EDS, TEM, BET, DRX, FTIR, and XPS.

In Valdarcas mine area, typical ochreous phases such as schwertmannite and goethite were identified as the dominant secondary phases. These brownish-yellow ferric amorphous and poorly crystalline minerals with high surface area (125 mg^2/m) can remove PTE via adsorption processes, contributing to their retention in the mining environment. In contrast, at São Domingos, efflorescent sulfate salts are more abundant. Melanterite and copiapite were the prevailing salts identified. With different morphologies, these minerals are highly soluble and therefore play a relevant key in the retention/mobilization cycles of hazardous contaminants, such as arsenic (As).

This integrative methodologic approach, based on the use of several techniques, allowed a complete characterization of these minerals. In addition to composition, the surface properties that are relevant for the adsorption ability, were also obtained. Therefore, the study revealed a diversity of behaviors for the identified phases, suggesting various roles in increasing the resilience of the contaminated systems.

Keywords: AMD, mineral attenuation process, secondary minerals.

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