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Competitive Sorption and Redox Speciation as Key Factors Controlling Antimony Mobility in Mining-Impacted Environments

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Antimony (Sb) is a suspected carcinogen found in various everyday products. It is primarily mined from stibnite ores, which often results in an uncontrolled release of Sb into the environment. In such situations, the mobility of Sb is largely influenced by interactions with iron (Fe) hydroxide minerals that form via aqueous Fe(II) oxidation. The effectiveness of this immobilization process depends on a range of geochemical factors, including Sb redox speciation, co-occurring ions, and dissolved organic carbon (DOC).

This study investigated how DOC and coexisting arsenic (As) affect Sb mobility in mining-impacted environments. Supplementary laboratory experiments involving aerobic Fe(II) oxidation were conducted to mimic environmental conditions with varying concentrations of DOC and As.

Water samples collected along the drainage channel at the abandoned mining site in Pezinok, Slovakia, had a neutral pH and contained approximately 50 µg L^{-1} Sb, 15 µg L^{-1} As, 2400 µg L^{-1} Fe, and up to 4 mg L^{-1} DOC. While Sb concentrations decreased slightly over the 150 m between the mine exit and the confluence with the receiving stream, As concentrations did not show a trend, even though the mine drainage passed through a redox-dynamic wetland environment. Along the flow path, up to 2200 mg kg^{-1} Sb and 4100 mg kg^{-1} As were retained in the sediments, suggesting a more effective scavenging mechanism for As compared to Sb. Although HPLC-ICP-MS detected only Sb(V) in the aqueous phase, Sb K-edge X-ray absorption spectroscopy (XAS) revealed that up to 28% of the sediment-bound Sb was in the Sb(III) state further inside the mine.

To better understand the effects of As and DOC on Sb immobilization via interactions with precipitating Fe(III) hydroxides, we conducted Fe(II) oxidation experiments under controlled laboratory conditions. These experiments demonstrated that both the presence of As and DOC at concentration levels similar to those at the mining site reduced Sb sequestration through competitive sorption and altered Fe(II) oxidation kinetics.

By integrating field observations with laboratory experiments, our study highlights the intricate interactions between DOC, As, and Fe cycling, which play a crucial role in the mobility and sequestration of Sb in mining-impacted environments.