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Towards Sb Isotope Fingerprinting of Concealed Mineral Deposits: Insights from an Old Mine Drainage System and Surface Waters in the Harz Mountains, Germany

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Antimony (Sb) contamination from abandoned mines can impact natural ecosystems long after mining activities have ceased. Recent analytical advances have demonstrated that Sb isotopes are a powerful geochemical tool for tracing contamination sources and processes in mining-affected regions [1]. However, despite the recognized toxicity of Sb, its biogeochemical cycling in aqueous systems remains poorly understood, particularly in Sb-unpolluted (<1 µg/L) and low- to moderately polluted waters (up to 105 µg/L).

To address this knowledge gap, we investigated Sb concentrations and isotopic compositions in unpolluted rivers from the Harz and Sb-polluted mine waters from the historic Wolfsberg Sb mine (Harz Mountains, Germany), along with Sb ores from this deposit. Water samples were collected during two seasons (winter and summer 2024), and Sb concentrations and Sb isotope ratios were determined together with pH (5.9 to 8.5) and electrical conductivity (35 to 587 µS/cm). Dissolved Sb concentrations range from <1 µg/L in Sb-unpolluted waters up to ~105 µg/L in mine drainage waters. Antimony isotopic compositions reflected in the δ^{123}Sb value of waters varied between 0.00 and 1.11 ‰. Mine-impacted waters exhibited heavier isotopic signatures (δ^{123}Sb = 0.50–1.11 ‰) compared to the dominant ore mineral stibnite in this area (0.00–0.30 ‰) but also to unpolluted waters (δ^{123}Sb = 0.18 ±0.06 ‰ (2SE, n = 24)). This enrichment in heavy isotopes suggests preferential release of heavy Sb during stibnite weathering, consistent with recent experimental findings [2].

500 m downstream after the confluence with mine drainage at Wolfsberg, Sb concentrations and δ^{123}Sb values in the main river increased from background levels (~0.8 µg/L; ~0.14 ‰) to elevated values (~7 µg/L; ~0.50 ‰), reflecting mixing and dilution processes between unpolluted river water and mine effluent (105 µg/L; ~0.51 ‰). These results demonstrate that combining Sb isotope signatures with concentration data provides a sensitive tracer for identifying contamination sources and to fingerprint the proximity and direction of Sb ore-derived inputs in mining-impacted catchments.

[1] Wen et al. 2023 *J Hazard Mater*. 446, 130622.
[2] Kaufmann et al. 2024 *Chem Geol*. 662(20), 122253.