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Metal stable isotopes coupled with magnetic separation to decipher pollution sources in industrial areas

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Metal contamination in soil poses a significant risk to environmental and human health. Conventional assessment methods typically compare chemical or isotopic compositions with those of established backgrounds or known pollution sources. However, accurately defining geochemical or anthropogenic baselines is challenging due to the complex interplay of natural and anthropogenic inputs. Previous approaches, such as multivariate statistical analysis or geological comparisons, have been employed to address this issue.

This study introduces an innovative methodology that integrates metal stable isotope analysis with wet high-intensity magnetic separation (WHIMS) to distinguish metal pollution from inherent geochemical backgrounds in soils affected by smelting activities. Contaminated soil samples from an industrial region in Asturias (Spain) were magnetically separated under varying field strengths into magnetic and non-magnetic soil fractions. Subsequent analyses were conducted to determine metal concentrations, Pb isotopic ratios, and Cd isotope compositions. Fly ash from the Zn smelter surrounding the area, local bedrock identified as the parent material, and biological samples (plants, moss, and tree bark) were similarly analyzed.

When the lowest magnetic intensity was applied, the magnetic fraction - corresponding to 5 wt% of the feed material- exhibited a Pb isotopic signal comparable to the pollution source (fly ashes). In contrast, the non-magnetic fraction reflected the Pb isotopic composition of the parent material (rock samples). Cd isotope data further corroborated these findings, showing an enrichment in lighter isotopes similar to fly ashes in the magnetic fraction. Moreover, the analysis of biological samples revealed the impact of pollution on the soil-plant system, evidenced by elevated Cd concentrations and a trend in Cd isotopic signatures that confirm the influence of the pollution source.

In summary, the combined application of stable isotope analysis and magnetic separation offers a robust tool for evaluating pollution levels, particularly in scenarios where distinct endmember sources are not readily identifiable.