Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.27179

Migration, Transformation and Bioavailability of Arsenic and Cadmium in High Geological Background Rice Paddy Systems

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Soils in high geological background areas often host multiple co-existing metals. Arsenic (As) and cadmium (Cd) are frequently associated due to electrostatic interactions between their occurrence states. The environmental geochemical behavior and associated health risks of high As and Cd levels in paddy systems have become a global ecological security concern. As and Cd exhibit strong migration capacity and bioavailability, posing threats to human health via food chain transfer. This study integrates field and laboratory experiments to investigate dynamic changes in As and Cd speciation and concentration driven by surface water-groundwater interactions. We analyze variations in hydrogeochemical conditions of paddy systems, elucidate migration-transformation processes and bioavailability of As and Cd, and reveal the mechanistic roles of dissolved organic matter (DOM) and iron oxides in regulating their mobility and transformation. Furthermore, we explore how redox fluctuations under surface water-groundwater interactions influence As and Cd behavior, clarify DOM- and iron oxide-mediated control on their release and bioavailability, and assess health risk implications. This research provides scientific insights for predicting As and Cd migration and agricultural health risks in shallow groundwater systems with elevated As/Cd levels. The findings offer critical guidance for mitigating ecological health risks in contaminated farmlands and theoretical-practical support for ensuring food safety.