The effect of soil saturation on carbon oxidation and arsenic release in the Mekong Delta

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Himalayan sediment transported down the major rivers of Asia is deposited in low-lying basins and deltas where arsenic partitions from the solid to aqueous phase, contaminating vast groundwater resources in South and Southeast Asia and ultimately exposing millions of individuals to unsafe levels of As. Reductive dissolution of As-bearing iron oxides controls aquifer As concentrations in sediments, where Fe and As reduction and solubilization is dependent on the availability of a suitable source of organic carbon (OC).

Despite the critical role of OC in mobilizing As, it has been poorly characterized in Southeast Asian sediments. We compared the abundance and chemical state of OC at three sites representative of the Mekong Delta (uncultivated seasonal wetlands, cultivated wetlands, and permanent lakes) by performing bulk C (1s) near-edge x-ray absorption fine structure (NEXAFS) spectroscopic measurements to compare the bulk C chemical composition of sediment profiles at each site. Permanganate oxidizable carbon (POXC) measurements suggest that microbially oxidizable C is concentrated in the top 50-100 cm, even when normalized by bulk C content. These results indicate that C available for microbial use is concentrated in the near-surface.

To assess the impact of aeration duration on chemical composition and bulk abundance of C, CO_2 flux and soil moisture measurements were taken at each site. Our results demonstrate that periods of sub-saturation allow more O_2 diffusion into sediment, oxidizing thermodynamically more stable C and increasing C oxidation kinetics compared to alternative electron acceptors (e.g. Fe(III)). This process leads to a decrease in both sedimentary C storage and As liberation. Conversely, sustained saturated (anoxic) conditions increase As mobilization when relatively more C oxidation is coupled to Fe(III) reduction. Redox oscillations in seasonally saturated sediments also lead to physical protection of organic matter through stabilization during cycles of Fe-oxide recrystallization, a process which we explore in these seasonally saturated wetlands.

Overall, the results of this study illustrate the importance of understanding the controls on microbial carbon availability in arsenic mobilization in seasonal wetlands and water-saturated sediments.