

Bio-inorganic interfaces in the critical zone

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At the particle scale, critical zone biogeochemical interfaces are heterogeneous and patchy. Patchiness results from the wide range in mutual affinities among primary bio-geo-chemical components that are continuously influent to terrestrial weathering systems (water, minerals, solutes, gases, cells). In addition, hydrologic events shift the disequilibrium state, generating short time-scale surface reactions, colloidal dynamics, and biotic/abiotic transformations that are superimposed on (and constrained by) long-term weathering history. A corollary is that the structure and reactivity of bio-inorganic interfaces are a function of the sequence of perturbations acting on the porous medium over an integrated soil residence time.

The complexity of critical zone systems raises challenging research questions that highlight the need to unravel these couplings and feedbacks: What products form when biochemical and geochemical components react in pore waters? How stable are these products to further biogeochemical transformation and how do they influence the evolution of interfacial structure in particles, aggregates, and porous media? How does this “architecture” dictate surface reactions and the bioaccessibility of carbon and/or contaminants? How does interfacial reactivity change over time and environment to control larger system (e.g., catchment) response?

These questions can be addressed by combining tools of analytical biogeochemistry with those of hydrology, geomorphology and ecology in bench-, meso- and field-scale experiments. One goal is to elucidate molecular- and pore-scale components and processes that are active contributors to observed meso- and field-scale phenomena (e.g., metalloid stabilization, carbon sequestration, catena structure formation, catchment hydrochemical response). Such studies require multi-faceted, interdisciplinary measurements in common systems and locations. Examples are presented from ongoing studies conducted at three scales (1) biomolecule-mineral surface reactions in aqueous suspensions, (2) metal(loid) transformation in phytostabilized tailings mesocosms, and (3) biogeochemical weathering fluxes in semi-arid catchments of the southwestern US.

Geochemical position of Pb, Zn and Cd in soils near a mine/smelter: Effects of land use, type of contamination and distance from pollution source

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Contaminated agriculture and forest soil samples with mining and smelting related pollutants were collected in the Pb-Zn-Ag mining area near Olkusz, Upper Silesia to (i) compare the chemical speciation of metals in meadow and forest soils situated at the same distance from the point source of pollution (paired sampling design), (ii) to evaluate the relationship between the distance from the polluter and the retention of the metals in the soil, and (iii) to assess the effect of deposited fly ash vs. dumped mining/smelting waste on the mobility of metals in the soil. The smelting emissions intensively contaminated mainly the upper soil horizons, while the deposition of processing waste resulted in a contamination of the deeper parts of soil profiles. The maximum concentrations of Pb, Zn and Cd were detected in a forest soil profile near the smelter and reached about 25 g kg⁻¹, 20 g kg⁻¹ and 200 mg kg⁻¹ for Pb, Zn and Cd, respectively. Forest soils are much more affected than agriculture soils. However agriculture soils suffer from the downward metal migration more than the forest soils. Metal mobility ranges in the studied forest soils are as follows: Pb>Zn≈Cd for relatively circum-neutral soil pH (near the smelter), Cd>Zn>Pb for acidic soils (further from the smelter). The mobilization of Pb, Zn and Cd in soils depends on the persistence of the metal-containing particles in the atmosphere, and consequently on the mineralogical transformation controlled by the soil pH. Under relatively comparable pH conditions, the main soil properties influencing metal migration are total organic carbon (TOC) and cation exchange capacity (CEC).