



Sorption Processes in Soils and Sediments

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Sorption processes at the mineral–water interface are fundamental to the chemical functioning of soils, and impact the biogeochemical cycling of both trace and major elements in soil and sediment environments. Surface complexation reactions control the solubility, and hence bioavailability and mobility, of trace elements and may promote electron transfer reactions between sorbed and structural ions. In turn, sorbed impurities may affect mineral dissolution and (re)precipitation reactions and, thus, influence the mineralogical composition and reactivity of the solid phase matrix. Our understanding of the basic mechanisms involved in the interaction between mineral surfaces and dissolved ions has become increasingly refined in recent decades through the application of advanced spectroscopic, microscopic, and modeling tools. The articles in this Special Issue illustrate the broad range of experimental approaches employed in studying trace element sorption, the importance of sorption processes to trace element bioavailability and mobility in soils, and the complexity of the underlying mechanisms.

Strawn [1] provides a comprehensive review of the molecular-level mechanisms involved in the sorptive interactions of trace elements with mineral and organic surfaces, and the main geochemical and mineralogical factors that determine the extent to which they operate in soil environments. The review starts with a description of the history of the study of sorption phenomena in soils, and next discusses the current state of knowledge, emphasizing the role of spectroscopic, microscopic, and computational techniques in shaping modern views. This in-depth and highly informative review will undoubtedly be a valuable resource for researchers and educators in soil chemistry.

The study by Kubicki and Ohno [2] illustrates the utility of combining computational and experimental methods in studying sorption reactions. The article addresses the mobilization of adsorbed phosphate in rhizospheres through competitive displacement by low-molecular-weight organic root exudates. DFT calculations of the configuration of phosphate and salicylate surface complexes on goethite were compared against spectroscopic results, and evaluated with respect to the thermodynamic favorability of the displacement of adsorbed phosphate by salicylate. The results demonstrate the feasibility of phosphate mobilization through this mechanism, consistent with experimental data.

Vamvuka et al. [3] present an experimental study of the solubility of metal pollutants in soils amended with ash obtained from co-combustion of solid municipal waste and agricultural waste, and subsequently blended with various chemical stabilizers. Column leaching experiments were combined with extensive chemical, mineralogical, and physical analyses to characterize metal mobility. The results identified phosphate and silica as key ingredients of the chemical stabilizers, reducing metal leaching by promoting adsorption and precipitation.

The study by Li et al. [4] addresses the analytical challenge of measuring the kinetics of desorption reactions in batch reactors, caused by the build-up of desorbed ions in solution. The authors present a method for studying phosphate desorption using a new hybrid anion resin that effectively and irreversibly removes desorbed phosphate ions from solution. Application to agricultural soils from the U.S. Midwest yielded estimates of the rates of



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phosphate desorption kinetics, which are critical for modeling the dynamics of phosphate sorption reactions in these soils. The resin may be used for other anions, such as arsenate, as well.

Petruzzelli and Pedron [5] describe an experimental study of the retention of tungstate in Mediterranean soils with variable physico-chemical properties. Soil pH and organic matter (SOM) content were found to be major regulators of the extent of tungstate retention, with sorption promoted by lower pH and higher SOM values. Tungstate retention involved both chemical and electrostatic interaction with the soil solid matrix, and desorption results indicated that part of the tungstate was irreversibly retained, particularly at lower loading levels.

Goswami and Rouff [6] studied the concentration and speciation of lead (Pb) in soils from community farms in Newark, New Jersey, USA. Results from single extractions indicate that soil Pb levels are variable, but sequential extraction results indicate that most Pb is associated with reducible and oxidizable soil fractions in all samples, while XAS results show the association of Pb with pyromorphite, iron-manganese oxides, and organic matter. The authors conclude that the risk of Pb mobility and bioavailability in these soils is low, but that Pb exposure through ingestion or inhalation during direct soil handling is still of concern.

The paper by Lusa and Bomberg [7] investigated the relation between the composition of microbial communities and the concentrations of radionuclides and metals throughout the 6.5 m depth profile of a boreal ombrotrophic bog. The authors observe correlations between microbial populations and metal content, which may be due to changes in chemical, mineralogical, and physical factors affecting both microbial growth and metal retention, by toxicity effects on various parts of the microbial community, and by the influence of microbiological processes on the solubility and retention of heavy metals and radionuclides.

Mierzwa et al. [8] conducted an in-depth investigation into the retention of pentavalent antimony (Sb(V)) by the iron oxide hematite by combining batch macroscopic experiments with attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopic analyses and surface complexation modeling. The results indicated that Sb(V) forms both inner- and outer-sphere complexes in proportions that vary with pH, and that these surface species could be successfully incorporated into surface complexation models to describe the macroscopic Sb(V) adsorption envelope.

The paper by Gonzalez-Rodriguez and Fernandez-Marcos [9] describes the adsorption and desorption behavior of the oxyanions vanadate (V(V)O₄), arsenate (As(V)O₄), and chromate (Cr(VI)O₄) in African volcanic soils rich in variable charge minerals. Distinct differences in sorption affinity were observed, with sorption maxima increasing in the order Cr < As ≤ V and susceptibility to desorption by phosphate increasing in the reverse order. The main mineral sorbents were found to be crystalline Fe-oxides and amorphous Al- and Fe-oxides.

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