

Jianming Xu
Pan Ming Huang
Editors

Molecular Environmental Soil Science at the Interfaces in the Earth's Critical Zone



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Preface

Resource depletion and environmental problems are challenging the world for its sustainability. The theme of the International Symposium of Molecular Environmental Soil Science at the Interfaces in the Earth's Critical Zone (ISMESS) is of special significance for understanding environmental pollution and global change processes. The Critical Zone (CZ) is the system of coupled chemical, biological, physical, and geological processes operating together to support life at the Earth's surface. Further advance on the frontiers of knowledge on this subject matter requires scientists to cross disciplines and scales to integrate understanding of processes in the CZ, ranging in scale from the environmental mineral-organism-humus-water-air interfaces to the impact on the globe and humankind. These fundamental interactive processes in the CZ have an enormous impact on ecosystem productivity, services, and integrity, and on human welfare.

Carbon is a major component of soils. Globally, the mass of soil organic carbon is more than that of carbon in living matter and in the atmosphere combined. However, the CO₂ emission from the soil to the atmosphere is the primary mechanism of soil carbon loss. Agricultural practices and land use conversion contribute substantially (approx. 32%) to the total anthropogenic CO₂ emission. Soil organo-mineral-microbe interactions affect carbon turnover and sequestration. Our understanding of the role of mineral colloids in carbon transformation, dynamics, and sequestration in the environment would contribute to developing innovative management strategies to minimize its impact on climate change.

The interfacial interactions at the soil-plant(root)-microbe interface (rhizosphere) profoundly affect the physicochemical and biological processes such as transformation, fate, and toxicity of heavy metals and organic pollutants. Microbial population in the rhizosphere can be 10~100 times larger than the population in the bulk soils. Therefore, the rhizosphere is bathed in root exudates and microbial metabolites and the chemistry and biology at the soil-root interface is governed by biotic (plant roots, microbes) and abiotic (physicochemical reactions) interactions, and thus differs significantly from those in bulk soil. Little is known about the physicochemical and biological interfacial interactions in the rhizosphere, especially at the molecular level. The dynamics, transformations, bioavailability, and toxicity of metal pollutants and anthropogenic organics should be influenced enormously by the chemistry and biology of the rhizosphere.

Nanoparticles are discrete nanometer (10⁻⁹ m) scale assemblies of atoms. A significant fraction of atoms are exposed on surfaces rather than contained in the particle interior of nanoparticles. The biogeochemical and ecological impacts of nanomaterials are some of the fastest growing areas of research today, with not only vital scientific but also environmental, economic, and societal consequences. Little is known about the distribution, formation, transformation, structural and surface chemistry of environmental nanoparticles and their biogeochemical and ecological impacts.

Material cycling and energy flow processes are affected both by abiotic and biotic factors, which affect ecosystem integrity and the environmental quality. However, there are great knowledge gaps on how and to what extent the processes are affected by the interfacial interactions of environmental nanoparticles, especially at the molecular level. The research on this subject matter should, therefore, be an issue of intense interest on a global scale for years to come.

The objective of this symposium is to provide a forum for the interactions and communication of soil chemists, mineralogists, microbiologists, and physicists with allied scientists including pure chemists, biologists, environmental scientists, ecologists, and ecotoxicologists to address the current state-of-the-art on "Molecular Environmental Soil Science". The main sessions of the symposium were: 1) The Role of Mineral Colloids in Carbon Turnover and Sequestration and the Impact on Climate Change; 2) Biogeochemical Interfacial Reactions and the Transformation, Transport and Fate of Vital and Toxic Elements; 3) Anthropogenic Organics, Crop Protection and Ecotoxicology; 4) Environmental Nanoparticles: Distribution, Formation, Transformation, Structural and Surface Chemistry, and Biogeochemical and Ecological Impacts; and 5) Environmental Processes & Ecosystem Health. Two eminent scientists of the International Union of Pure and Applied Chemistry (IUPAC)

were invited to serve as Plenary Lecturers (IUPAC Lecturers) and 18 world renowned leading scientists were invited to give lectures in the 5 sessions of the symposium.

The symposium was held in Zhejiang University, Hangzhou, China on October 10-14, 2009. Zhejiang University, founded in 1897, is a key comprehensive university whose academic and research endeavors cover eleven disciplines, namely philosophy, literature, history, education, science, economics, law, management, engineering, agriculture and medicine. The University now has 112 specialties for undergraduate studies, and it is entitled to confer masters degrees in 317 programs and doctoral degrees in 283 programs. Under its administration there are 14 National Key Laboratories, 2 National Engineering Research Centers and 3 National Engineering Technology Centers. Besides, it has set up 35 national key specialties and 43 post-doctor stations. Soil Science in Zhejiang University is the National Key Discipline of China.

The participants of this symposium represent five continents: Asian delegates from China, Iran, Pakistan, Vietnam, D.P.R. Korea and R.O. Korea; European scientists from Austria, Belgium, France, Italy, the UK, Russia and Spain; Australasian participants from both Australia and New Zealand; delegates from the USA, Canada and Brazil in the Americas; and representatives from Egypt, Kenya and South Africa on the African continent.

It is the first time to hold such an international symposium in China. The IUPAC Project Committee has contributed to funding the symposium under the program for conferences on New Directions in Chemistry. The Project Committee noted that the Conference identifies, and builds on, the need to view and understand the CZ at the molecular level. It will provide a novel interface that will facilitate the integration of contributions from traditionally separate disciplines. It will add a molecular and nanoparticle dimension to a field of endeavor that has traditionally been viewed on a different scale (dimension). It will identify and focus on emerging challenges for research that will be predominantly cross-discipline in nature. It will help to secure the appreciation of the relevance of chemistry to this field that is of utmost importance to sustain humankind. Therefore, it is hoped that the symposium would lead to identification of gaps in knowledge and as such to provide future research directions and promote research on soil processes at the interfaces at the molecular level in the Earth's Critical Zone. It is expected to advance the frontiers of knowledge on biophysico-chemical processes in soil and related environmental systems and their biogeochemical and ecological impacts and also to promote education in this extremely important and challenging area of science for years to come.

The book of proceedings is composed of extended abstracts that present new ideas, methods, findings, and experiences on the 5 sessions of the symposium. All the extended abstracts have been subject to peer review by external referees, by International Scientific Committee members of the symposium, and by the editors of the proceedings. On behalf of the Organizing Committee, we would like to thank members of the International Scientific Committee and the authors for their invaluable collaboration. Special thanks are extended to our sponsors: The International Union of Soil Sciences, The International Union of Pure and Applied Chemistry, Organization for the Prohibition of Chemical Weapons, National Natural Science Foundation of China, Soil Science Society of China, Y.C. Tang Disciplinary Development Fund, Zhejiang University, Zhejiang Provincial Natural Science Foundation of China, and Zhejiang Provincial Key Laboratory of Subtropical Soil and Plant Nutrition. Valuable personal time of Mr. Jianjun Wu, Dr. Yan He, concerning the careful revising, typesetting and proof-checking of this book is also greatly acknowledged.

Dr. Jianming Xu
Chair of the Organizing Committee
ISMESS 2009

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Co-Chair of the Organizing Committee
ISMESS 2009

August 2009

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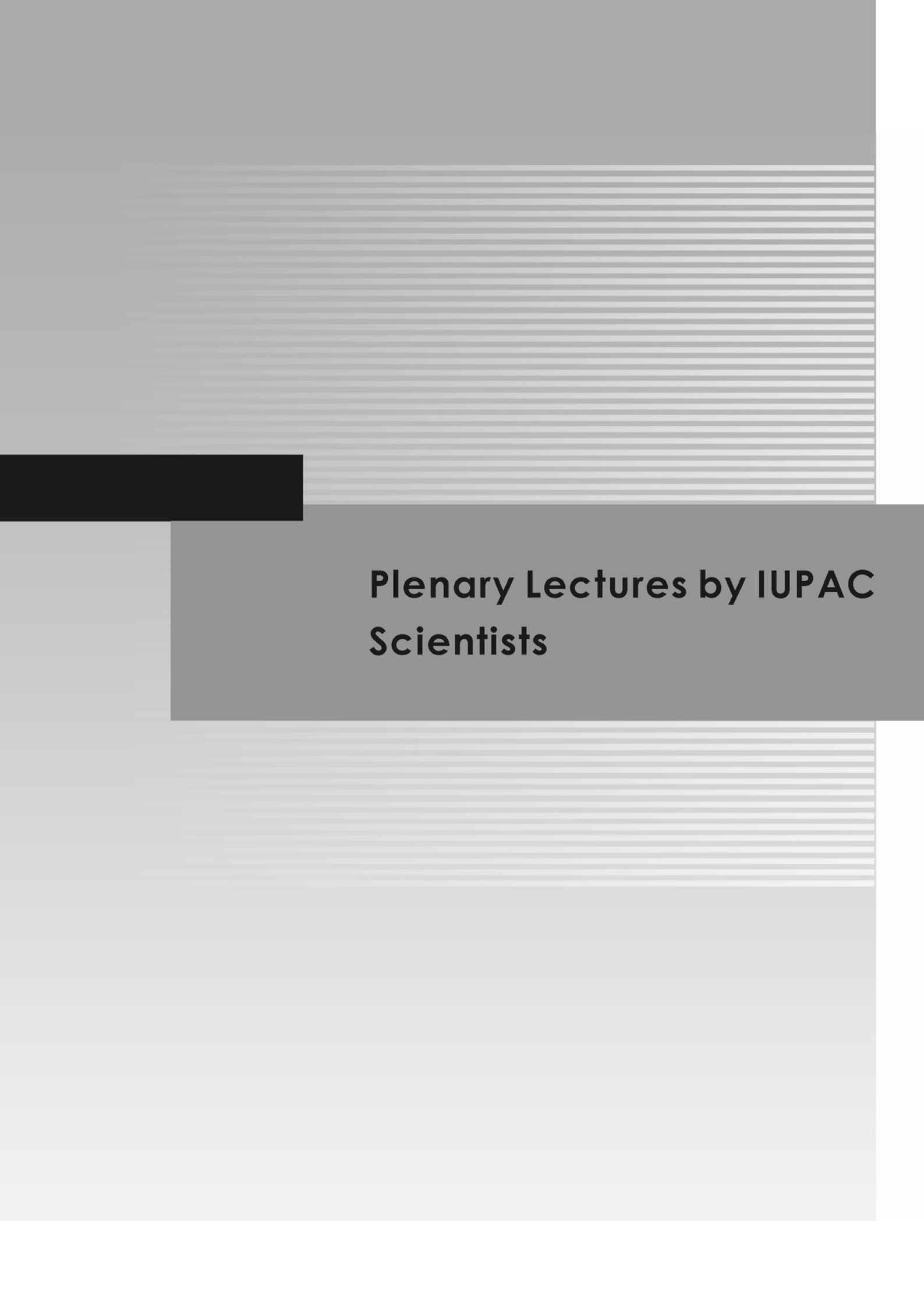
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Plenary Lectures by IUPAC Scientists

Advances in the Use of Synchrotron Radiation to Elucidate Environmental Interfacial Reaction Processes and Mechanisms in the Earth's Critical Zone

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Abstract: The employment of bright light sources generated at synchrotrons has greatly advanced our understanding of important environmental interfacial (mineral/water, mineral/microbe, plant/soil) reaction processes in the soil, environmental, and geological sciences over the past two decades. This plenary paper will provide background on principles and types of synchrotron radiation techniques with an emphasis on the use of synchrotron-based X-ray absorption spectroscopy (XAS), X-ray fluorescence spectroscopy (XRF), X-ray diffraction (XRD) and microtomography to elucidate speciation of contaminants in heterogeneous soils, surface precipitation phenomena, mechanisms of rapid redox transformations, microbial transformations on mineral surfaces, air and terrestrial emanated particulate reactivity and composition, and metal reactivity and speciation in hyperaccumulator plants.

Keywords: Biogeochemical processes; Environmental interfaces; Molecular scale; Spatial and temporal scales; Surface spectroscopy

Introduction and Discussion

It has become increasingly recognized that to accurately predict and model fate/transport, toxicity, speciation, bioavailability, and risk assessment of plant nutrients, toxic metals, oxyanions, radionuclides, and organic chemicals in the Earth's Critical Zone, we must have fundamental information at multiple spatial and temporal scales, and our research efforts must be multidisciplinary and interdisciplinary. The critical zone is "the heterogeneous, near surface environment in which complex interactions involving rock, soil, water, air and living organisms regulate the natural habitat and determine the availability of life sustaining resources" (NRC, 2001). The critical zone is an interfacial region of mass and energy flux comprising terrestrial, lacustrine, and marine components of the continental crust and is one of two primary loci of life

on Earth and for most of human activity. The critical zone is comprised of an array of spatial scales, ranging from the atomic to the global, and temporal scales, ranging from seconds to eons. The physical, chemical, and biological processes within the critical zone mediate exchange of mass and energy which is required for biomass productivity, chemical recycling, and water storage. The critical zone is the most heterogeneous and abstruse portion of the entire Earth (NRC, 2001). If we are going to sustain the planet for human habitation we must understand the physical, chemical, and biological processes and reactions in the critical zone over a range of spatial and temporal scales (NRC, 2001; Hochella, 2002; Sparks, 2002).

With the advent of state-of-the-art, *in-situ*, analytical techniques, some of which are synchrotron-based (e.g., X-ray absorption spectroscopy, XAS) one can elucidate reaction mechanisms at small spatial and