International Symposium of the German Priority Programme SPP 1315 Biogeochemical Interfaces in Soil on:

Biogeochemical Interfaces in Soil – Towards a Comprehensive and Mechanistic Understanding of Soil Functions

Leipzig, Helmholtz Centre for Environmental Research – UFZ, “Kubus”,
October 06 – 08, 2014

Book of Abstracts
Table of Contents:

Programme 3
Oral Presentations 10
  Session 1
  Unravelling BGI structure: Formation & Architecture of BGIs 10
  Session 2
  Exploring BGIs: New Avenues for “Provocative” Joint Experiments and Complementary Cutting-Edge Techniques 19
  Session 3
  Microbial Ecology of BGIs: Soil (Micro-)Organisms as “Architects” and “Actors” of BGIs 32
  Session 4
  BGIs in Changing Environments: BGIs Dynamics & Heterogeneity with Consequences for Properties & Processes 40
  Session 5
  Quantitative Understanding of BGIs Functions: Theoretical Concepts & Models to Explain Structure, Properties & Functions of BGIs 50

Posters 60
  Session 1
  Unravelling BGI structure: Formation & Architecture of BGIs 60
  Session 2
  Exploring BGIs: New Avenues for “Provocative” Joint Experiments and Complementary Cutting-Edge Techniques 63
  Session 3
  Microbial Ecology of BGIs: Soil (Micro-)Organisms as “Architects” and “Actors” of BGIs 75
  Session 4
  BGIs in Changing Environments: BGIs Dynamics & Heterogeneity with Consequences for Properties & Processes 93
  Session 5
  Quantitative Understanding of BGIs Functions: Theoretical Concepts & Models to Explain Structure, Properties & Functions of BGIs 110

List of Participants 133
Programme
**PROGRAMME OF THE SYMPOSIUM**
06.-08. OCTOBER 2014, LEIPZIG KUBUS AT THE UFZ-LEIPZIG

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Topic</th>
<th>Presenting Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:20-8:30</td>
<td>Opening Note</td>
<td>Kai Uwe Totsche</td>
</tr>
</tbody>
</table>

**Session I: Unravelling BGI structure: Formation & Architecture of BGI**
*Chaired by: Geertje J. Pronk*

| 8:30-9:15      | **Formation of Preferential Flow and Architecture of Biogeochemical Interfaces in Soil** | Henry Lin         |
| 9:15-9:35      | Formation and Maturation of Biogeochemical Interfaces in Soil           | Anja Miltner      |
| 9:35-9:55      | A Light Issue: Microbial Controls Upon the Architecture of the Soil:Atmosphere Interface | Invited: Karl Ritz|
| 9:55-10:25     | Rest-Coffee Break                                                      |                   |

**Chaired by: Joanna Hanzel**

| 10:25-11:10    | **Root Architects and Plastic Plumbers**                              | Iain Young        |
| 11:10-11:30    | Contribution of Microbial Biomass to the Formation of Soil Organic Matter and BGI | Matthias Kästner  |
| 11:30-11:50    | An Interdisciplinary Approach Towards Understanding Biogeochemical Interface Formation Using Artificial Soils | Geertje J. Pronk  |
| 11:50-12:10    | Hot Spots and Hot Moments: Effect of Plant Litter on the Formation of Biogeochemical Interfaces in Soil | Michael Schloter  |
| 12:10-12:30    | Soil Particle Wettability as a Controlling Factor in Biogeochemical Interface Formation | Marc-Oliver Göbel |
| 12:30-13:45    | Lunch                                                                 |                   |
### Monday Afternoon, October 6th

**Session II: Exploring BGIs: New Avenues for “Provocative” Joint Experiments and Complementary Cutting-Edge Techniques**

*Chaired by: Ingrid Kögel-Knabner*

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:45-14:30</td>
<td><strong>Imaging BGIs: A Simultaneous Look from Different Perspectives May Offer Clues</strong></td>
<td><strong>Hans-Jörg Vogel</strong></td>
</tr>
<tr>
<td>14:30-14:50</td>
<td>Preferential Sequestration of Organic Matter in Organo-Mineral Clusters as Revealed by Nano-Scale Secondary Ion Mass Spectrometry and Isotopic Tracing</td>
<td><strong>Katja Heister</strong></td>
</tr>
<tr>
<td>14:50-15:10</td>
<td>Quantification of pH-Dependent Species of Organic Molecules with UV/VIS Spectroscopy and Factor Analysis</td>
<td><strong>Thomas Ritschel</strong></td>
</tr>
<tr>
<td>15:10-15:30</td>
<td>Multi-Imaging Approach to Study the Root-Soil Interface</td>
<td><strong>Nicole Rudolph-Mohr</strong></td>
</tr>
<tr>
<td>15:30-15:50</td>
<td>Visualization of Enzyme Activities at Soil-Root Interface</td>
<td><strong>Baharsadat Razavidezfuly</strong></td>
</tr>
<tr>
<td>15:50-16:20</td>
<td><strong>Rest-Coffee Break</strong></td>
<td></td>
</tr>
<tr>
<td>16:20-17:05</td>
<td><strong>Revealing (Bio-)Physical Structure and Microbial Colonization of BGI in Soil: From Qualitative Observation to Quantitative Modelling</strong></td>
<td><strong>Thilo Eickhorst</strong></td>
</tr>
<tr>
<td>17:05-17:25</td>
<td>X-Ray Photoelectron Spectroscopy (XPS) as a Versatile Tool to Relate Surface Chemical Composition and Wetting Properties</td>
<td><strong>Susanne K. Woche</strong></td>
</tr>
<tr>
<td>17:25-17:45</td>
<td>Characterization of Wet Aggregate Stability of Soils by $^1$H-NMR Relaxometry</td>
<td><strong>Christian Buchmann</strong></td>
</tr>
<tr>
<td>17:45-18:05</td>
<td>How Can Magnetic Resonance Imaging (MRI) Help Understanding Colloidal Particle Transport in Soils</td>
<td><strong>Eric Michel</strong></td>
</tr>
<tr>
<td>18:05-18:25</td>
<td>Rapid Formation of Non-Extractable Residues of Sulfonamides: Paramagnetic Spin Probing Revealed Covalent Bonding of Aromatic Amino Group</td>
<td><strong>Michael Matthies</strong></td>
</tr>
<tr>
<td>18:25-18:45</td>
<td>The Influence of Extracellular Oxidative Enzymes on the Formation of Non-Extractable</td>
<td><strong>Andreas Schäffer</strong></td>
</tr>
<tr>
<td>Time</td>
<td>Topic</td>
<td>Presenting Author</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>8:30-9:15</td>
<td><strong>Microbial Diversity at the Interface</strong></td>
<td>George A. Kowalchuk</td>
</tr>
<tr>
<td>9:35-9:55</td>
<td>Transport of Phenanthrene in Soil Columns Influence the Bacterial Community Structure</td>
<td>Doreen Babin</td>
</tr>
<tr>
<td>9:55-10:40</td>
<td><strong>Spatial Heterogeneity, Diversity, and Ecosystem Function</strong></td>
<td>James Prosser</td>
</tr>
<tr>
<td>10:40-11:10</td>
<td><strong>Rest-Coffee Break</strong></td>
<td></td>
</tr>
<tr>
<td>11:10-11:55</td>
<td><strong>Microorganisms: Active Inhabitants and Architects of BGIs in Artificial Soils</strong></td>
<td>Kornelia Smalla</td>
</tr>
<tr>
<td>11:55-12:15</td>
<td>Reducing Diffusion Limitation Shifts the Dominant Nitrate Reduction Metabolism From Incomplete Denitrification to Dissimilatory Nitrate Reduction to Ammonium</td>
<td>Lasse Pedersen</td>
</tr>
<tr>
<td>12:15-12:35</td>
<td>The Soil-Litter Interface: A Hot Spot for Biogeochemical Interactions</td>
<td>Christian Poll</td>
</tr>
<tr>
<td>12:35-14:00</td>
<td><strong>Lunch</strong></td>
<td></td>
</tr>
</tbody>
</table>
## Tuesday Afternoon, October 7th

### Session IV: BGIs in Changing Environments: BGIs Dynamics & Heterogeneity with Consequences for Properties & Processes

*Chaired by: Nicole Rudolph-Mohr*

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00-14:45</td>
<td><em>Trophic Interdependences Shape Spatial Self-Organization of Microbial Consortia on Complex Hydrated Soil Surfaces</em></td>
<td>Dani Or</td>
</tr>
<tr>
<td>14:45-15:05</td>
<td>Bacterial Impact on the Wetting Properties of Soil Minerals</td>
<td>Jan Achtenhagen</td>
</tr>
<tr>
<td>15:05-15:25</td>
<td>Fungal-Mineral Interface During Leaf Litter Decomposition</td>
<td>Flavia Pinzari</td>
</tr>
<tr>
<td>15:25-15:45</td>
<td>How Does the Addition of Sulphur to Soil Influence Chemosynthesis and Carbon Flux?</td>
<td>Brian P. Kelleher</td>
</tr>
<tr>
<td>15:45-16:05</td>
<td>Understanding Root Growth Induced Changes in Soil</td>
<td>Sonja Schmidt</td>
</tr>
<tr>
<td>16:05-16:40</td>
<td>Rest-Coffee Break</td>
<td></td>
</tr>
</tbody>
</table>

*Chaired by: Jörg Bachmann*

<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:40-17:25</td>
<td><em>Active Microbial Dispersal in Soils: Effect of Spatial Heterogeneity and Varying Hydration Conditions</em></td>
<td>Barth F. Smets</td>
</tr>
<tr>
<td>17:25-17:45</td>
<td>Soil Organic Matter Decomposition – The Roles of Microbial Habitats and of Microbial Communities</td>
<td>Naoise Nunan</td>
</tr>
<tr>
<td>17:45-18:05</td>
<td>Drought Impact on Spatial Heterogeneity of Enzyme Activities on the Root-Soil Interface</td>
<td>Muhammad Sanaullah</td>
</tr>
<tr>
<td>18:50-20:30</td>
<td>Dinner</td>
<td></td>
</tr>
<tr>
<td>20:30-22:00</td>
<td><em>Poster Session II (Poster No.: 31-54)</em></td>
<td>Chaired by: Susanne K. Woche</td>
</tr>
</tbody>
</table>
### Wednesday Morning, October 8th

**Session V: Quantitative Understanding of BGIs: Theoretical Concepts & Models to Explain Structure, Properties & Functions of BGIs**  
*Chaired by: Friederike Lang*

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Topic</th>
<th>Presenting Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30-9:15</td>
<td><strong>Molecular Models and Simulations of Soil Organic Matter: Structure, Dynamics and Interactions with Other Entities</strong></td>
<td><em>Chris Oostenbrink</em></td>
</tr>
<tr>
<td>9:15-9:35</td>
<td>Organic Functional Group Density and Structural Dynamics of Soil Organic Matter Take Key Role in Cation Bridge Formation</td>
<td><em>Yamuna Kunhi Mouvenchery</em></td>
</tr>
<tr>
<td>9:35-9:55</td>
<td>Organic Sorbate Induced Cooperative Hydration of Soil Organic Matter</td>
<td><em>Michael Borisover</em></td>
</tr>
<tr>
<td>10:15-10:35</td>
<td>Modeling Surface Chemistry of Ferrihydrite</td>
<td><em>Invited: James Kubicki</em></td>
</tr>
<tr>
<td>10:35-11:00</td>
<td><strong>Rest-Coffee Break</strong></td>
<td></td>
</tr>
<tr>
<td>11:00-11:45</td>
<td><strong>A Conceptual Approach to Experimental Pedology</strong></td>
<td><em>Ingrid Kögel-Knabner</em></td>
</tr>
<tr>
<td>11:45-12:05</td>
<td>Delineation of Biogeochemical Processes Controlling Contaminant Fate in an Mesoscale Aquifer by Compound-Specific Isotope Analyses</td>
<td><em>Martin Elsner</em></td>
</tr>
<tr>
<td>12:05-12:25</td>
<td>Micro-Scale Modeling of Pesticide Degradation Coupled to Carbon Turnover in the Detritusphere</td>
<td><em>Holger Pagel</em></td>
</tr>
<tr>
<td>12:25-12:45</td>
<td>Hierarchical Structure of Biogeochemical Interfaces to Predict the Transport of Reactive Chemicals in Soil</td>
<td><em>Thomas Ritschel</em></td>
</tr>
<tr>
<td>12:45</td>
<td><strong>A Final Note and The End of the Symposium</strong></td>
<td><em>Patricia Schmitz-Möller &amp; Kai Uwe Totsche</em></td>
</tr>
</tbody>
</table>
## INTERNAL MEETING FOR SPP-MEMBERS

**Wednesday Afternoon, October 8th**

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Topic</th>
<th>Presenting Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:45-14:00</td>
<td>Nanothermal Analysis of Young Soils</td>
<td>Gabriele E. Schaumann</td>
</tr>
<tr>
<td>14:00-14:15</td>
<td>Computational Chemistry and Advanced Physico-Chemical Characterization: Quantitative Reconstruction and Modelling of BGI, Their Properties and Interactions</td>
<td>Gabriele E. Schaumann</td>
</tr>
<tr>
<td>14:15-14:30</td>
<td>Combined Experimental and Modeling Study on Adsorption of MCPA Herbicide by Goethite</td>
<td>Daniel Tunega</td>
</tr>
<tr>
<td>14:30-14:45</td>
<td>Hierarchical Structure of Biogeochemical Interfaces in Soil to Predict Transport of Reactive Chemicals in Soil</td>
<td>Thomas Ritschel</td>
</tr>
<tr>
<td>14:45-15:15</td>
<td><strong>Coffee Break</strong></td>
<td></td>
</tr>
<tr>
<td>15:30-15:45</td>
<td>The Soil-Litter Interface: A Hot Spot of Biogeochemical Interactions</td>
<td>Christian Poll</td>
</tr>
<tr>
<td>15:45-16:00</td>
<td>Worm Column Experiment</td>
<td>Marcus Horn</td>
</tr>
<tr>
<td>16:00-16:15</td>
<td>Stabilization of Microbial Biomass in Soils: Implications for SOM Formation, Xenobiotic Degradation and Residue Formation</td>
<td>Matthias Kästner</td>
</tr>
<tr>
<td>16:15-16:30</td>
<td>Interactions of Bacteria with Minerals at BGI in Soil</td>
<td>Anja Miltner</td>
</tr>
<tr>
<td>16:30-16:45</td>
<td>Final Discussion</td>
<td></td>
</tr>
<tr>
<td>16:45</td>
<td><strong>The End</strong></td>
<td></td>
</tr>
</tbody>
</table>
Oral Presentations

Session 1:

Unravelling BGI Structure:
Formation & Architecture of BGIs
Session 1: Unravelling BGIs Structure: Formation & Architecture of BGIs

Keynote Talk

Formation of Preferential Flow and Architecture of Biogeochemistry in Soils

Henry Lin

Department of Ecosystem Science and Management, The Pennsylvania State University, USA

Preferential flow (PF) is ubiquitous and controls a wide variety of soil physical, chemical, and biological processes. The complex and dynamic interaction between preferential flow and matrix flow results in diverse flow networks embedded in the mosaic subsurface. The presence of macropores in different soils, for instance, often leads to spatial concentrations of water and chemicals through the Critical Zone that is poorly described by classical approaches. This has significant implications for modeling and predicting hydrologic processes and biogeochemical dynamics. As an example, macropores often trigger “hot spots” and “hot moments” of biogeochemical reactions. Interpretations of point measurements without knowing macropores are now often questioned, because the uncertainty of whether soil solution is extracted from stagnant or high velocity flowpaths (such as macropores) makes it difficult to reliably determine mass flux rates. Macropore linings, on the other hand, could restrict lateral mass transfer and reduce sorption and retardation, thus enhancing physical and biochemical non-equilibriums in field soils. Because chemicals carried by macropore flow are not in intimate contact with the soil matrix, their binding by soil particles is considerably reduced. This will impact the residence time of chemicals in the Critical Zone.
Soils are heterogeneous fine-structured 3-phase systems and thus are characterised by abundant interfaces. These biogeochemical interfaces (BGI) provide a particular habitat for soil microorganisms and most of the processes occurring in soils, and are therefore hot spots for these processes. As BGI develop over time, their characteristics change; as a result, they support different types of processes at different times, resulting in temporal variability and thus hot moments for these processes. In order to understand and control soil processes, we need to understand the characteristics, the formation, and the maturation of BGI. BGI contain minerals as well as biological and abiotic (chemical) soil components. These components interact and determine biological, physical and chemical properties of the BGI. A particular important characteristic is the occurrence of concentration and energy gradients at BGI, which drive biological activity as well as chemical and physical processes. BGI affect many microbially-driven soil processes such as SOM formation and turnover of all kinds of organic compounds. BGI can be found at different spatial scales ranging from the molecular to landscape scale and control processes at temporal scales ranging from femtoseconds to millennia. The multitude of soil constituents and the large range in scales result in a wide variety of BGI in soils, which all need to be examined and described. During formation of BGI, we can distinguish three phases: In the mixing phase, the chemical and geological constituents are mixed and come into contact with each other. In the colonisation phase, the first organisms colonise the mixed material and start their activity. This finally results in the interaction phase which is characterised by processes involving two or more of the BGI components. Here, BGI at different scales (from molecular to horizon scale) and their impact on selected soil processes will be discussed with respect to their formation (initial stage) and maturation (development over time). Particular focus will be on the intra- and intermolecular interactions, on selected microbial activities and on the influence of earthworms on these activities. The combination of various techniques allowed us to identify the functions of BGI as buffers, accumulators and transformers in soil and thus as important drivers of soil processes.
Session 1: Unravelling BGIs Structure: Formation & Architecture of BGIs

Invited Talk

A Light Issue: Microbial Controls Upon the Architecture of the Soil-Atmosphere Interface

Karl Ritz1,2, Elena Armenise1, Robert Simmons1, Amin Garbout2, Sacha Mooney2, Craig Sturrock2, Sujung Ahn3 and Stefan Doerr3

1School of Energy, Environment and Agrifood, Cranfield University, Cranfield, UK
2Division of Agriculture & Environmental Sciences, University of Nottingham, Sutton Bonington, UK
3College of Science, Swansea University, Swansea, UK

The soil surface is a crucial interface, which connects the atmosphere to the pedosphere. The nature and properties of this zone play important roles in governing many aspects of soil function, including hydrological processes, propensity to erosion, gas exchange, seedling emergence, and biotic interactions. It is well recognised that “biological soil crusts” are common and of ecological significance in many natural habitats, particularly in arid and semi-arid regions, but a more general prevalence of a distinct soil surface biota is becoming increasingly apparent. Particularly little is known about the nature, properties and functional significance of the soil surface biota in arable and horticultural systems, and less still about the interactions between soil structure and biology in this zone. Microbial communities inhabiting the soil surface tend to be dominated by photoautotrophs, driven by light, and are very distinct from those in the soil matrix below. “Physical crusts” often develop on soils via the action of raindrops impacting the soil surface, resulting in aggregate breakdown and the re-organisation of disaggregated soil particles. These then form a surface layer that is typically less porous and more compact than the underlying bulk soil. We conducted a laboratory study to investigate the relationships between microbial community structure and soil structural dynamics and hydrological properties in two contrasting-textured soils used in horticultural production. We manipulated the surface microbial communities by controlling light, and via prokaryotic- and eukaryotic-selective inhibitors. The ultra-fine-scale spatial and temporal dynamics of structural seal formation was visualised and quantified via X-ray micro computed tomography. Results showed significant variations and a complex topology of the extreme surface in relation to treatment. The porosity between different types of underlying crusts, and the volume of surface-connected pores varied significantly between the two soil types. Fungal- and photoautotroph-dominated systems showed increased porosity, but reduced hydraulic connection, penetrative resistance and structural resilience, than bacterially-dominated systems. Greater hydrophobicity was manifest in the photoautotroph-dominated systems. These results demonstrate the significant role the surface biota can play in the functional behaviour of soil surfaces, the substantive part played by photoautotrophs in such functions, and attendant implications for potentially managing the nature of the soil surface.
We have only captured a glimpse of the multitude of processes on going across the biogeochemical and biophysical space in soils. We recognise after decades of research and technology advances that soil is teeming with life and contains the majority of biodiversity on the planet. This has led us into a decade of empirical science where we have measured and counted soil (micro) biology in an attempt to understand how soil works. This “biology of numbers and differences” approach has provided invaluable information about the soil microbiology. However, arguably overall this approach has failed to provide a deeper understanding of soil. The key to any understanding of such complex structures and spatio-temporal processes that dominate most soil systems, lies not in single discipline efforts, but rather in the emergence of integrated cross-disciplinary efforts by a multitude of scientists. Habitat genesis and resilience in all porous media are key processes in all relevant functions. Soil, the most complex biomaterial on the planet, relies on an undefined and unquantified balance of physico-chemical and biological activity to create and maintain diverse habitat space, the surface area of which acts as a driver for most exchange process in soil: microbe-mineral; root-soil; microbe-microbe; water-microbe; root-water etc. Despite soil teeming with microbial life, we now are beginning to understand that the physics of the soil determines many of the biological rate processes from nutrient exchange, water dynamics and general diffusion processes. This talk will focus on the small volume of soil known as the rhizosphere and present data that cover the biophysics of soil ecosystems, focusing in on water relations, habitat genesis and how the biology and physics of soil interact to determine function.
Soil organic matter (SOM) plays an important role in soils, both for soil fertility and for the soil carbon cycle. The molecular imprint of the direct precursors of soil organic matter will determine the mineralisation, transformation and stabilisation of SOM. Recently, it has been shown that microbial biomass residues contribute significantly to the formation of SOM (Simpson et al., 2007; Miltner et al., 2012). Although living microorganisms only constitute about 1-2% of the carbon in soil, their contribution to SOM formation is much higher because of their rapid turnover. A high contribution of microbial residues to SOM can explain why microbial biomolecules are relatively stable in soil and even accumulate during SOM development, but also other chemical and physical properties of SOM such as the elemental composition and the water repellency.

We studied the fate of microbial biomass residues in soils by incubating 13C-labelled microorganisms in soil for up to 240 days. The microorganisms were selected to represent different types of microorganisms, each with its characteristic cell wall composition and included Escherichia coli (Gram negative bacterium), Bacillus subtilis (Gram positive bacterium) and Laccaria bicolor (ectomycorrhizal fungus). During incubation, we traced mineralisation, incorporation into biomass as detected by analysis of biomarkers (fatty acids, amino acids, proteins), and transformation to SOM of the labelled carbon. We also visualised microbial residues in soil samples by scanning electron microscopy. We found that the carbon from all types of biomass residues was partly mineralised, partly incorporated into microbial biomass, and partly transformed into non-living SOM. The partitioning between these three processes, however, was slightly different for the different biomass types. Over all treatments, 50-65% of the microbial biomass C remained in the soil during incubation. However, only a small part remained in the microbial biomass, the majority was transformed to SOM. In particular, proteins seemed to be rather stable in our experiments. Total amino acid contents did not decline during degradation, and quite a number of B. subtilis-derived proteins were conserved throughout the experiment. However, the biomass residue-derived carbon was also incorporated into other proteins which could be assigned to a wide variety of soil microorganisms, indicating that many different soil microorganisms thrive on the residues of other organisms. Scanning electron micrographs showed a low number of intact cells, but mainly fragments of about 200-500 nm size. Similar fragments were found in artificial groundwater microcosms where the only possible origin was microbial biomass residues, in particular cell wall fragments. These results indicate that microbial biomass residues, in particular cell wall fragments and proteins, are stabilised in soil and contribute significantly to SOM formation. The extent of this contribution is difficult to estimate as it depends on the residue material, on the degrading organisms and on the environmental conditions.

References
An Interdisciplinary Approach Towards Understanding Biogeochemical Interface Formation Using Artificial Soils

Geertje J. Pronk1,2, Doreen Babin3, Franziska Ditterich4, Julia Giebler5, Katja Heister1, Michael Hemkemeyer6, Ellen Kandeler4, Ingrid Kögel-Knabner1,2, Yamuna Kunhi Mouvenchery7, Christian Poll4, Gabriele E. Schaumann7, Michael Schloter8, Kornelia Smalla3, Annelie Steinbach5, Christoph C. Tebbe6, Lukas Y. Wick5 and Susanne K. Woche9

1Lehrstuhl für Bodenkunde, Technische Universität München, Freising-Weihenstephan, Germany
2Institute for Advanced Study, Technische Universität München, Garching, Germany
3Institute for Epidemiology and Pathogen Diagnostics, Federal Research Centre for Cultivated Plants, Julius Kühn-Institute, Braunschweig, Germany
4Institute of Soil Science and Land Evaluation, Soil Biology Section, University of Hohenheim, Stuttgart, Germany
5Department of Environmental Microbiology, Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany
6Johann Heinrich von Thünen Institute for Biodiversity, Braunschweig, Germany
7Institut für Umweltwissenschaften, AG Umwelt- und Bodenchemie Universität Koblenz-Landau, Landau, Germany
8Helmholtz Zentrum München, German Research Center for Environmental Health, Neuherberg, Germany
9Institute of Soil Science, Leibniz Universität Hannover, Hannover, Germany

An interdisciplinary approach was used to gain understanding of the formation of biogeochemical interfaces in soil. Artificial soils with different mineral composition and charcoal presence were designed to study the establishment of microbial communities, their functionality and the resulting development of organic matter (OM). The artificial soils were composed to create a simplified soil-like material with well-defined composition and initial conditions and contained different mixtures of the minerals illite, montmorillonite, ferricydrate and boehmite, and charcoal, and sampled after 3, 6, 12 and 18 months of incubation. The samples were then analysed for microbial abundance and diversity, functionality as determined by respiration and enzyme activity, OM composition, physical structure and surface properties. Here, we present the integrated results of this study, focusing on the combination of different techniques to gain insight into the development of biogeochemical interfaces in soils. The mixtures quickly developed into soil-like systems, and although surface properties and organic matter developed similarly for all compositions, charcoal presence and mineral composition did have a clear effect on the development of microbial communities. The functionality of the microbial community, as shown by enzyme production and alkane degradation, was at least partly controlled by the minerals present, either due to direct interactions of microbes with mineral surfaces, or due to a control on nutrient availability by sorption to mineral surfaces. Overall, the artificial soils used in this study provided a suitable approach to gain a mechanistic understanding of the microbiological, chemical and physical processes taking place at biogeochemical interfaces in well-defined soil-like systems. This combination of a range of interdisciplinary methods illustrates how microbial communities interacted with, and were affected by, the OM, mineral and charcoal surfaces present in their habitats.
Hotspots and Hot Moments: Effect of Plant Litter on the Formation of Biogeochemical Interfaces in Soil

Annelie Steinbach1, Julia Giebler1, Irina Tanuwidjaja2,3, Nicolas Weithmann2, Stefanie Schulz2, Franz Buegger4, Antonis Chatzinotas1, Geertje J. Pronk3,5, Cordula Vogel5, Lukas Y. Wick1, Ingrid Kögel Knabner3,5, Hauke Harms1 and Michael Schloter2

1Department Environmental Microbiology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany
2Research Unit Environmental Genomics, Helmholtz Centre Munich, Neuherberg, Germany
3Chair of Soil Science, Department Ecology and Ecosystem Management, Technical University of Munich, Freising, Germany
4Institute of Soil Ecology, Helmholtz Centre Munich, Neuherberg, Germany
5Institute for Advanced Study, Technical University of Munich, Garching, Germany

Plant litter creates a large number of new biogeochemical interfaces (BGIs) in soil and increases soil heterogeneity. As a consequence, bulk soil habitats, with are low in microbial activities, are transformed into hotspots, with highly active microbial communities after litter fall. Over time microbial activities decreases at this BGIs as a result of reduced nutrient contents and soluble compounds of the plant litter leach to soil layers deeper than the litter–soil interface, changing also here temporally microbial community structure and function. This concept of hot spots and hot moments has been widely proposed in literature but rarely proven on the small scale, where microbes shape their environment. As plant litter material contains a large number of plant waxes, alkane degrading microbes are a highly important part of the litter degrading microbial communities. Thus in the frame of our project we focused on the effects of litter application on the abundance, diversity and activity of microbial communities involved in alkane degradation using the alkane monooxygenase gene alkB as a proxy in time and space. We performed several microcosm experiments addressing questions on the role of the litter material as well as of the soil type for the formation of characteristic BGIs mainly at the border of litter and soil, but also in deeper soil layers. Therefore we used soils, which were under agricultural use with different soil texture. In addition we performed studies using mixtures of inorganic materials, which form the soil matrix, which had been inoculated with microbes from a “natural soil” together with sterile manure to stimulate soil formation (“artificial soils”) at different maturation stages. For the “natural” soils our results indicate a clear response pattern of all investigated biotic and abiotic parameters depending on the applied litter material, the type of soil used, the time point of sampling and the soil compartment studied. As expected the distribution of alkanes of different chain length formed a steep gradient from the litter layer to the bulk soil. At the litter–soil interface the community structure and abundance patterns of alkB were driven by the applied litter type and its degradation. Surprisingly, the differences between the different compartments in one soil were more pronounced than the differences between similar compartments in the soils studied. For the “artificial” soils we observed an overall increasing divergence in community composition of alkB harbouring microbes during maturation, without litter application. The impact of metal oxides on alkane degrading communities increased during soil maturation whereas the charcoal impact decreased over time of maturation. Amongst the clay minerals illite influenced the alkB harbouring bacteria significantly, but not montmorillonite. The litter application induced strong community shifts in soils for those soils that have been maturated for a longer time period towards functional guilds typical for younger maturation stages pointing to a resilience of the alkane degradation function fostered by a potential ‘seed bank’ formation. Overall our data clearly indicates the importance of plant litter for the formation of BGIs in soil. The effects observed however vary strongly on the soil type and the soil development stage.
Experimental findings reveal that sorption of organic matter or attachment of bacteria can enhance water repellency of originally wettable mineral particles during the initial stages of biogeochemical interface (BGI) formation. This, in turn, can feed back on subsequent BGI formation as soil particle wettability controls the movement and distribution of water in the soil, and hence, strongly affects the transport of dissolved organic matter, nutrients, and microorganisms. Corresponding processes depend on solid–liquid interactions, which are determined by the interfacial free energies of the involved phases. The solid surface free energy not only determines the wettability of particles but is also important for their adhesion properties. Focusing on both, the objective of this study was to investigate the effect of soil particle interfacial properties on (i) liquid phase distribution and (ii) colloidal transport and interactions in porous media. As mineral matrix we used quartz sand particles (63–200 μm) of different wettability. Distribution and connectivity of water was visualized by confocal laser scanning microscopy (CLSM) and environmental scanning electron microscopy (ESEM). Transport and retention of colloids was studied by analyzing the breakthrough behavior of 1 μm carboxylated microspheres in saturated sand columns at different ionic strengths. Interaction free energies approximated from zeta (ζ)-potential and contact angle data were used to explain the colloid retention behavior. As revealed by CLSM, reduced particle wettability leads to a decrease in wetted area and water phase connectivity. The effect of wettability decreased with increasing water content and was no longer significant with respect to liquid phase spatial distribution at water contents >30 vol-%. ESEM condensation experiments corroborate these findings, showing that on water repellent particles water condensed as small drops, whereas it condensed uniformly on wettable particles. The liquid menisci formed between water repellent particles had smaller cross-sectional areas than in the wettable matrix, illustrating that water connectivity between particles can be considerably reduced. The breakthrough experiments revealed that colloids were more effectively retained in water repellent than in wettable sand. The large deposition rates found for water repellent sand could primarily be explained by a very small electron-donor component of surface free energy, leading to strongly attractive acid–base interactions at small separation distances. In addition, increasing ionic strength reduced the repulsive electrostatic interactions and generally increased colloid deposition with the effect being more pronounced again for the water repellent sand. However, the calculated values of interaction free energy should be considered only as an approximation because nanoscale surface chemical heterogeneity and roughness, as revealed by atomic force microscopy, can potentially bias the determination of the actual interaction energy conditions. Overall, our findings demonstrate the intrinsic relationship between a particle’s wettability (i.e., its affinity for water) and its ability to interact with colloids and emphasize the relevance of particle wettability as a controlling factor for both liquid distribution and adhesion phenomena in porous media.
Session 2:
Exploring BGIs: New Avenues for “Provocative” Joint Experiments & Complementary Cutting-Edge Techniques, incl. Spectroscopy, (Spectro )Microscopy & Tomography
Most of soil functions depend on biological, chemical and physics processes within a complex architecture of pores and solid materials. This is true for the recycling of nutrients and the storage of carbon, the filtration of groundwater and for quality of soils as habitat for a multitude of organisms. The notion of biogeochemical interfaces (BGIs) is thought to include the local, microscopic conditions where biological actors meet their physicochemical environment and where reactions are controlled by the accessibility of required ingredients and especially by the availability of water and oxygen. The fundamental difficulty for a profound understanding of soil processes and their interaction is the fact that soils are opaque and, thus, the detailed soil architecture and the direct observation of ongoing processes is hardly possible. Today, new tools are available to make soil transparent and to characterize soil architecture with minimal disturbance and in full three dimensions. Especially X-ray tomography is a suitable tool to quantify the spatial structure of pores and solid at resolutions ranging from the sub-micron scale to the scale of soil horizons. Besides the physical structure of pores and solid which determines the flow of water, oxygen, solutes and particles also the biochemical structure is of central importance. This, however, cannot be visualized by X-ray tomography and is typically obtained only after destructive sampling. In this presentation we discuss an avenue towards a more complete visualization and quantification of the soils’ functional architecture. It is based on X-ray tomography at various spatial resolutions to arrive at a exhaustive picture of the soil pore structure, i.e. transport pathways. The biochemical structure can be obtained from chemical mapping of impregnated cross-section as provided by new techniques as SEM-EDX or NanoSIMS. The challenge is to project the results back to the three dimensional reality and to connect the spatial scales from sub microns to soil horizons.
Preferential Sequestration of Organic Matter in Organo-Mineral Clusters as Revealed by Nano-Scale Secondary Ion Mass Spectrometry and Isotopic Tracing

Cordula Vogel¹, Katja Heister¹, Carsten W. Mueller¹, Carmen Höschen¹, F. Buegger², Stefanie Schulz³, Michael Schloter³ and Ingrid Kögel-Knabner¹,4

¹Lehrstuhl für Bodenkunde, Technische Universität München, Freising-Weihenstephan, Germany
²Institute of Soil Ecology, Helmholtz Zentrum München, Neuherberg, Germany
³Research Unit of Environmental Genomics, Helmholtz Zentrum München, Neuherberg, Germany
⁴Institute for Advanced Study, Technische Universität München, Garching, Germany

The association of organic matter (OM) with mineral particles is one major mechanism in soil OM sequestration. The contacting different organic, inorganic and biological components of a soil define the soil’s biogeochemical interface, which is an active hotspot of fundamental soil processes. By combining nano-scale secondary ion mass spectrometry (NanoSIMS) with stable isotope tracing, it is possible to study the formation and spatial heterogeneity of organo-mineral associations and to visualize the architecture of the biogeochemical interface of soil at a relevant scale. Here, we follow the formation of organo-mineral associations over time by imaging the complex interaction between soil mineral surfaces and decomposed organic compounds and demonstrate the heterogeneous composition and the development of biogeochemical interfaces in soil. We incubated a topsoil (sieved < 2 mm, Ap horizon of a Luvisol) with ¹³C and ¹⁵N labelled litter material under controlled laboratory conditions. Samples were taken 2 hours after the start of the incubation and after 1, 7, 21 and 42 days. Parallel to the determination of microbial biomass ¹³C, salt-extractable organic carbon ¹³C and the isotopic composition of bulk soil and soil fractions (obtained by a combined density and particle size fractionation) using isotope ratio mass spectrometry, the spatial distribution of OM was investigated by NanoSIMS analysis of the clay-sized fraction. By quantification of exposed areas visible by NanoSIMS, we show that only up to 19% of the mineral surfaces are covered by OM, whereas most mineral surfaces do not show any OM coverage. Our study demonstrates that mineral particles in clustered structures with rough surfaces exhibit the preferential binding spots for OM. Comparison of the OM-coated areas revealed by the 2D NanoSIMS imaging and N₂ adsorption gives evidence that mineral particles with a high specific surface area are covered by OM in these clusters. Consequently, we identify distinctive micro-scale spots enriched in ¹³C and ¹⁵N and a preferential binding of OM to rough surfaces of mineral clusters as a highly active domain in soil.

Reference
Quantification of pH-Dependent Species of Organic Molecules with UV/VIS Spectroscopy and Factor Analysis

Thomas Ritschel and Kai Uwe Totsche

Institute of Geosciences, Friedrich Schiller University of Jena, Jena, Germany

Spectroscopic methods are among the most common techniques in natural sciences. The spectra measured for example with UV/VIS or fluorescence spectroscopy contain information on electron configuration of the atoms and molecules in the sample. Since many electron transitions are covered by a single measurement, it is difficult to quantify the effect of single functional groups. Even in single component systems, multiple species can be present due to different protonation, complexation or dimerisation. Factor analysis of organic compounds showed, that the shift of spectra at different pH values is caused by the superimposition of species with different protonation. We therefore made the attempt to reconstruct the underlying spectral contribution of these species exemplified by organic model compounds. We focused on carboxylic groups, which are easily affected by pH and show strong light absorption in the UV range due to the π-electron system, and the phenolic groups, which deprotonate in alkaline solutions. Specifically, vanillic acid as surrogate for lignin, salicylic acid as common root exudate and MCPA as model herbicide were investigated. The evaluation was done by factor analysis with a non-negativity constraint (positive matrix factorisation, Kim and Park, 2008). We adapted the algorithm to include fixed background species and optionally unimodal spectra. This allowed us to quantitatively reconstruct species distribution from UV/VIS absorption and to distinguish between the contribution of carboxylic and phenolic groups. This offers the possibility to quantify organic column effluent concentrations in nearly realtime and to track the pH value without directly measuring it.

Reference
Session 2: Exploring BGIs: New Avenues for “Provocative” Joint Experiments & Complementary Cutting-Edge Techniques, incl. Spectroscopy, (Spectro-)Microscopy & Tomography

Multi-Imaging Approach to Study the Root–Soil Interface

Nicole Rudolph-Mohr¹, Paul Vontobel² and Sascha E. Oswald¹

¹Institute for Environmental and Earth Science, University of Potsdam, Potsdam, Germany
²Paul Scherrer Institute, Villigen, Switzerland

Dynamic processes occurring at the soil-root interface crucially influence soil physical, chemical, and biological properties at local scale around the roots that are technically challenging to capture in situ. Combining fluorescence and neutron imaging, we developed and validated a new multi-imaging approach capable of simultaneously quantifying H₂O⁻, O₂⁻, and pH-distribution around living plant roots. The interrelated patterns of root growth and distribution in soil, root respiration, root exudation, and root water uptake can be studied non-destructively at high temporal and spatial resolution. Fluorescence sensor foils were attached at the inner-sides of thin boron-less glass-containers where one Lupinus albus plant was grown in each container. On day 11 and 25, we wetted the containers from the bottom, and subsequently took time series of fluorescence and neutron images during day and night cycles. The neutron radiographs made it possible to visualize and quantify the root system in association with the observed pH and oxygen patterns. The older part of the root system with higher root length density was associated with fast decrease of water content and rapid change in oxygen concentration. pH values around the roots located in areas with low soil water content was significantly lower than the rest of the root system. The results suggest that the combined imaging setup is able to map important biogeochemical parameters around living plants with a high spatial resolution sufficient to relate patterns of the observed biogeochemical parameters to the root system.
Visualization of Enzyme Activity at Soil-Root Interface

Baharsadat Razavidezfuly1, Muhammad Sana Ullah1, Evgenia Blagodatskaya2 and Yakov Kuzyakov1

1Department of Agricultural Soil Science, University of Göttingen, Göttingen, Germany
2Department of Soil Science of Temperate Ecosystems, University of Göttingen, Göttingen, Germany

Extracellular enzymes are important due to their role in decomposition of many biological macromolecules abundant in soil such as cellulose, hemicelluloses and proteins. Enzyme activity is commonly described by the Michaelis–Menten relationship, which is a saturating function of substrate concentration (Allison et al., 2010; Chen et al., 2012). Nonetheless a lack of spatially explicit methods for the determination of the distribution of enzyme activity in the rhizosphere has been emphasized several times. Recently, zymography was introduced as a new technique in situ to visualize enzyme activity in soil. An underestimation of enzymes activity could occur by this technique, as it is based on diffusion of enzymes through the 1 mm gel plate. Here, we further developed soil zymography method to obtain a better knowledge on enzyme activity at soil-root interface with a higher resolution. We grew Maize in rhizoboxes (12.3×12.5×2.3 cm) for 14 days under optimum conditions. We applied basic zymology to obtain fingerprint of enzymes activity in undisturbed soil-plant system. Then, we gently dug out plant with the roots while the rhizospheric soil was still attached to the roots. We visualized the activity of three enzymes involved in C, P and N cycling (β-glucosidase, phosphatase and leucine amino peptidase) using zymography method with small modifications. We did not use gel plate and directly attached a membrane saturated with substrate to the plant root. Thereafter, we also carefully sampled the rhizosphere soil attached to the roots and the bulk soil and determined the Michaelis–Menten kinetics [maximal rate of activity (V_max) and half-saturation constant (K_m)] by fluorogenically labeled substrates method. Our results of zymography method showed greater activity of phosphatase than β-glucosidase both in very vicinity of plant roots and in the rhizosphere soil. We also found that the activity of leucine amino peptidase was the lowest. These differences were also confirmed with fluorogenically labeled substrates method which enabled us to distinguish differences in enzymes kinetics between microbial communities of rhizoplane, rhizosphere and bulk soil. Thus, the combination of zymography with enzymes kinetics is promising for determining the spatial distribution of enzyme activity in the rhizosphere as a function of distance from root.

References
Biogeochemical interfaces (BGI) are formed as a result of the complex structure and composition of solid, liquid, and gaseous compounds in soils. They are influencing various soil processes and functions being relevant for soil ecosystem services such as nutrient cycling, water availability, and climate regulation. A variety of advanced microscopic, spectroscopic, and tomographic techniques have been introduced in recent years to unravel physico-chemical properties and mechanisms of BGI on the micro- and even the nanometer scale. Microorganisms are of great importance for a wide range of processes in soils as well and therefore interact with BGI and the resulting gradients. Their physiology is regulated by the environmental conditions on the scale of microbial habitats which are mainly the features of BGI. The microbial colonization of BGI in soil is hence of great importance when studying processes on this particular scale. A set of techniques has been developed recently to study the colonization and distribution of microorganisms in the undisturbed soil matrix and thus in their microbial habitat in situ. This is done via 16S rRNA targeted fluorescence in situ hybridization (FISH) combined with micropedological resin impregnation. The impregnation of the fragile soil structure is a good way to preserve the in situ arrangements of soil compounds forming the physical structure of the soil matrix including the pore space being relevant for the support with water and air. The preparation of high quality polished blocks and thin sections of these resin impregnated samples enables a detailed analysis of the spatial information on the level of microbial habitats in soil. A correlative microscopic approach of the aforementioned techniques allows the characterization of BGI and the resulting physico-chemical living conditions as well as the identification and localization of soil microorganisms on the microscale. This gives qualitative insights of the features in microbial habitats and related interfaces (soil-root interfaces and BGI e.g.) which are of great importance for the study of the microbial ecology of microbes in soil. Since the various processes of BGI have a relevance on the large scale and vice versa upscaling is of great importance for the investigation of their influence on ecosystem functioning. Furthermore spatial modelling based on these observations is required to understand and predict the effects of changing physico-chemical conditions. Accurate quantitative data are therefore required which can be retrieved from correlative microscopic/spectroscopic analysis directly or generated by statistical analysis of individual spatial data or spatial extrapolation. Examples for these approaches will be presented based on applications in paddy soil systems. The influence of physical structure dynamics as it occurs under submerged paddy soil management due to the cycles of flooding and drying on biogeochemical features and microbial dynamics will be shown. Spatio-temporal effects and their consequences for greenhouse gas emission and iron oxidation will be highlighted. Based on microcosm approaches examples for reliable quantitative data acquisition of microbial distribution in the soil matrix and the soil-root interface will be demonstrated.
Session 2: Exploring BGIs: New Avenues for “Provocative” Joint Experiments & Complementary Cutting-Edge Techniques, incl. Spectroscopy, (Spectro-)Microscopy & Tomography

X-Ray Photoelectron Spectroscopy (XPS) as a Versatile Tool to Relate Surface Chemical Composition and Wetting Properties

Susanne K. Woche1, Marc-Oliver Goebel1, Daniel Tunega2, Roland Šolc2, Georg Guggenberger1 and Jörg Bachmann1

1Institute of Soil Science, Leibniz Universität Hannover, Germany
2Institute of Soil Research, University of Natural Resources and Life Sciences Vienna, Austria

As particle wetting properties (in terms of contact angle CA) are determined by the chemical composition of only the first nm (CA_interphase, (Ferguson and Whitesides, 1992)) a surface specific chemical analysis is needed to relate CA to chemical composition. Here, X-ray photoelectron spectroscopy (XPS) offers fascinating possibilities. Bombardment of the surface with X rays results in the emission of photoelectrons with an element-specific binding energy. The maximum analysis depth of about 10 nm is considerably smaller than that of common surface analysis techniques like EDX and ATR-FTIR (about 1 μm) and close to the CA_interphase. Relating CA and surface chemical composition so far indicated the surface O/C ratio as a general parameter (CA increases with decreasing O/C ratio). Knowing the analysis depth and assuming that BGI mainly consist of organic material, detection of elements like Si and Al should be ascribable to the underlying mineral, thus indicating either a BGI thickness <10 nm or an incomplete coverage. Evaluation of these peaks probably could allow a further BGI characterization with respect to CA, especially in cases where the carbon concentration cannot be used due to “adventitious carbon” (carbon components sorbed to the surface from the ambient air). As natural BGI consist of a wide variety of compounds that are almost impossible to identify in full, in a first step defined model systems were helpful to test the usefulness of non-BGI elements that usually are not connected with CA. Glass slides (“model surface”) were coated with defined organic components (“model BGI”) by exposure to organosilanes (dichlorodimethylsilane DCDMS, dimethyldiethoxysilane DMDES, octadecyltrichlorosilane OTS, aminopropyltriethoxysilane APTES) of varying C chain length (DCDMS, DMDES: C1; APTES: C3; OTS: C18) and polarity (DCDMS, DMDES, OTS: non-polar; APTES: partly-polar). XPS survey spectra were recorded, CA was determined, and based on energetic considerations surface structure and CA modeled. CA of the DCDMS, OTS, and APTES slide were found to be related to chain length and polarity with modeling resulting in the same trend (i.e., CA OTS > CA DCDMS > CA APTES). Only DMDES that in theory should display the same CA as DCDMS, was found to show a considerably smaller CA. Probably at least in part due to adventitious carbon, surface C concentration exhibited no defined relation with CA, but all slides showed a distinct Na peak from the underlying glass. Relating CA and Na content depicted surprising results. Not only a correlation could be found (i.e., CA increased with decreasing Na content), but the DMDES slide indeed showed a higher Na content than the DCDMS slide. This indicates that use of non-BGI elements may be an additional means to chemically characterize particle wetting properties which is supported by respective first attempts with natural soil material from a soil chronosequence where the Al concentration was found to be related to CA.

References
Characterization of Wet Aggregate Stability of Soils by $^1$H-NMR Relaxometry

Christian Buchmann, Maximilian Meyer and Gabriele E. Schaumann

Institute for Environmental Sciences, Environmental and Soil Chemistry, Universität Koblenz-Landau, Landau, Germany

For the assessment of soil structural stability against hydraulic stress, wet-sieving or constant head permeability tests are typically used but rather limited in their intrinsic information value. The multiple applications of several tests is the only possibility to assess important processes and mechanisms during soil aggregate breakdown, e. g. the influences of soil fragment release or differential swelling on the porous systems of soils or soil aggregate columns. Consequently, the development of new techniques for a faster and more detailed wet-aggregate stability assessment is required. $^1$H nuclear magnetic resonance relaxometry ($^1$H-NMR) might provide these requirements as it has already been successfully applied on soils. We evaluated the potential of $^1$H-NMR for the assessment of wet-aggregate stability of soils, with more detailed information on occurring mechanisms at the same time. Therefore, we conducted single wet-sieving and constant head permeability tests on untreated and 1% polyacrylic acid-treated soil aggregates of different textures and organic matter contents, subsequently measured by $^1$H-NMR relaxometry after percolation. The stability of the soil aggregates were mainly depending on their organic matter contents and the type of aggregate stabilization, whereby additional effects of clay swelling on the measured wet-aggregate stability were identified by the transverse relaxation time ($T_2$) distributions. Regression analyses showed that only the percentage of water-stable aggregates could be determined accurately from percolated soil aggregate columns by $^1$H-NMR measurements. $^1$H-NMR seems a promising technique for wet-aggregate stability measurements but should be further developed for non-percolated aggregate columns and real soil samples.
How Can Magnetic Resonance Imaging (MRI) Help Understanding Colloidal Particle Transport in Soils

Alizée Lehoux¹²³, Eric Michel¹², Paméla Faure³, Denis Courtier-Murias³, Francois Lafo-lie¹² and Philippe Coussot³

¹INRA, UMR1114 EMMAH, Avignon, France
²UAPV, UMR1114 EMMAH, Avignon, France
³CNRS ENPC IFSTTAR, UMR8205 Laboratoire Navier, Champs-sur Marne, France

The capability to predict the fate of colloidal particles in the subsoil is of paramount importance for scientists, engineers or policy-makers, as such particles can carry adsorbed pollutant towards the groundwater or be themselves pollutants. Current models often fail to predict observed colloid fate, indicating the need for a better understanding of the processes controlling colloid attachment, detachment and transport in the soil. Most of these processes can only be studied indirectly (e.g. using particle breakthrough curve (concentration as a function of time) recorded during simulated rainfalls). For this reason, the soil can be considered as a “black box” system. Imaging techniques (X-ray tomography, MRI) have increasingly been used to open the black box and study water movement in soil cores, but they have seldom been applied to investigate the fate of colloidal particles in soils. With the aim of gaining internal information on their transport, we injected a pulse of superparamagnetic nanoparticles (longitudinal relaxation 70 s⁻¹ mM⁻¹) in saturated sand columns and recorded: (i) their effect on proton MRI signal (double spin echo sequence, acquisition duration 70 s) as a function of the core depth (150 mm, resolution 1.6 mm) and time and (ii) the particle breakthrough curves at the column outlet. The nanoparticles were either negatively (np⁻) or positively (np⁺) charged. We found that, as expected in negatively charged quartz sand, np⁻ particles were entirely recovered at the column outlet, while np⁺ particles were completely retained. For both particles, MRI recordings permitted to follow particle pulse displacement in the columns, providing otherwise inaccessible information on the retention dynamics and locus of np⁺ particles. Interestingly, we found that both suspended and adsorbed nanoparticles contributed to the MRI signal. For this reason, we built two calibrations relationships between the MRI signal of suspended (respectively adsorbed) particles and their concentration in pore water (respectively on the solid phase). We then compared the recorded MRI signal with the signal computed from these calibrations and the outputs of a colloid transport model based on a kinetic reversible particle deposition onto sand grains. In this contribution we will discuss how the large spatially and time resolved internal data yielded by MRI (i) features this technique as a cutting edge tool to test colloid transport models to their very limits and (ii) provides an unmatched situation to understand “why” and “where” particle retention occurs.

Acknowledgement
One of us (AL) benefited of a PhD grant funded by IFSTTAR and INRA
Rapid Formation of Non-Extractable Residues of Sulfonamides: Paramagnetic Spin Probing Revealed Covalent Bonding of Aromatic Amino Group

Michael Matthies¹, Tanja Müller¹, Olga Alexandrova¹, Jörg Klasmeier¹, Hans-Jürgen Steinhoff² and Kalman Hideg³

¹Institute of Environmental Systems Research, University Osnabrück, Osnabrück, Austria
²Department of Physics, University Osnabrück, Osnabrück, Austria
³Department of Organic and Medicinal Chemistry, University of Pécs, Pécs, Hungary

Sulfonamide antimicrobial agents comprise an important class of human and veterinary pharmaceuticals, which are applied to soil via sludge or manure amendment. Soil incubation experiments with sulfadiazine (SDZ) showed a rapid formation of nonextractable residues (NER) (Förster et al., 2009), which is attributed to the nucleophilic addition reaction of the aromatic amino group to quinones of soil organic matter (SOM) (Gulkowska et al., 2014). Müller et al. (2010) observed an instantaneous loss of extractability of SDZ on a time scale of minutes as well as kinetically determined sequestration and NER formation over 24 h in two different soils with and without manure, for air-dried and for moist soils. We present a new approach of using stable paramagnetic electron spin probes to investigate the rapid interaction of amino groups of sulfonamides and other xenobiotics with SOM. We used the nitroxide spin labels TEMPO (2,2,6,6-Tetramethylpiperidin-1-oxyl), amino-TEMPO (4-amino-2,2,6,6-Tetramethylpiperidin-1-oxyl) and anilino-NO(2,5,5-Trimethyl-2-(3-aminophenyl)pyrrolidin-1-oxyl), which differ in their hydrophobicity and reactivity to SOM. A significant broadening of the ESR-signals of anilino-NO incubated with luvisol soil from Merzenhausen indicated a strong restriction of the re-orientational motion of the spin probe, which could not be observed with the other two spin probes. The same signals could be detected with Leonardite humic acid, which suggest a strong bonding to soil humic substances, i.e. covalent bonding. Sequential desorption from incubated soil using ultrafiltration revealed an almost exponential decrease of the percentage of all three spin probes remaining in the soil. The fractions of TEMPO and amino-TEMPO almost completely diminished with increasing volume of percolate, whereas those of anilino-NO approximated a stationary level of 6% remaining in soil. We conclude that large fractions of all three spin probes are weakly bound to soil with low binding energy, because they can be extracted by an excess of water. For anilino-NO, results indicate an additional fraction to be irreversibly bound to soil. This finding supports the conclusion from the ESR-spectroscopic analysis of the interaction of the spin probes with SOM and Leonardite humic acid. Our work clearly demonstrates for the first time the benefit of using spin probes to investigate the interaction of functional amino groups of xenobiotics with natural soil.

References
The Influence of Extracellular Oxidative Enzymes on the Formation of Non-Extractable Residues (NER) of $^{14}$C-Metalaxyl in Soil

Andreas Schaeffer$^1$, Jens Botterweck$^1$, Burkhard Schmidt$^1$, Roschni Kalatoor$^2$ and Jan Schwarzbauer$^2$

$^1$Institute for Environmental Biology and Chemodynamics (UBC), Institute Biology V, RWTH Aachen, Aachen, Germany
$^2$Institute of Geology and Geochemistry of Petroleum and Coal, RWTH Aachen University, Aachen, Germany

The influence of extracellular phenoloxidases and peroxidases on the formation of non-extractable residues (NER) of the systemic fungicide metalaxyl (N-(methoxyacetyl)-N-(2,6-xylyl)-DL-alaninate) in soil was examined in a time course study over 90 days. Metalaxyl was incubated as (ring-U-$^{14}$C) labeled radioactive compound in an Eutric cambisol soil from Ul-tuna, Sweden. To prove that xenobiotics like metalaxyl are incorporated and/or bound to organo-clay complexes by oxidative enzymatic coupling reactions, different sterilization techniques were established resulting in (A) samples with neither microbial activities nor extracellular phenoloxidase and peroxidase activities; (B) samples without microbial activities but remaining activities of these enzymes. Incubation in such sterilized samples was compared with native soil samples (C). The fate and behavior of the fungicide was studied within the bulk samples and their particle size fractions. NER were located mainly in the silt fraction of the soil and increased in the course of time reaching a final amount of around 25% in (C), about 10% in (B) and about 5% in (A) of applied radioactivity after 92 days of incubation. Amounts of NER formed were closely correlated to microbial activities, organic matter content and extracellular phenoloxidase and peroxidase activities. The analysis of the bound residues showed that the parent substance and its main transformation product, metalaxyl acid, were mainly bound to the humic matter fractions by ester and amide linkages, except the compounds bound to the humine fraction, which were stronger bound to the matrix, e.g. by ether or carbon-carbon linkages. Finally $^{14}$C-metalaxyl was incubated in sterilized soil after addition of alginate immobilized laccase leading to increased amounts of NER within in the soil samples, proving that immobilized oxidative enzymes contribute to the formation of xenobiotic NER.
Effect of Phenanthrene and Hexadecane on the Release and Transport of Mobile Organic Matter in Artificial Soil - A Two Layer Column Study

Katharina Reichel1, Doreen Babin2, Irina Tanuwidjaja3, Marc-Oliver Göbel4, Armin H. Meyer5, Kornelia Smalla2, Michael Schloter3 and Kai Uwe Totsche1

1Institute for Geoscience, Chair of Hydrogeology, Friedrich Schiller University of Jena, Germany
2Institute for Epidemiology and Pathogen Diagnostics, Julius Kühn Institut, Braunschweig, Germany
3Research Unit of Environmental Genomics, Helmholtz Zentrum Munich, Germany
4Institute for Soil Science, Leibniz University of Hannover, Germany
5Institute for Groundwater Ecology, Helmholtz Zentrum Munich, Germany

Biogeochemical interfaces (BGIs) in soils are “hot spots” of microbial communities and turnover of organic substances. We hypothesize that the model compounds and additional carbon sources phenanthrene (PHE) and hexadecane (HEX) influence microbial communities, which in turn may affect the release of mobile organic matter (MOM), including biocolloids, and the properties of BGIs in pristine soils. We explored the release of PHE and HEX using a new experimental approach employing two-layer columns (10x12 cm) filled with an artificial mineral soil mixture (quartz, illite, goethite). In this set-up, the lower layer, further called “reception layer” (RL, 10 cm), contained the mineral soil material and the upper layer (2 cm) served as source layer (SL) and consisted of the mineral mixture, sterile manure (as OM source) and microbial community extracted from a Luvisol (Scheyern, Germany). SL was spiked with PHE or HEX (2.0 mg g⁻¹) and, to identify the active microbial degraders, two columns were additionally spiked with labeled 13C-PHE or 13C-HEX (2.0 mg g⁻¹). Un-spiked columns served as controls. In general, five different variations of SL-spiking were run in parallel with two replicates per treatment. The experiment was carried out under unsaturated flow conditions. All columns were irrigated with artificial rain water for around 35 days (d) (0.5 pore volume day⁻¹) with several flow interrupts (FI) of different durations (1-30 d) to allow reactions on solid phases. Physicochemical and chemical parameters (pH, EC, turbidity, TOC/DOC, anions/cations, PHE, HEX and their metabolites) and microbial community composition were analysed in effluent samples. After the transport experiment, columns were sliced into 1 cm thick layers and microbial community composition, morphology and topography of solid phases and contact angle were determined along the columns depths. The release of MOM from the columns was in general controlled by non-equilibrium. The maximum release of organic carbon (after 0.7-0.9 pore volumes) is delayed which is caused by longer flow path through the columns. PHE and HEX had no effect on MOM release. Turbidity and hydrodynamic diameter, two parameters that relate to suspended particles and colloids, were unaffected in all the treated columns. In all effluent fractions, diverse and heterogeneous bacterial communities were found. This proves the assumption that microorganisms are mobile in the studied artificial soil and under designed flow conditions. Denaturing gradient gel electrophoresis (DGGE) results showed high similarities in bacterial communities associated with the immobile solid phase among different depth layers and treatments. Few bacterial populations in DGGE fingerprints were depended on the distance to SL in PHE-spiked columns.
Session 3: Microbial Ecology of BGIs: Soil (Micro-)Organisms as “Architects” & “Actors” of BGIs
Microbial Diversity At the Interface

George A. Kowalchuk

Department of Ecological Science, Vrije Universiteit, Amsterdam, The Netherlands

Soil-borne microbial diversity is vast and still rather poorly understood. Molecular, and more recently high-throughput sequencing, approaches have facilitated numerous surveys of this diversity, providing us with a newfound appreciation for soil-borne microbial diversity and revealing insight into some broad environmental drivers of soil-borne microbial community structure. However, we still have a rather crude understanding of the forces that drive patterns of microbial diversity in soil environments and the biogeochemical interfaces they contain. The scale at which microbes interact with their structured soil environment, and the organisms with which they share these habitats, is rarely taken into account in studies of microbial diversity. This failure to take the physical structure of soil into account hampers our ability to detect meaningful interactions and insights into microbial lifestyles and activities in soil. To tackle these limitations, we have adopted two general approaches: (a) fine-scale sampling and deep interrogation of patterns of microbial diversity, and (b) laboratory experiments using artificial soil systems to track the impact of fine-scale soil structure on patterns of bacterial interactions and the maintenance of biodiversity. Using fine-scale sampling, we examine the micro-scale patterns of microbial diversity of individual soil grains and root surfaces via high-throughput tag pyro-sequencing approaches. To complement this in situ approach, we also track microbial diversity patterns in artificial soil-like systems in response to manipulations of soil structure and moisture, and therefore connectivity. Combining our survey-based and experimental approaches has allowed us to adopt a more microbe-centric point of view in our examination of soil-borne microbial diversity, facilitating a better understanding of the drivers of microbial composition, diversity and function.
Session 3: Microbial Ecology of BGIs: Soil (Micro-)Organisms as “Architects” and “Actors” of BGIs

Influence of Organic Matter on Microbial Community Structure and Activity in Soil Microhabitats

Michael Hemkemeyer1, Tobias Schlinsog1, Bent T. Christensen2, Rainer Martens1 and Christoph C. Tebbe1

1Thünen Institute of Biodiversity, Braunschweig, Germany
2Department of Agroecology, Aarhus University, Foulum, Denmark

Differently sized soil particle fractions (PSF) differ in mineral composition and in soil organic matter (SOM) content and composition. PSF thereby provide microhabitats associated with distinct surface properties. Previous studies demonstrate that the different microhabitats may select for structurally distinct microbial communities (Neumann et al., 2013), and that differences in SOM, generated by contrasting long-term fertilisation, may influence the microbial community involved in degradation of organic pollutants (Neumann et al., 2014). This study examines the impact of SOM accumulated in individual PSF on the structure and function of the microbial communities, using phenol mineralisation as an indicator of function. Soil was from unfertilised, mineral fertilised and animal manured treatments in the Askov Long-Term Field Experiment (Denmark), which has now been continued for 120 years. The treatments have similar particle size distribution and pH but differ in SOM contents. Soil samples were separated into a sand-sized fraction (63–2000 μm) containing also particulate organic matter (POM), coarse silt (20–63 μm), fine silt (2–20 μm), and clay (< 2 μm) by mild sonication, wet sieving and centrifugation. DNA was extracted from bulk soil and from PSF. Microbial populations were determined by quantitative PCR (qPCR) of small subunit (SSU) rRNA genes. The same genes were used for genetic profiling using terminal restriction fragment length polymorphism (T-RFLP). To investigate the mineralisation of phenol, the PSF were incubated with sterile quartz for better aeration, especially of the finer fractions. The mineralisation of added 14C-phenol was monitored by quantification of liberated 14CO2 trapped in NaOH. The distribution of 14C-phenol within the soil was examined in adsorption studies and subsequent fractionation. Bulk soil contained 2.4–3.9·1010 gene copies g⁻¹ soil of bacteria, 0.5–1.3·109 of archaea, and 5.5–9.0·108 of fungi. Generally, microbial abundance was negatively correlated with particle size and was highest in manured soil. Communities of all three microbial domains responded to particle size and fertilisation regime, but to different degrees: Bacterial communities were predominantly determined by PSF, while the fertilisation regime was the main driver for archaea. Both factors were equally important for fungi. Phenol mineralisation correlated positively with microbial abundances, except for the sand-sized fraction, suggesting an impact by POM. Highest mineralisation rates were found in the manured soil. This was related to phenol adsorption being smallest in the manured soil and thus leaving more phenol bioavailable. Our study shows that SOM accumulated under different fertiliser regimes leads to microhabitats that support structurally and functionally different soil microbial communities.

References
Mobile organic matter (MOM) in soil provides nutrients for microbes residing distantly from the organic-rich top layer. Furthermore, MOM contains biocolloids which facilitates the propagation of bacteria within the soil profile. Organic pollutants are often associated with MOM which controls their environmental fate and release. In this study, we investigated whether the transport of phenanthrene used as model compound for organic pollutants affects the composition of MOM and the soil bacterial community structure. Therefore, we conducted a two-layer column transport study under unsaturated conditions. Columns (10 x 12 cm) were filled with pristine Luvisol soil. The upper 2 cm of columns contained Luvisol (0.2 mg g⁻¹) either unspiked (control) or phenanthrene-spiked. Each treatment consisted of two replicates. Columns were irrigated with artificial rain water (1-1.5 pore volume day⁻¹) for one month with several flow interruptions (FIs) of varied duration to allow reactions at biogeochemical interfaces. After the end of the flow period, columns were sliced into several layers (source, interface, recipient) to obtain a depth profile. The bacterial community composition was studied by denaturing gradient gel electrophoresis (DGGE) and pyrosequencing of 16S rRNA genes amplified from total community DNA which was extracted from effluent and soil slices. Furthermore, the presence of genes involved in the degradation of phenanthrene and physico-chemical parameters (pH, TOC/DOC, phenanthrene etc.) were determined. By DGGE, a changing bacterial community composition was found in effluent samples over the flow period. TOC/DOC and the number of bacterial 16S rRNA gene copies in effluent samples showed similar trends suggesting a rate-limited release but only a small impact of spiked phenanthrene was observed. Bacterial communities showed a high homogeneity within the soil profile. The main responder to phenanthrene was affiliated to Geothrix fermentans belonging to the Acidobacteria phylum. The effect of phenanthrene on the bacterial community structure and the abundance of genes involved in the aerobic degradation of phenanthrene decreased to the recipient layer. Highest phenanthrene concentrations were found in the interface layer indicating a slow transport of phenanthrene to deeper soil layers. In conclusion, this study suggests an impact of phenanthrene on quality and quantity of MOM resulting in changes of the soil bacterial communities.
Spatial Heterogeneity, Diversity and Ecosystem Function

James I. Prosser

Institute of Biological and Environmental Sciences, University of Aberdeen, Aberdeen, UK

Soil microbial ecology has been dominated during the past 25 years by studies of the diversity of soil microorganisms, particularly bacteria and archaea. This interest resulted from the application of molecular techniques that provided evidence for diversity of 16S rRNA and functional genes that much higher than expected and the high relative abundance of organisms that were previously unknown or considered to be rare in soil. This high diversity raised two fundamental questions: why is sequence diversity so high and what are the consequences for such high diversity on ecosystem function. The second question has received most attention and the majority of studies characterise sequences in nucleic acids extracted from 1 – 10 g soil. Although diversity is studied at this scale, many of the mechanisms thought to influence both the origin and consequences of diversity are believed to operate at much smaller scales. Consequently the majority of studies are not mechanistically based and much of the “noise” obtained in diversity data is blamed on lack of consideration of small-scale heterogeneity and excused by inability to measure small-scale diversity. This presentation will explore the dangers of ignoring heterogeneity, ways in which small-scale mechanisms can generate predictions that can be tested at larger scales and ways in which molecular data can give information on the consequence of heterogeneity.
Microorganisms: Active Inhabitants and Architects of BGIs in Artificial Soils

Kornelia Smalla1, Doreen Babin1, Guo-Chun Ding2, Cordula Vogel1, Geertje J. Pronk3,4, Katja Heister3, Ingrid Kögel-Knabner3,4, and Michael Schloter5

1Institute of Epidemiology and Pathogen Diagnostics, Julius Kühn-Institut, Braunschweig, Germany
2College of Resources and Environmental Sciences, China Agricultural University, Beijing, China
3Lehrstuhl für Bodenkunde, Technische Universität München, Freising-Weihenstephan, Germany
4Institute for Advanced Study, Technische Universität München, Garching, Germany
5Research Unit for Environmental Genomics, Helmholtz Zentrum München, German Research Center for Environmental Health, Neuherberg, Germany

Soils belong to the most complex materials on earth. Constituents of different origin are in close contact and interact with each other. The presence of various microsites goes along with a diverse soil microbiota. The advent of new molecular techniques in microbial ecology opens up new ways to explore the microbial diversity in soil. Total community DNA-based analysis was employed to disentangle microbial community composition and responders to spikes in long-term matured artificial soils. The joint SPP1315 experiment using artificially composed soil like mixtures was established to elucidate the formation of biogeochemical interfaces. Artificial soils were composed by adding the microbial fraction from a natural Luvisol as inoculum to four soil compositions differing in the type of clay mineral (illite, montmorillonite) and the presence of charcoal or ferrihydrite. After more than two years of incubation, soils were spiked with phenanthrene and/or plant litter. Total community DNA (TC-DNA) was extracted directly from soil samples taken 0, 7, 21 and 63 days after spiking. The microbial communities were studied by DGGE and 454 pyrosequencing of 16S rRNA genes amplified from TC-DNA. The combination of both cultivation-independent techniques provided insights into the microbial community composition, temporal changes and allowed assumptions on mineral-microbial interactions. We observed that the type of clay mineral was the main factor shaping the bacterial community composition over a long-term incubation. Actinobacteria, Bacteriodetes, and Alphaproteobacteria were more abundant in soils containing illite whereas montmorillonite-soils exhibited more Gammaproteobacteria and Firmicutes. Influences of ferrihydrite or charcoal were seen on lower taxonomic levels. We could show that the bacterial communities established in matured artificial soils changed in response to phenanthrene spiking and that more pronounced shifts were observed in montmorillonite-soils compared to other artificial soils with both methods. High numbers of sequences affiliated to the genus Kocuria were found in artificial soils composed solely of montmorillonite, whereas Arthrobacter was enriched in all other phenanthrene-spiked soils. In addition, several litter-responders were identified (e.g. Adhaeribacter, Devosia, and Luteimonas). The present study showed the long-term driving influence of the soil mineral composition and charcoal on microbial community composition. To conclude, the analysis of 16S rRNA gene fragments amplified from total community DNA provided insights into the bacterial community composition established in artificial soils and potentially contributing to the formation of biogeochemical interfaces and to disentangle responders to the phenanthrene and litter spike which might have potential degradative functions. However, 16S rRNA gene-based methods employed provide only a rather course view of the structural and functional diversity and fail to gain information on the active bacterial fraction and its mobile gene pool, on spatial arrangements and synergistic or antagonistic interactions. However, the information gained on dominant bacterial OTUs dwelling in artificial soils and responding to the spikes can now be used to develop of probes for advanced microscopy analysis at the micro-scale.

Session 3: Microbial Ecology of BGIs: Soil (Micro-)Organisms as “Architects” and “Actors” of BGIs

Keynote Talk

Microorganisms: Active Inhabitants and Architects of BGIs in Artificial Soils
Reducing Diffusion Limitation Shifts the Dominant Nitr...
The soil-litter interface is an important biogeochemical interface where carbon enters the soil. Whereas most studies focused on the flow of litter C into the soil and its microbial utilisation, much less attention was drawn to possible consequences of C transport on soil processes not directly connected to litter C turnover. This talk will provide an overview of our experiments, which focused on microbial-physicochemical interactions during coupled soil organic matter decomposition and degradation of MCPA (2-Methyl-4-chlorophenoxyacetic acid) at the soil-litter interface. We used the herbicide MCPA as a model compound for organic chemicals and studied microbial MCPA degradation, abundance of microbial degraders and adsorption, desorption and transport of MCPA. In a first experiment, transport of litter compounds was identified as important process, which regulates the activity of the MCPA degrading community resulting in accelerated MCPA degradation at the soil-litter interface (Poll et al., 2010). Increased bacterial and fungal MCPA degradation might be hierarchically regulated: (1) At the cellular level by co-substrate availability and activity of unspecific enzymes (e.g. laccases), (2) at the community level by the ecology of different degrader populations and (3) at the microhabitat level by interaction between MCPA degraders and organo-mineral surfaces as well as transport processes. In a series of experiments, we tested different regulation mechanisms. Whereas preliminary results indicate that only small amounts of MCPA-C were incorporated into the fungal biomass and that commercially available fungal laccases did not increase MCPA degradation, we were able to detect differences between the ecology of specific degrader populations (Ditterich et al., 2013). We could also show that MCPA-C was incorporated by microorganisms and stabilized in soil as biogenic residues. In a batch experiment, we found that the observed small-scale mechanisms at the soil-litter interface were relevant at a larger scale depending on the amount of added MCPA and litter (Saleh et al., in prep.). Finally, we developed and applied a mechanistic model, which integrates biological and physical processes to improve our understanding of the microbial regulation of MCPA degradation at the soil-litter interface (Pagel et al., 2014).

References
Session 4: 
BGIs in Changing Environments: BGIs Dynamics & Heterogeneity with Consequences for Properties & Processes
Trophic Interdependencies Shape Spatial Self-Organization of Microbial Consortia on Complex Hydrated Soil Surfaces

Dani Or

Department of Environmental Systems Science, ETH Zurich, Switzerland

Microbial life in soil occurs within fragmented pore spaces and aquatic habitats where motility is restricted to thin liquid films capable of supporting motion, and for relatively short hydration windows (immediately following wetting events). The limited ranges of self-dispersion, and the physical confinement, enforce spatial association among trophically interdependent microbial species with different and competing resource requirements. The spatial organization and functional patterns of such complex diffusion-controlled communities remain unclear. We report a mechanistic modeling study of multispecies microbial communities grown on hydrated soil surfaces. Model results show how trophic dependencies and cell-level local interactions within patchy diffusion fields lead to niche partitioning and promote spatial self-organization of motile microbial cells. The spontaneously forming patterns of segregated yet coexisting species were shown to be robust to spatial heterogeneities and temporal perturbations (hydration dynamics), and responded primarily to the type of trophic dependencies and boundary conditions (nutrient fluxes at boundaries). The spatially self-organized consortia form ecological templates that optimize nutrient utilization (and potentially other functions), these patterns could form the basis for subsequent sessile and EPS-embedded microbial colonies forming on newly inhabited soil surfaces. The limited spatial range of microbial displacement on surfaces defines a hydration-dependent separation distance for the activation of spatial self-organization (i.e., members separated beyond this distance cannot "join" the consortium). The study provides new insights into potential mechanisms by which differences in nutrient affinities among microbial species could give rise to spatial order in an extremely heterogeneous and complex soil microbial world.
Bacterial Impact on the Wetting Properties of Soil Minerals

Jan Achtenhagen¹, Marc-Oliver Göbel², Anja Miltner¹, Susanne K. Woche² and Matthias Kästner¹

¹Department of Environmental Biotechnology, Helmholtz-Centre for Environmental Research-UFZ, Leipzig, Germany
²Institute of Soil Science, Leibnitz Universität Hannover, Hannover, Germany

Soil water repellency (SWR) is a widely observed phenomenon with severe impacts like increased erosion, inhibited plant growth and surface runoff. Nevertheless, a physicochemical framework to explain the occurrences and origin of SWR is still a major field of research. Recent studies have shown that microbial biomass residues, in particular cell fragments, contribute significantly to the formation of soil organic matter (SOM) and are therefore important biogeochemical interfaces. It was also shown that osmotic stress increases the hydrophobicity of bacterial cell surfaces. If microorganisms are an important source of SOM, the attachment of cells and their residues on mineral grains should decrease wettability of minerals while the effect should be more pronounced in case of osmotic stress. Cultures of Pseudomonas putida, either unstressed or exposed to osmotic stress, and cell fragments were mixed with minerals and the impact on surface wetting properties was investigated by determining the solid-water contact angle. Scanning electron microscopy was used for visualization of structures in the sub-μm size range and environmental scanning electron microscopy was used to determine the micro-scale wettability. Attachment of bacteria to quartz surfaces resulted in a significant increase in hydrophobicity of the surfaces (contact angle increase by up to 90°), in particular for stressed cells, even if the surface coverage by bacterial biomass was very low (<5%). Cell fragments and cytosol as well were found to decrease wettability significantly (contact angles of up to 100°). These findings may explain various phenomena related to SWR, like critical soil water content and may be one important parameter for the formation of SWR after irrigation with treated sewage effluents. The results also support the hypothesis of a microbial origin of SWR, in which macromolecular biological structures may have a greater impact than specific classes of organic compounds.
Fungal-Mineral Interface During Leaf Litter Decomposition

Flavia Pinzari¹, Loredana Canfora¹, Melania Migliore¹, and Rosario Napoli¹

¹Consiglio per la Ricerca e la sperimentazione in Agricoltura, Centro di Ricerca per lo studio delle relazioni tra pianta e suolo, Rome, Italy

For some authors, the decomposition of cellulose and other organic compounds in soil is positively correlated to the concentration of macronutrients, such as N and P. Several studies on leaf litter decomposition demonstrated that the content of N and P can define the decomposability of the organic substrate (Melillo et al., 1982). But the effect of other nutrients such as Mn, K, Ca and micronutrients (Mo, Cu, Zn, Fe) seemed equally essential on the rate of decomposition. Perez and Jeffries (1992) for example found that Mn acts as an activator of fungal enzymes such as Mn-peroxidase that work in the breakdown of lignin. Along the complex process of degradation of the organic substance in the soil, the elements present in limiting quantities can induce competition between decomposers and result rapidly immobilized in the biomass of the same, with the consequent increase of their concentration in the litter. Tiunov and Scheu (2005) showed how decomposition processes at the level of the soil and litter are often driven by fungi, whose functional diversity may be determinant at a spatial scale in which fungal hyphae interact with each other and with both mineral and organic compounds. These microsites can be characterised by different concentrations of microelements as a consequence of fungal ability to dissolve or deposit some mineral compounds. Salamanca et al. (1998) and Briones and Ineson (1996) showed a net transfer of nutrients such as potassium (K), calcium (Ca) and magnesium (Mg) between different litters. The translocation of nutrients and the leaching activity or hyphae allows the pioneers fungi to overcome the limitations offered by a poor substrate. Actually in most natural habitats the spatial distribution of organic particles and minerals is patchy. In this study we used a combination of experimental techniques to compare fungal communities developing in two leaf litter environments, characterised by the same rock substrate (volcanic soil), but with different forest coverage (Quercus spp. and Fagus sylvatica L.). The data here showed are relevant to the changes in elemental composition of leaf litter after fungal development and to a comparison of the fungal communities in the two systems. Decomposing Quercus and Fagus leaves were analysed with a variable pressure SEM instrument (EVO50, Carl-Zeiss Electron Microscopy Group) equipped with a detector for electron backscattered diffraction (BSD). Most of the fungal structures documented on leaf litter proved to be capable of concentrating several important biogenic microelements (N, P, S, K, Mg and Ca), that are at a lower concentration or absent in the background substrate before fungal colonisation. Moreover it was documented the formation of oxalates directly on leaf surfaces as a result of the active translocation of calcium by the fungal mycelium. The compared ecosystems, although sharing several important variables (macroclimate, exposition, soil parental material) showed to support different fungal communities that have specific decomposition abilities towards both the organic and mineral substrate.

References
How Does the Addition of Sulphur to Soil Influence Chemosynthesis and Carbon Flux?

Kris M. Hart¹, Anna N. Kulakova², Christopher C. R. Allen², Andre J. Oppenheimer⁴, Hussain Masoom³, Denis Courtier-Murias³, Ronald Soong³, Leonid A. Kulakov², Paul F. Flanagan², Brian T. Murphy¹ and Brian P. Kelleher¹

¹School of Chemical Sciences, Dublin City University, Glasnevin, Ireland
²The School of Biological Sciences, Queen’s University Belfast, Medical Biology Centre, Belfast, N. Ireland
³Department of Chemistry, Division of Physical and Environmental Science, University of Toronto at Scarborough, Toronto, Ontario, Canada
⁴Department of Mathematics and Statistics, Shackouls Honors College, Mississippi State University, Mississippi State, USA

The sequestration of CO₂ in soil represents a potential solution to rising atmospheric carbon concentrations and lowering agricultural productivity (King, 2010). The microbial contribution to soil organic matter (SOM) has recently been shown to be much larger than previously thought and thus its role in the carbon cycle may also be underestimated (Simpson et al., 2007). Both photoautotrophic and chemoautotrophic soil microorganisms can fix CO₂ through a variety of assimilatory pathways (Yuan et al., 2012). Chemoautotrophs can work without sunlight as an energy source and glean energy through the oxidation of reduced elements such as sulphur. Recently we showed that by adding an electron donor, in this case S₂O₃²⁻ to a soil slurry, there was an order of magnitude increase in the uptake of CO₂ by chemoautotrophs (Hart et al., 2013). What then happens when sulphur is added to soil as is done commonly in agriculture? Here we show that over a 12 week period, the addition of sulphur to soil results in an initial surge in production of CO₂ through microbial respiration/degradation and this is followed by an order of magnitude increase in the sequestration of carbon from the atmosphere as elemental sulphur is oxidised to sulphate. Stable isotope Probing (SIP) shows that Thiothrix spp (a chemoautotrophic bacterium) take advantage of the reduced conditions to become the dominant group that consumes ¹³CO₂ and uses the carbon for cellular growth. Through nuclear magnetic spectroscopy (NMR) we can discern the direct incorporation of atmospheric carbon, facilitated by the oxidation of sulphur, into soil carbohydrate, protein and aliphatic compounds and differentiate these from existing biomass.

References


Session 4: BGIs in Changing Environments: BGIs Dynamics & Heterogeneity with Consequences for Properties & Processes

Understanding Root Growth Induced Changes in Soil

Sonja Schmidt\textsuperscript{1}, Glyn Bengough\textsuperscript{2,3} and Paul Hallett\textsuperscript{4}

\textsuperscript{1}Abertay University, The SIMBIOS Centre, Dundee, UK
\textsuperscript{2}The James Hutton Institute, Invergowrie, Dundee, UK
\textsuperscript{3}The University of Dundee, Geotechnical Engineering, Dundee, UK
\textsuperscript{4}The University of Aberdeen, School of Biological Sciences, Aberdeen, UK

With increasing demand for food and variable water regimes due to climate change, it is important to get a better understanding the processes involved in roots growing through soil. It is known that roots change their environment during growth and changes in soil structure will affect water and nutrient availabilities for plants but little is known how soil structural properties change over time. More detailed information on the mechanisms involved of roots pushing through soil will help us to model root growth and water and nutrient uptake by plants. The aim of this study was to obtain data on soil structure in the rhizosphere and at the root soil interface during root growth of young maize seedlings as well as data on failure mechanisms of soil under pressure. 3D volumetric images of growing maize roots were taken over a period of six. Soil was compacted to two different levels (50kPa and 200kPa) and wetted to two matric potentials (-10kPa and -100 kPa). 2D cross sections of different positions along the roots were analysed for changes in porosity, pore connectivity and root-soil contact for different time steps. Particle image velocimetry (PIV) was used to quantify particle movement during the root growth. Soil physical characteristics were determined using a crack propagation – notched bend test and a compression test. Soil structural changes were observed during root growth. Root-soil contact increased with time whereas porosity decreased in close proximity to the root. Soil deformed radially and some aggregates were destructed during root growth while others were pushed into the pore space. Soil mechanical behaviour was significantly affected by compaction but not by the water content. These data on the changes in soil structure will help us to predict water and nutrient availability for plants.
Active Microbial Dispersal in Soils: Effect of Spatial Heterogeneity and Varying Hydration Conditions

Barth F. Smets

Department of Environmental Engineering, Technical University of Denmark, Lyngby, Denmark

Though we often consider microbes in soil as attached onto soil interfaces, the fact that they can disperse should not be overlooked. Indeed, the ability of microbes to be spatially dynamic has wide ranging consequences for microbial ecology (e.g. gene flow in microbial communities) and for the provision of the key soil services (e.g. degradation of xenobiotics). However, our current knowledge of spatial organization and spatial dynamics of microbes in soil at the microscale is limited. While passive dispersal via water flow or soil biota is a major dispersal route, it is important to evaluate the contribution of active dispersal to microbial spatial dynamics. In bacteria, active dispersal, termed motility, is enabled by diverse appendages and, in the case of swarming motility, by the secretion of surface active biomolecules. It is unclear to which degree different types of motility can take place in the soil pores, a habitat characterized by a complex 3D geometry and variable hydration. To address these questions, we have taken advantage of the Porous Surface Model (PSM) a unique experimental platform that allows direct monitoring of microbial motion under controlled matric potential. Using gfp-tagged Pseudomonas strains and isogenic mutants with various abilities to express various types of motility, we have aimed to quantify the physical barriers of bacterial motility. Our results demonstrate how hydration and substratum topography control bacterial motility under unsaturated conditions. These findings can form the basis of improved biodegradation models that include microbial dispersal processes.
Soil microbial communities live in a complex three-dimensional framework in which a range of microbial niches with a variety of properties exists. The importance of these habitat properties relative to the intrinsic properties of microbial communities in the regulation of SOM decomposition and so CO₂ emissions is still unclear. Some studies suggest that abiotic processes dominate SOM decomposition, mainly through physical mechanisms (i.e. occlusion within aggregates, adsorption onto minerals) that limit the access decomposers have to organic substrates. Microbial habitat properties are therefore likely to profoundly affect microbial decomposition of SOM. In contrast, others studies have concluded that soil microbial communities acting as catalysts of biogeochemical cycles by converting organic material to inorganic substances play a dominant role in SOM decomposition. Most studies on the relationship between microbial diversity and SOM decomposition indicate that the lack of relationship between the two is due to a certain functional redundancy that exists within microbial communities. However, the experiments on which this conclusion is based generally appear to contain the same dominant microbial species and therefore the same dominant active species. In order to determine which of microbial habitat properties or intrinsic microbial community properties is the dominant regulator of SOM decomposition, we sterilised samples from 6 soils, cross-inoculated them with communities originating from each of the 6 soils and measured C mineralisation in the inoculated soils during an incubation that lasted for a period of XXX days. The 6 soils varied in texture, pH, OM status and contained different microbial communities (verified by t-RFLP), meaning that there were 36 treatments (6 soils x 6 communities) which contained a range of different habitat x microbial community combinations. The cumulative respiration curves were fitted with two-compartment first order model, and the parameters were analysed to determine what affected the CO₂ emissions. Microbial habitat properties were more closely related to SOM decomposition. Nevertheless, the mineralisation rate of the native pool (β parameter) was affected by the structure of the microbial communities.
Rhizosphere is one of the most important hotspots in soil with very tight biotic and abiotic interactions, the spatial structure of which defines the complexity and heterogeneity of root-soil interface. We modified in situ soil zymography and used it for identification and localization of hotspots of β-glucosidase activity in the rhizosphere of maize depending on soil drying-rewetting. Under drought stress (30% of field capacity), zymographic images showed very highlighted spots of β-glucosidase activity along roots. The zymographic signals were especially high at root tips and were much stronger for activity of β-glucosidase under drought as compared with optimal moisture (70% of field capacity). This distribution of enzyme activity was confirmed by fluorogenically labelled substrates applied directly to the root exudates of the same maize plant, sampled within 1 hour after zymography. The activity of β-glucosidase by root associated microorganisms in root exudates was significantly higher by drought stressed plants as compared with optimal moisture. In contrast, the β-glucosidase activity in destructively sampled rhizosphere soil was lower under drought stress compared with optimal moisture. Furthermore, drought stress did not affect β-glucosidase activity in bulk soil, away from rhizosphere. Consequently, we conclude that higher release of mucilage by roots under drought had stronger impact on β-glucosidase activity in the rhizosphere. Remoistening of these drought-stressed plants eliminated the differences in fingerprints of β-glucosidase activity due to drought stress. Thus, the zymography revealed plant-mediated mechanisms accelerating β-glucosidase activity under drought at the root-soil interface. So, coupling of zymography and enzyme assays in the rhizosphere and non-rhizosphere soil enables precise mapping the changes in two-dimensional distribution of enzyme activities due to climate change within dynamic soil interfaces.
The Dynamics and Properties of Biogeochemical Interfaces in Soil: The Impact of a Changing Environment

Georg Haberhauer, Martin H. Gerzabek, Daniel Tunega, Georg J. Lair, and Franz Zehetner

Institute of Soil Research, Department for Forest and Soil Sciences, University of Natural Resources and Life Sciences, Vienna, Austria

Many of the soil functions – such as the filter and buffer function for providing clean water or the source of raw material – are closely related to the bio-geochemical characteristics of soils. Many of the soil properties relating to soil functionality depend not only on bulk composition but on compositional and structural features of the biogeochemical interfaces (BGIs). Properties such as hydrophobicity of surfaces, reactivity with respect to interaction with inorganic and organic pollutants vary in time due to weathering processes and the anthropogenic impact on soils. A chronological framework for fluvial deposits along a soil sequence at the Danube River near Vienna, Austria, a long term experiment using different treatment methods and an experimental study exposing soil to different climate conditions confirm that changes in the environment do have an impact on soil organic matter (SOM) dynamics and its sorption properties for organic and inorganic compounds. There is increasing evidence that the behaviour of pollutants at the micro- or larger scales is driven by their interactions at nanoscale. Using advanced computational molecular modelling methods to model such biogeochemical interfaces in soil is a new field in soil science and can yield deeper understanding of crucial molecular interactions within BGIs. Still one of the challenges is bridging and linking molecular and higher (e.g. microscopic) scales of complex and heterogeneous BGIs systems investigated by molecular simulations and experimental techniques. Current spatial and temporal scales in molecular modelling, which are manageable in a realistic computational time, are up to tenths of nanometers and microseconds. Molecular simulation methods are helpful in exploring basic mechanisms and elementary steps, which cannot be investigated experimentally at present. Within this presentation several examples and results of modelling experiments relating to BGIs and certain environmental conditions will be shown. These models include the interactions of organic molecules with soil components (soil minerals, SOM), the role of water and cation bridges in SOM stabilization, hydration and wettability of SOM and wettability of mineral and organo-mineral surfaces. Further developments to link these theoretical models to experimental studies to investigate BGIs in response to environmental changes will be discussed.
Session 5:
Quantitative Understanding of BGIs Functions: Theoretical Concepts & Models to Explain Structure, Properties & Functions of BGIs
Molecular Models and Simulations of Soil Organic Matter: Structure, Dynamics and Interactions With Other Entities

Chris Oostenbrink

Institute of Molecular Modeling and Simulation, University of Natural Resources and Life Sciences, Vienna, Austria

Molecular dynamics simulations give insight into molecular processes at a resolution that is often inaccessible by experiments. The structure and (thermo)dynamics of small molecules interacting with various media are commonly studied by computer simulations in material sciences and biomolecular sciences. However, extensive molecular simulations of soil constituents are hampered by ill-defined molecular systems and restrictions in the description of the relevant interactions. Here, we present a library of building blocks for classical molecular simulations of soil organic matter. An approach to establish condensed phase, amorphic systems will be presented, which can subsequently be used for extensive in silico experiments, e.g. addressing the structure of the systems, their thermodynamic stability or the adsorption of small molecular pollutants. We will demonstrate the need for extensive sampling of the conformational space and suggest applications of modern simulation methods to soil components.
Organic Functional Group Density and Structural Dynamics of Soil Organic Matter Take Key Role in Cation Bridge Formation

Yamuna Kunhi Mouvenchery$^{1,2}$ and Gabriele Ellen Schaumann$^2$

$^1$Department of chemistry, N.S.S. College, Manjeri, Kerala, India
$^2$Department of soil and environmental chemistry, Institute of Environmental Sciences, University of Koblenz-Landau, Landau, Germany

Cations and water molecules cross-link soil organic matter (SOM) segments and with this, form cation bridges (CaB) and water molecule bridges (WaMB), respectively. The spatial distance between the OM functional groups as well as the cation size is determinant for the formation of CaB (Kunhi Mouvenchery et al., 2013). Thus small cations will not be able to cross-link over large distances. It is hypothesised that water molecules can assist multivalent cations to bridge large distances between OM molecules, either as hydration water or as bridging agents between cations and OM molecules, via CaB-WaMB associations (Schaumann et al., 2013). A strongly held hydration sphere of cations may result in cross-links bridging larger distances than the bare cations do. This will form inner sphere complexes. Larger CaB-WaMB associations may bridge even larger distances by involving more water molecules between the hydrated cation and organic functional groups. In order to verify this hypothesis, experiments were conducted with the aim of inducing CaB, on two different SOM materials. Samples were selected based on the effective exchange capacity (CEC), under the assumption that sample with higher CEC represents SOM rich in active functional groups. Low CEC samples possess low functional group density and hence the spatial distance between adjacent functional groups will be large. A peat of CEC = 123 mmolckg$^{-1}$ and a forest SOM of CEC = 303 mmolckg$^{-1}$ were selected. After removal of the originally present cations, samples were treated with bivalent cations (Mg$^{2+}$, Ca$^{2+}$ and Ba$^{2+}$) in variable concentrations and WaMB transition temperature ($T^*$; Schaumann et al., 2013) was measured at definite intervals. $T^*$, measured by differential scanning calorimetry (DSC), reflects the change in matrix rigidity due to disruption of WaMB at $T^*$. The higher $T^*$, the more stable are the WaMB and the more rigid is the matrix held together by WaMB. Cation treatment did not cause significant change in matrix rigidity in peat, but induced strong aging effects. For the forest soil, Mg$^{2+}$ formed weaker interactions within the SOM than Ca$^{2+}$ and Ba$^{2+}$, as revealed by change in $T^*$ values after cation treatment. After aging for eight weeks matrix rigidity was enhanced in all samples, indicating strengthening of the existing interactions or the formation of new CaB and/or WaMB interactions. The final matrix of Mg$^{2+}$-treated samples was even more rigid than that of Ca$^{2+}$ and Ba$^{2+}$. This can be easily explained as: initially less rigid Mg$^{2+}$-treated samples underwent higher degree of structural reorganisation during aging than in the other two, more rigid set. It could be that reorganisation of SOM segments and water molecules occurred such a way that Mg$^{2+}$ was able to form cross-links in the form of CaB-WaMB associations. This cumulative study thus reveal the relevance of SOM quality and the role of water molecules in CaB formation, and the role of CaB interactions in soil aging process.

References
Hydration is well expected to affect properties and functions of soil organic matter (SOM) which is the important component of biogeochemical interfaces in soil. The better understanding of the SOM hydration at the micro-environment scale may be reached by examining the interplay between water and organic molecules sorbing by SOM. Therefore, the aim of this presentation is two-fold. The first goal is to attract the attention to the significance and complexity of water participation in sorption interactions of organic compounds with SOM, and, specifically, to the cooperative character of this participation. The second goal is to discuss how the complexity of the SOM assemblage could be responsible for the cooperative SOM hydration induced by some organic sorbates. The analysis is based on sorption data accumulated for various organic compounds on model SOM sorbents at variable water contents and activities (Borisover and Graber, 2002; Graber et al., 2007; Borisover et al., 2011; Borisover, 2013). The major points are that (a) multiple organic compounds interacting with SOM drive water molecules into the SOM phase, and (b) several molecules of water may have to participate cooperatively in this organic sorbate-induced SOM hydration. The organic sorbate-induced cooperative SOM hydration is expected for very many organic compounds containing N, S, O atoms (in contrast to sorption of rather „less polar” organic molecules which push water out of the SOM phase). Driving water molecules into SOM (i.e., the organic molecule-water collaboration in sorption) may be linked to the necessity of solvating the SOM surfaces exposed/deformed due to the interaction with an organic sorbate. However, it is much less clear why several molecules of water have to participate cooperatively in this process. Therefore, this raises questions on the SOM „architecture”. The hypotheses on the hydration-induced local SOM conformational changes that could enhance the uptake of following water molecules and/or on the enhanced water-water interactions in a SOM phase could be suggested as possible mechanisms for the cooperative SOM hydration but the proofs for these interpretations are needed, yet. It appears that organic sorbate-induced hydration of SOM may occur even in fully wet SOM thus calling for considering soil/SOM sorption reactions of organic molecules from water as occurring with a co-sorption of several water molecules. However, a direct monitoring of a co-participation of water and organic molecules sorbing on SOM sorbents from the liquid phase would be very useful in order to make a further advance in the conception.

References
Physicochemical and steric properties of organic chemicals on the one hand and physicochemical surface properties and structural properties of the sorbent on the other hand determine sorptive interactions at biogeochemical interfaces, thereby controlling the mobility and (bio-)degradation of these substances. Our aim is to test the hypotheses (1) that the sorption and distribution of organic chemicals at biogeochemical interfaces is either determined by the molecules’ hydrophobic R-groups ("R-determined" chemicals) or its functional groups ("F-determined" chemicals) and (2) that the retention of organic chemicals by mineral-organic associations is determined by microdiffusion processes. We studied the sorption of Phenanthrene and Bisphenol A (R-determined-chemicals) and MCPA and Bentazone (F-determined-chemicals) on pure minerals, on biofilm model substances (polygalacturonic acid), and on mineral-organic mixtures by isothermal titration calorimetry (ITC) in combination with macroscopic sorption experiments. According to our hypothesis the thermodynamic characterisation indicated that the interaction of “R-determined” chemicals on pure minerals is an entropy-driven process while the reaction of “F-determined”-chemicals is enthalpy-driven. In a second approach we studied sorption of MCPA and Phenanthrene to artificial mineral-organic micro-aggregates. The micro-aggregates were synthesized in batch experiments by shaking minerals (kaolinite, goethite, quartz) in combination with differently processed particulate organic matter (POM) in 0.01 M KCl at pH 4. Differently processed POM was derived from Oi and Oa horizons of a podzol. All primary materials as well as the formed mineral-organic aggregates were characterized by SEM, and analytical centrifugation. Additional the POM was characterized by FTIR and C and N concentrations were determined. Aggregates were characterized by ultrasound application and density fractionation. Diffusion into micro-aggregates was addressed in batch experiments with 14C-labeled MCPA and Phenanthrene in 0.1 M KCl at pH 4. Density fractionation of the mineral/organic mixtures showed that 59 to 93 % of the organic C was associated to minerals. Results from sorption kinetics showed, that aggregation decreases the retention of polar organic compounds (MCPA) by reducing the accessibility of polar sorption sites. Diffusion becomes the governing process for the retention of polar organic compounds. No significant difference between sorption kinetics of Phenanthrene to different POM and micro-aggregates was found, indicating that high affinity of Phenanthrene to organic matter dominates the retention process.
Modeling Surface Chemistry of Ferrihydrite

James D. Kubicki

Department of Geosciences, The Pennsylvania State University, USA

Ferrihydrite is a critical substrate for adsorption of species such as soil organic matter and nutrients in the environment (Brown and Calas, 2012). The nanoparticulate nature of ferrihydrite is inherent to its formation, and hence it has been called a “nano-mineral” (Hochella and Madden, 2005). The nano-scale size and unusual composition of ferrihydrite has made structural determination of this phase problematic. Michel et al. (2007) have proposed an atomic structure for ferrihydrite, but this model has been controversial (Rancourt and Meunier, 2008; Manceau, 2011). Recent work has shown that the Michel et al. (2007) model structure may be reasonably accurate despite some deficiencies (Maillot et al., 2011; Pinney et al., 2009; Hiemstra, 2012). This work utilizes density functional theory (DFT) calculations to model the structure of ferrihydrite nanoparticles and the surface charging and adsorption behavior based on the Michel et al. (2007) model as refined in Hiemstra (2013). Periodic projector-augmented plane-wave calculations were performed with the Vienna Ab-initio Simulation Package (VASP; Kresse and Furthmüller, 1996) on an approximately 1.6 nm diameter nanoparticle (Fe_{38}O_{112}H_{110}). After energy minimization of the surface H and O atoms, surfaces were extracted to model the interaction of the Fe-OH and Fe-OH\textsubscript{2} groups with H\textsubscript{2}O. Charging energies were calculated in order to begin to model the atomistic details of ferrihydrite surface chemistry. The model will be used to assess the possible configurations of adsorbed humic acids and phosphate on various surfaces.

References
A Conceptual Approach to Experimental Pedology

Ingrid Kögel-Knabner\textsuperscript{1,2}, Katja Heister\textsuperscript{1} and Geertje Johanna Pronk\textsuperscript{1}

\textsuperscript{1}Chair of Soil Science, Technische Universität München, Freising-Weihenstephan, Germany
\textsuperscript{2}TUM Institute of Advanced Study, Garching, Germany

Understanding the process of how aggregates are formed, stabilized and turn over will help us to understand and predict the retention and movement of gases, water and solutes in soil; the growth, vigour and productivity of plants; and the activity, growth and movement of soil organisms. These questions are vital for many current agronomic and environmental issues. Beyond all our qualitative knowledge on soil formation, we are far from being able to quantify the complex processes of soil structure development, which have different space scales and time scales depending on soil type, texture and management. A coordinated experiment within the PP 1315 "Biogeochemical interfaces in soils" was set up to investigate the formation of soil structures under controlled conditions and with defined parent mineral and organic starting materials. It was considered that soil as a functioning complex natural body with unique characteristics and emergent behaviours cannot be deduced from an isolated investigation of its constituents or single processes, but only by considering the interplay of components and processes during soil formation. The experiment revealed that it is possible to produce soil aggregates in the laboratory (Pronk et al., 2012, 2013). The experiment showed that the essential ingredients to produce an emergent aggregated soil material are a parent mineral material composed of phyllosilicates and/or iron oxides, an organic substrate and a heterotrophic microbial community. A series of artificial soils of eight different compositions was produced in this simple system that excluded the influences of environmental conditions, soil fauna, or roots on aggregate formation, nor did it take place in situ, but never-the-less intensive aggregate formation took place. Such experiments provide a new means to understand soil formation under controlled conditions and with controlled parent materials.

References
Delineation of Biogeochemical Processes Controlling Contaminant Fate in an Mesoscale Aquifer by Compound-Specific Isotope Analyses

Shiran Qiu1, Dominik Eckert2, Heide Bensch1, Michael Maier1, Armin Meyer1, Ramona Brejcha1, Martina Höche1, Olaf Cirpka2 and Martin Elsner1

1Institute of Groundwater Ecology, Helmholtz Zentrum München, Neuherberg, Germany
2Center for Applied Geoscience, University of Tübingen, Tübingen, Germany

For a comprehensive understanding of the fate of organic contaminants in the subsurface it is important to identify the dominant interactions (sorption, dispersion and degradation) occurring at biogeochemical interfaces. According to their chemical structures (conformity, heteroatoms, OH and, COOH -groups) and their bioavailability, organic micropollutants, like the herbicide diclobenil, its metabolite BAM or pharmaceuticals such as ibuprofen and diclofenac, are expected to behave differently in environment subsurfaces. With current methods insights about the controlling processes are limited. Within this study we aimed to explore under controlled conditions (closed mass-balance, use of a conservative tracer in an aquifer mesocosm) whether the analysis of naturally occurring isotope ratios in organic contaminants (compound-specific isotope analysis) can give information about molecular interactions in nature. In a pulse experiment we injected the aromatic hydrocarbon toluene together with D2O as conservative tracer into a mesoscale aquifer filled with natural sediment (Qiu et al., 2013) (Figure 1). Breakthrough curves of concentrations (Fig. 1a) as well as 13C/12C ratios in toluene (Fig. 1b) demonstrated indeed the influence of both, sorption and biodegradation, and could be modelled by application of an optimized reactive transport model (Eckert et al., 2013). In particular, isotope trends even demonstrated that degradation underwent Michaelis-Menten kinetics. In ongoing work we evaluate isotope fractionation of herbicides and pharmaceutica in similar experiments with the aim to investigate the influence of heteroatoms and functional groups on sorption and degradation at biogeochemical interfaces.

Figure 1. a) Measured and modeled concentrations of D2O (green dots and line) and toluene (black crosses and black line). b) Experimental and simulated carbon isotope trends resulting from various fractionation processes. Lines show modeled isotope data fitted to experimental data.

References


**Micro-Scale Modeling of Pesticide Degradation Coupled to Carbon Turnover in the Detritusphere**

Holger Pagel¹, Christian Poll², Joachim Ingwersen¹, Franziska Ditterich², Aurelia Gebala², Ellen Kandeler² and Thilo Streck¹

¹Institute of Soil Science and Land Evaluation, Section of Biogeophysics, University of Hohenheim, Stuttgart, Germany
²Institute of Soil Science and Land Evaluation, Section of Soil Biology, University of Hohenheim, Stuttgart, Germany

The detritusphere (soil close to the soil-litter interface) is characterized by a high availability of litter-derived organic substrates stimulating microbial growth and activity. It is a hotspot of carbon (C) turnover and degradation of pesticides. To improve our understanding of the regulation mechanisms, which are responsible for stimulated degradation of the herbicide MCPA (2-Methyl-4-chlorophenoxyacetic acid) at the soil-litter interface, we applied the recently developed PECCAD model (PEsticide degradation Coupled to CArbon turnover in the Detritusphere; Pagel et al., 2014) to the data of a detailed microcosm experiment. We prepared ¹⁴C-MCPA (50 mg kg⁻¹) amended soil cores and set up three experimental treatments: 1) maize litter (control), 2) MCPA and 3) MCPA + maize litter. The litter was placed on top of the soil cores and the microcosms were incubated at 20 °C for 23 days. The soil cores were sampled at five dates and samples were obtained from 7 layers down to 1 mm thickness. We analyzed MCPA and different C pools (soil and CO₂) for total concentration as well as isotopic composition (¹³C, ¹⁴C). We measured three molecular markers (tfda genes, 16SrRNA genes and fungal ITS fragments) to estimate the abundance of bacterial MCPA degraders, total bacteria and fungi in soil. The PECCAD model was calibrated using these data by means of a multi-objective Pareto analysis. In the detritusphere, we observed increased concentrations of dissolved organic C (DOC) and accelerated degradation of MCPA. Litter stimulated the microbial community as reflected by increased abundances of molecular marker genes. Fungal ITS fragments showed the strongest response to litter-C input indicating that fungi benefited most from additional substrate supply. The PECCAD model could match observed dynamics of MCPA, DOC and microbial biomass C at the soil-litter interface. Although the strong increase of fungal ITS fragments in the detritusphere was underestimated by PECCAD, the model reflected the strong response of fungi to litter-C input. PECCAD simulations indicate that fungal activity and growth was specifically stimulated by low quality DOC, whereas bacterial MCPA degraders benefited from high quality DOC in addition to MCPA. MCPA degradation occurred predominantly via co-metabolic transformation by fungi according to the parameterized PECCAD model. Among the microbial populations bacterial MCPA degraders then incorporated by far the most MCPA-C, primarily because they took up high quality DOC produced by co-metabolic transformation of MCPA and to a much lesser extend also due to direct uptake of MCPA for growth. Mathematical modeling combined with experimental work provided comprehensive insight into coupled C and MCPA dynamics at the soil-litter interface. Our study demonstrates that knowledge about the micro-scale dynamics of hot spots in soil is very important to understand fundamental soil functions, such as decomposition of organic matter and degradation of pesticides.

**References**

Hierarchical Structure of Biogeochemical Interfaces to Predict the Transport of Reactive Chemicals in Soil

Thomas Ritschel¹, Jannis Tzararas², Marc-Oliver Göbel³, Susanne K. Woche³, Katharina Reichel¹, John Maximilian Köhne², Hans-Jörg Vogel², Jörg Bachmann³ and Kai Uwe Totsche¹

¹Institute of Geosciences, Friedrich Schiller University, Jena, Germany
²Department of Soil Physics, Helmholtz Centre for Environmental Research GmbH (UFZ), Halle, Germany
³Institute of Soil Science, Gottfried Wilhelm Leibniz University, Hannover, Germany

The reactive transport and transformation of organic chemicals (OC) in soils impact soil ecological and filter functions. A quantitative understanding of the processes and rates that control the distribution and persistence of OC is a mandatory prerequisite for the prediction of their fate in soils. Yet, "predictive models" to a large extent rely on parameters that have been obtained from "fitting" procedures with no predictive capabilities. Therefore, a desire not only in fundamental soil science would be to have a strategy that allows for independent quantitative reconstruction of properties. Our joint experiment on "Hierarchical structure of biogeochemical interfaces in soil to predict the transport of reactive chemicals in soil" contributes to this ambitious goal. Results from pore scale model simulations suggest that highly irregular spatial distributions of reactive sites may strongly affect the macroscopic flow and transport patterns of OC, i.e. their breakthrough behavior. In natural soils, a spatially heterogeneous distribution of reactive interfaces can be expected to be more likely than a homogeneous distribution. Another issue that will be addressed is the availability/accessibility of reactive surfaces for mobile reactive substances. Even though some OC have a high sorption affinity to mineral surfaces, in natural porous media, these surfaces can be located inside aggregates, at grain-grain contacts, or in domains which do not participate in water flow. A quantification of the available surface is therefore a crucial step.

To study the decisive structural properties of a porous medium and its constituents and to get a mechanistic understanding of solute transport, we launched a joint column experiment to independently predict the reactive transport of target compounds. We started our experiments with a well-defined SPP artificial soil. The results were encouraging regarding the conservative transport, but structural diversity and hierarchy in the pore network were not covered by the approach. Therefore, we developed a new artificial structure. As a reference, two columns were set up with spherical borosilicate glass beads (diameter: 3mm). To create a distinct hierarchy in the pore size distribution, these glass beads were mixed with porous glass beads with an inner porosity of about 60 μm and filled in another two columns. These porous glass beads serve as a model aggregate embedded in a matrix of larger pores. For any given soil column, the starting point is the quantification of the pore structure of freshly packed columns for pore sizes > 0.1 mm using micro-computed tomography (μ-CT) followed by image analysis (group of Vogel, Halle). The 3D structure is then evaluated with the pore network model (PNM) to get effective continuum scale parameters (i.e. dispersivity). This allows for the prediction of a conservative tracer breakthrough without using any fitted parameters. The columns are then transferred to Jena for experiments, run in both closed and open flow mode, for investigating chemical fate and transport dynamics at variable saturated flow conditions (group of Totsche, Jena). The solutes under study include NaCl as conservative tracer and MCPA and vanillic acid as reactive chemicals. After the hierarchy in the pore space can be represented by the PNM in a way that successfully predicts conservative transport, we will coat part of the porous medium with reactive minerals (e.g. goethite). In this way we aim at creating a 3D map of reactivity spots in the soil column, superimposed on its physical pore system geometry. If this can be achieved, the transport and breakthrough behavior of reactive chemicals can be predicted without any continuum scale parameter fitting.
Poster Presentations

Session 1: Unravelling BGI Structure: Formation & Architecture of BGIs
Litter and rhisodeponies are a key organic C input into soil. Newly, important role in soil organic matter (SOM) is attributed not only to aromatic and aliphatic (recalcitrant) fractions but also to easily extractable organic compounds. Thus, dissolved organic carbon may play important role also in SOM stabilization. The objective of this study was to assess seasonal variability in contribution of aboveground litter input and root related input to dissolved organic carbon. We explored how these patterns differ between plantations of different tree species. We studied four tree species sites including one conifer (*Pinus sylvestris*) and three broadleaf species (*Quercus robur*, *Alnus glutinosa* and *Salix caprea*) at one large plant experiment area in post-mining sites near Sokolov, Czech Republic. Soil was sampled from *Oe* and *A* horizons every two months. In addition, we sample fresh litter and established sand filled ingrow cores that allow sampling roots with associated root exudates. Dissolved organic matter was extracted on the basis of its availability: HWC (Hot Water Carbon) and WSC (Water Soluble Carbon) extractions. Both extracts were determined on TOC (Total Organic Carbon) and TN (Total Nitrogen) analyzer, SUVA (Specific UV Absorbance) measurement and NMR spectroscopy. Results show two peaks of the increase in labile components availability. The first one was in June and the second one was in December. These peaks were separated by the decline in October. We expect, the first peak corresponds with root derived material and the second one with leaves input. This pattern was more pronounced in broadleaf with seasonal litter fall and less in conifer. Sites with well-developed *Oe* layer had this trend more apparent in *Oe* layer, the others in *A* layer. We consider HWC and WSC are good indicators responding to changes in the carbon input during seasons.
Investigation of the Degradation of 13C-Labeled Fungal Biomass in Soil-Fate of Carbon in a Soil Bioreactor System

Michael Schweigert¹, Thomas Fester¹, Anja Miltner² and Matthias Kaestner²

¹Department of Environmental Microbiology, Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany
²Department of Environmental Biotechnology, Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany

Nutrient balances and degradation processes in boreal forests are mainly influenced by interactions of plant roots and ectomycorrhizal fungi. Plants benefit from nitrogen compounds provided by their symbiotic interaction partner. In return ectomycorrhiza are provided by large amounts of carbon from the plants which is used for the synthesis of hyphal networks in soil and for metabolic activity for nutrient uptake. Therefore ectomycorrhizal fungi play a major role in ecosystems of boreal forests and are consequently an important sink for carbon by building large amount of mycelia. Recently, it has been shown that microbial biomass residues contribute significantly to soil organic matter formation. This suggests that also residues of ectomycorrhizal fungi may be an important source for soil organic matter formation in forest soils where these fungi are abundant. However, the fate of ectomycorrhizal biomass residues in soils is unknown. We therefore investigated the fate of ectomycorrhizal biomass in soil in a soil bioreactor system to quantify the contribution of this material to soil organic matter formation. As a model organism, we selected Laccaria bicolor, which was labelled by growing the fungus on ¹³C glucose. The stable isotope-labeled biomass was then homogenized and incubated in a podzol from a typical forest site in Central Germany. The fate of the labeled biomass was traced by analyzing the amount of ¹³C mineralized and the amount remaining in the soil. The fungal biomass carbon was mineralized rather rapidly during the first 50 days. Then the mineralization rate slowed down, but mineralization continued until the end of the experiment, when approximately 40% of the ¹³C was mineralized and 60% remained in soil. In addition, we analyzed biomolecules such as fatty acids to trace the incorporation of the L. bicolor-derived biomass carbon into other microorganisms and to identify potential primary consumers of fungal biomass. By these analyses, we found a significant incorporation of L. bicolor-derived carbon into a wide variety of different bacterial taxa, indicating the relevance of fungal biomass residues for soil bacteria as a carbon source. In a later phase of the experiment, we will also trace the fate of soil organic carbon into the fungal biomass and the plant partner (Picea abies). These results will provide a comprehensive view of the role of ectomycorrhizal fungi and their residues on soil carbon cycling.
Session 2: Exploring BGIs: New Avenues for “Provocative” Joint Experiments & Complementary Cutting-Edge Techniques, incl. Spectroscopy, (Spectro )Microscopy & Tomography
In situ Analysis of Pore Scale Processes at Biogeochemical Interfaces in Model Systems

Christian Metz, Natalia P. Ivleva, Reinhard Niessner and Thomas Baumann

Institute of Hydrochemistry, Technische Universität München, Munich, Germany

Biogeochemical interfaces (BGI) in soil control the fate of organic chemicals and the functioning of soil as a filter to protect groundwater resources. Biogeochemical interfaces are transient in space and time, thus rendering batch tests under equilibrium conditions and without spatial restrictions inadequate to predict the overall behavior. Instead, the concentration gradients of organic chemicals have to be measured and the spatial and temporal dynamics of the BGI themselves have to be monitored. Processes at BGI can be visualized and quantified using microfluidic structures mimicking the pore topology of the soil, so called micromodels. In combination with Raman microspectroscopy chemical information can be retrieved from a micromodel experiment with a spatial resolution on the order of 1 μm² and a temporal resolution in the seconds-range. To increase the sensitivity, silver nanoparticles have been added to the water phase flowing through the micromodel to make use of the amplifying surface-enhanced Raman effect. Currently chemical gradients of moderately lipophilic substances have been acquired with a limit of detection of 10⁻⁸ mol/L. Challenges to overcome include the interactions between silver nanoparticles and target analytes which might alter the mass transfer rates, and the settling of nanoparticles in the channel. As high resolution acquisition comes with a limited field-of-view (FoV) and, e.g., the growth of a biofilm outside of the FoV alters the flow pattern, the flow velocity has to be monitored using fluorescent latex beads and single particle tracking. For a fast measurement of well-defined variables, like the pH-value or the oxygen concentration, thin film polymers with encapsulated sensor dyes are chosen. When looking at microbial growth in porous media, not only the development of a biofilm changes the flow paths and the accessibility to the microbes, but also the development of locally confined gas bubbles, as with P. denitrificans. Here, the growth rate is correlated with bacterial activity and the results indicate different bacterial densities in pore bodies and pore throats. Imaging results at the interface and the development of the concentration gradient suggest, that the interface is highly dynamic in the beginning. Marangoni convection with velocities in the upper μm/s range is reaching several dozens of μm from the interface into the solution. A diffusion controlled mass transfer is established at a later stage only. This observation might explain part of the first flush phenomenon.
Aging Dynamics of Soil Organic Matter – Implications from $^1$H Solid-State NMR on Sequestration of Pollutants and Ions

Alex Jäger$^1$, Marko Bertmer$^1$ and Gabriele E. Schaumann$^2$

$^1$Institut für Experimentalphysik II, Universität Leipzig, Leipzig, Germany
$^2$Institut für Umweltwissenschaften, Universität Koblenz-Landau, Landau, Germany

Physical entrapment and release of chemicals in soil organic matter (SOM) is strongly depending on the mobility of organic matter segments in the supramolecular SOM structure. The segment mobility depends significantly on the water content and shows patterns of a polymer aging dynamics, i.e., a linear decrease in molecular mobility on a logarithmic time scale$^1$. In this study, we present experimental results of an aging experiment on samples in hermetically sealed containers that had been triggered by a heating / cooling event of 30 minutes at 110° C to disturb the system and follow the regeneration which we refer to as physical aging. Two soil samples, a sapric histosol with high organic matter content and a gleyic podsol with low organic matter content, were investigated. By $^1$H solid-state nuclear magnetic resonance (NMR), we traced the changes in mobility making use of a wide line decomposition scheme$^2$. Via differential scanning calorimetry (DSC) we observed changes in the matrix rigidity, expressing in a step-like transition temperature, that shifts during the aging process. Both methods observe effects within a time span of almost one year. Possible implications on the immobilization of organic chemicals in terms of a sequestration into nanovoids generated by a stable water molecule bridges (WaMB) network will be discussed. Also the influence of long chain aliphatics and SOM segments with higher degrees of motional freedom on the mobilization effects are taken into account as an alternative view on SOM dynamics. On the basis of these findings we offer predictions to the environmental fate of organic pollutants such as phenol or naphthalene and prevalent ions such as Na$^+$, Ca$^{2+}$, and Al$^{3+}$.

References:
Jäger A, Schwarz J, Mouvenchery YK, Schaumann GE, Bertmer M. Physical long term regeneration dynamics of soil organic matter as followed by $^1$H solid-state NMR methods. to be submitted.
Pore scale modeling is the fundamental approach for modeling single or multiphase flow in porous media, which is of great importance to vadose zone flow and transport of interest, e.g., for contaminant remediation. This approach provides a way for the parameterization of macro-scale constitutive parameters, i.e. porosity and permeability, which in effect govern the overall performance of many flow and transport models. Pore scale modeling is a challenging task in a complex and tortuous nature of the pore structures that requires high-resolution imaging techniques for obtaining the integral description of the pore geometries, and efficient and robust numerical methods of handling the complex geometries. The advent of X-ray microtomography (µCT) has made it possible to obtain three-dimensional images of soil aggregate down to sub-micron resolution which allows for the characterization of the pore space structure. In recent years, the numerical lattice Boltzmann equation approach for modeling of fluid flow and transport has received increased attention because of its simple formulation and applications in complex geometries. The lattice Boltzmann method follows simple and local update rules based on the motion and collision of particles on a cubic lattice (voxels) within a digital µCT image to approximate Navier Stokes equation for the fluid flow simulation. Recent advancement in computer technology introducing high performance parallel computing and development of easy-to-use graphical user interface software, as well as effective visualization of generated results from those simulations, enable simulation of the complex dynamics (velocity vector field) and particle transport processes (solute/colloid tracking) at a pore scale level. The main focus of this study is the quantitative description of immiscible air-water phases by capillary pressure – water saturation – hydraulic conductivity relationships for both the drainage and imbibition process in a 3D unsaturated soil image obtained by synchrotron-based µCT. The hysteretic effects of both capillary pressure and hydraulic conductivity were investigated by the combination of a pore-morphology based approach and the lattice Boltzmann solver, respectively. Moreover, the transport of a biogenic colloid like Escherichia coli as pathogens indicator organism was studied. As a result, the direct influences of pore size distribution in relation to the colloidal sizes and pressure gradients on their transport and breakthrough curves are analyzed.
Spatiotemporal Process Monitoring of Conservative and Reactive Tracer Transport in a Synthetic Soil Column

Johannes Kulenkampff\textsuperscript{1}, Madeleine Stoll\textsuperscript{1,2}, Frieder Enzmann\textsuperscript{2}, Marion Gründig\textsuperscript{1}, Alexander Mansel\textsuperscript{1} and Johanna Lippmann-Pipke\textsuperscript{1}

\textsuperscript{1}Institute of Resource Ecology, HZDR Research Site Leipzig, Germany
\textsuperscript{2}Institute for Geosciences, Johannes Gutenberg-University, Mainz, Germany

Transport and retardation of chemical species in soils as observed by input-output approaches are commonly interpreted by process simulations and break-through curve (BTC) fitting. Positron emission tomography (PET) provides a direct quantitative spatiotemporal (4D) visualization method for the propagation of compounds labelled with a PET-tracer at intermediate resolution and molecular sensitivity (Kulenkampff \textit{et al.}, 2013). In the framework of SPP 1315, we conducted transport experiments on an artificial soil column with both reactive and conservative tracers, which were monitored with sequential PET imaging. The soil column used (I: 94.5 mm, d: 40 mm; composition: 94% sand, 5% illite, 1% goethite; porosity: 29%) was prepared under CO\textsubscript{2}-atmosphere and structurally characterized by μCT imaging as widely homogeneous. For the conservative tracer experiment, 5 mL 0.001 M NaNO\textsubscript{3} + 0.01 M [\textsuperscript{18F}KF was flown through the equilibrated column. For the reactive species experiment, 64Cu was produced at the Leipzig cyclotron by the nuclear reaction \textsuperscript{64}Ni(p,n)\textsuperscript{64}Cu and separation by ion exchange. 5 mL of 0.0008 M [\textsuperscript{64Cu}Cu(MCPA)\textsubscript{2} was produced from 2 mL \textsuperscript{64}Cu\textsuperscript{2+} in 0.1 M HNO\textsubscript{3}, 1 mg Cu(NO\textsubscript{3})\textsubscript{2}·3H\textsubscript{2}O and 2 mg MCPA in synthetic pore water. The labeled solution was adjusted to pH 5 and flown through the column, which had no former contact with MCPA and had been preconditioned for 4 days with synthetic pore water at pH 5. In both experiments the flow rate was 0.1 ml/min. In the conservative experiment, the break-through occurred after 140 min, and – in spite of the homogeneous packing of the column – the tracer propagation observed with PET showed a preferential flow field towards the rim of the sample. The reactive [\textsuperscript{64Cu}Cu(MCPA)\textsubscript{2} pulse was strongly retarded with a break-through of the activity after 66 h. Fig. 1 shows a snapshot of both experiments after 110 min. Preferential and superficial transport, commonly ignored in input-output approaches, controls the effective volume and reactive internal surface area, and thus impacts interpretation and inverse numerical modelling of BTCs. Such effects can be assessed and quantified with PET process tomography, especially when the pore structure is heterogeneously altered by microbial activity.

Reference
**Session 2: Exploring BGIs: New Avenues for “Provocative” Joint Experiments & Complementary Cutting-Edge Techniques, incl. Spectroscopy, (Spectro-)Microscopy & Tomography**

**Poster No. 7**

**15N/14N Isotope Analysis Indicates Deprotonation of Glyphosate in Oxidative Degradation at MnO2 Surfaces**

Emmanuel Mogusu¹, Benjamin Wolbert², Dorothea Kujawinski², Maik Jochmann² and Martin Elsner¹

¹Institute of Groundwater Ecology, Helmholtz Zentrum München, Neuherberg, Germany
²Instrumental Analytical Chemistry, University of Duisburg-Essen, Essen, Germany

Glyphosate (N-(phosphonomethyl) glycine), the most widely used herbicide worldwide, is biodegradable. The main metabolite AMPA (aminomethylphosphonic acid) has been frequently detected in soil and water (Helander et al., 2012; Borggaard et al., 2008). The speciation of glyphosate directly influences its interactions with mineral surfaces that contribute to its degradation in the environment. We (i) developed a nitrogen stable isotope method to investigate the interaction of glyphosate with mineral surfaces and (ii) used the method to investigate nitrogen isotope fractionation during transformation of glyphosate at Manganese dioxide (MnO2) surfaces (Barret and McBride et al., 2005). Glyphosate was degraded by MnO2 as evidenced by the formation of both AMPA and sarcosine as transformation products within 10 hours of the experiment. 15N/14N ratios in glyphosate, AMPA and sarcosine were measured by gas chromatography-isotope ratio mass spectrometry (GC-IRMS) (Elsner et al., 2012) after derivatization with isopropyl chloroformate and trimethyl silyl diazomethane (Mogusu et al., in prep.). Nitrogen isotope fractionation during abiotic degradation of glyphosate at the manganese dioxide (MnO2) surface was as high as -17‰ ± 0.5‰. A similar fractionation of -20‰ was reported for equilibrium nitrogen isotope effects (EIE) between [-NH2] (protonated) versus [-NH−] (non-protonated) amino groups (Hofstetter et al., 2011). This result suggests that the abiotic breakdown of glyphosate with MnO2 involves the equilibrium deprotonation of the amino group as initial step that makes it possible for the phosphate group to attach to the MnO2 surface.

**References**


Session 2: Exploring BGIs: New Avenues for "Provocative" Joint Experiments & Complementary Cutting-Edge Techniques, incl. Spectroscopy, (Spectro-)Microscopy & Tomography

Poster No. 8

Mapping Soil Carbon Distribution in Intact Soils Using a Combination of Hyperspectral and X-Ray Fluorescence Imaging Techniques

Sharon M. O’Rourke¹,², Alexander B. McBratney² and Nicholas M. Holden¹

¹UCD School of Biosystems Engineering, University College Dublin, Belfield, Ireland
²USyd Faculty of Agriculture & Environment, The University of Sydney, Australia

The link between the small (<mm) scale spatial organisation of soil carbon (C) and the long-term security of the abiotic C store is poorly understood. Deep soil is assumed to be a C reservoir however the vertical distribution of C remains unknown (Schmidt et al., 2011). Part of the problem is that conventional soil sampling and C analysis of macro samples, collected at standard 10 cm depths or similar characteristic soil horizon intervals, miss much of the inherent soil variability. In terms of soil imaging, there is a knowledge gap at the soil profile scale (Lorenz and Lal, 2005), thus failing to adequately link what is known about soil C at the sub-millimeter to landscape scales. The aim of this research is to develop a tool to map soil C at the microaggregate scale within intact soil cores 1 m long. The technology employed is laboratory based hyperspectral imaging. Due to the heterogeneous composition of soil, referencing spectral data with C values determined for macro samples may not be optimal. Therefore a second technology, X-ray fluorescence (XRF) core scanning, which measures the elemental profile at a similar pixel scale as hyperspectral imaging, is being investigated to determine if candidate indicators for the estimation of soil C can be identified. Data was sampled at 10, 1 and 0.1 cm resolutions from hyperspectral images and XRF profiles, respectively. Multiple correlation was performed to identify candidate indicators of C from elemental profiles. Partial Least Squares regression was employed to build prediction models to estimate C, first from conventionally measured soil C values and then using indicators of C from XRF. Preliminary results of this method development will be discussed.

References
Numerical and Experimental Investigation of Breakthrough Features Appearing in Closed-Flow Transport Experiments

Thomas Ritschel and Kai Uwe Totsche

Institute of geosciences, Friedrich Schiller University Jena, Jena, Germany

The investigation of solute transport with column outflow experiments can be carried out in a closed flow mode by recirculation of effluent solution to the solution supply vessel that feeds the column inflow. While the experimental effort is rather similar to classical approaches and the possibility to study liquid solid interactions as well as structural properties of the porous medium remains intact, the closed-flow mode eliminates disadvantages arising from open-flow approaches. As an example, the feedback during equilibration with the solid phase is maintained like in batch experiments. Furthermore, the breakthrough exhibits an oscillation of concentration in the effluent and the solution supply vessel under defined boundary conditions, i.e. low volume of the solution supply vessel. Since each oscillation represents one cycling of tracer solution through the porous medium, interaction processes imprint on the whole data range of the breakthrough. As a consequence, the breakthrough shows additional characteristic and indicative features that permit further interpretation of involved processes and gives intrinsic control over boundary conditions. A numerical simulation of closed flow experiments is based on the coupling of a transport equation with the partial differential equation that describes the course of concentration in the solution supply vessel. This is especially interesting since the column influent is short-circuited to the effluent via the mixing process in the solution supply vessel, resulting in a dynamic boundary at the column inflow. We present ways of implementation in an implicit euler scheme. Furthermore, we conducted a set of experiments to verify this numerical model. We show that a single tracer breakthrough can be used to determine the dispersion, the exact applied pumping rate and, depending on the tracer, the water content or the retardation. In addition, the kinetics involved in liquid solid interaction can be observed directly.
Non-Invasive Imaging Techniques to Study O$_2$/pH Micro-Patterns and Pesticide Degradation at Lupine Roots

Nicole Rudolph-Mohr$^1$, Sebastian Zuehlke$^2$, Sebastian Gottfried$^2$, Sascha E. Oswald$^1$ and Michael Spiteller$^2$

$^1$Institute of Geosciences Environmental and Earth Science, University of Potsdam, Potsdam, Germany
$^2$Institute of Environmental Research (INFU) of the faculty of chemistry and chemical biology, Technical University of Dortmund, Dortmund, Germany

The soil-root interface is a highly heterogeneous system, e.g. in terms of O$_2$ and pH distribution. The destructive character of conventional methods disturbs the natural conditions of those biogeochemical gradients. Therefore, experiments aiming to control these influences and study pesticide kinetics under given O$_2$ and pH conditions suffer from a large uncertainty of the “real” O$_2$/pH at a certain position. Our approach with two different imaging techniques will examine the soil – root interface as well as the dissipation of the applied pesticide at high spatial resolution. Homogenous soil was batched in 150 x 150 x 15 mm glass containers equipped with pH/O$_2$ sensitive foils, wetted to 60 % water content and a sprouted seed of Lupinus albus was centrally applied to each container. The plants were grown for 25 days with a daily photoperiod of 14 h. After a growing period of 7 days, the samples were imaged once a day to capture oxygen concentration and pH distribution. 2 days after the last pH/O$_2$ imaging the containers were opened and lyophilized and the surface roots were harvested for matrix-assisted laser desorption/ionization imaging mass spectrometry (MALDI-IMS). The obtained outcomes show directly that the pH has an influence on enantioselective dissipation of the acetanilide fungicide metalaxyl. In areas with high pH from an applied racemic mixture, the R-enantiomer dissipates faster than the S-enantiomer. Moreover, we found significantly reduced oxygen values in the bulk soil and vicinity of metalaxyl treated roots compared to control plant roots. The combination of (MALDI-IMS) and fluorescence imaging indicated the oxygen-dependent degradation of metalaxyl at the root surface. The results presented here underline the great potential of combining different imaging methods to examine the soil – root interfaces as well as the dissipation of organic pollutants in small soil compartments.
Do Micro Scale Effects Constrain the Quantification of Soil Organic Matter by NanoSIMS?

Christian Schurig¹, Thomas Schrank¹, Carsten W. Müller¹, Carmen Höschen¹, Lydia Pohl², Kai U. Totsche² and Ingrid Kögel-Knabner¹

¹Lehrstuhl für Bodenkunde, Technische Universität München, Freising-Weihenstephan, Germany
²Lehrstuhl Hydrogeologie, Institut für Geowissenschaften, Friedrich-Schiller-Universität Jena, Jena, Germany

Soils are highly heterogeneous structures in which both organic and inorganic as well as living and non-living building blocks are interacting to form biogeochemical interfaces (BGI; Totsche et al., 2010). While processes at these interfaces are occurring at the micro- or submicron-scale, they are reasoned to influence the behaviour of soils at the global scale, for example as soils being carbon sinks (e.g. Schulze and Freibauer, 2005; Totsche et al., 2010; Schmidt et al., 2011). Consequently, analytical methodologies with a high resolution are required in order to investigate these processes with the final goal to mechanistically understand BGI formation. Among spectroscopic methodologies nano scale secondary ion mass spectroscopy (NanoSIMS) is a relatively young technique and has only been used for soil science during the last decade (e.g. Herrmann et al., 2007; Mueller et al., 2012; Vogel et al., 2014). Although NanoSIMS measurements were demonstrated to match bulk scale measurements (GC-IRMS) regarding the isotopic enrichment of soil samples (Vogel et al., 2014), the influence of various matrices on the detection of soil organic matter adsorbed at minerals has not been investigated. With the present study we performed sorption experiments of dissolved organic matter on model minerals, such as Boehmite and Illite. We measured adsorption by conventional bulk scale methods and compared the data with NanoSIMS measurements. With the data obtained we aim to develop scaling factors to both compared bulk scale to submicron scale measurements and to scale organic matter measurements at various minerals within an individual NanoSIMS measurement.

References
Highly permeable soils containing little carbon require new environmentally sustainable long-term technologies that improve their retention of water and nutrients in the root zone. A new subsurface water retention technology (SWRT) membrane configuration, installed at strategic soil depths, has been designed to capture and retain twice as much volumetric water content in plant root zones in a manner that promotes large increases in the above and belowground biomass growth while reducing deep leaching losses of agricultural chemicals into groundwater. Multiple ecosystem services of these SWRT membranes include improved soil carbon sequestration, formation of new stable soil aggregates, increased water use efficiency, reduced root turnover and increased shoot to root ratios among horticultural and row cropping systems. These and additional hydropedological rhizosphere opportunities to convert more than 3 billion hectares of sandy soils into sustainable agricultural production systems to feed the world's growing population, with less water, will be presented.
Influence of Anaerobic Digestates Derived from Various Input Substrates on the Wetting Behavior of Soils Affected by Functional Groups of Their Organic Material

Amrei Voelkner¹, Ruth H. Ellerbrock², Dörthe Holthusen¹, Susanne Ohl³, Eberhard Har-tung³ and Rainer Horn¹

¹Institute of Plant Nutrition and Soil Science, University of Kiel, Kiel, Germany
²Institute of Soil Landscape Research, Leibnitz Centre for Agricultural Landscape Research, Müncheberg, Germany
³Institute of Agricultural Engineering, University of Kiel, Kiel, Germany

Anaerobic digestates, as a by-product of biogas production, are used as organic fertilizers on arable fields due to their high amounts of nutrients. It is generally estimated that the digestates of different crops can interact with the soil particles and influences the soil structure. With the application of digestates, soluble monovalent salts, polysaccharides, humic substances and fatty acids can be transferred to the soil matrix and surround mineral particles as coatings. The consequence of the organic amendment can be the degradation of soil functions provoked by increased water repellency (Arye et al., 2011). Hence, diminished wettability of the soil can result in a reduced water infiltration which indeed preserves stable aggregates but can nevertheless lead to higher risk of soil erosion and preferential flow. For our research we chose disturbed soil samples from the A-horizon of two differently textured soils (loamy and sandy soil material) from arable land and applied 30 m³ ha⁻¹ and 90 m³ ha⁻¹ of digestates derived from maize and sugar beet to examine the wetting behavior of soils after amendment. Therefore, the wetting properties were determined by calculating the sorptivity-based Repellency Index (Tillman, 1989) with moist soil samples. Additionally, the contact angle of air-dried samples (< 2 mm) was measured using the Wilhelmy-Plate-Method (Bachmann et al., 2003) and additionally the sessile drop method. To account for the impacts of the digestates for hydrophobicity, the functional groups of the organic fractions were investigated applying FT-IR (Fourier-Transform-Spectroscopy) and DRIFT (Diffuse Reflectance Infrared Fourier Transform Spectroscopy) (Ellerbrock et al., 2005). As a result, the digestates clearly influence the water repellency of the soil. The application of 30 m³ ha⁻¹ of digestates causes a significant resistance to wettability in both soils. In comparison to the loamy soil, the sandy soil material shows an enhanced wettability after an application rate of 90 kg h⁻¹ of digestates. The composition of the soil organic matter exhibits different portions of functional groups (C-O/C=O) after the application of digestates which influence the wetting behavior of the soils. We conclude from the results that the soil texture is the decisive factor controlling the impact of digestates.

References
Session 3: Microbial Ecology of BGIs: Soil (Micro-)Organisms as “Architects” & “Actors” of BGIs
Biosorption Mechanisms of Cu(II) by Extracellular Polymeric Substances (EPS) from *Bacillus Subtilis*

Wenting Ma, Xing Liu and Peng Cai

State Key Laboratory of Agricultural Microbiology, College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China

Biosorption mechanisms of Cu(II) by extracellular polymeric substances (EPS) from *Bacillus subtilis* were investigated using a combination of batch experiments, Fourier transform infrared spectroscopy (FTIR), isothermal titration calorimetry (ITC), and X-ray absorption fine structure (XAFS) spectroscopy. A three discrete site non-electrostatic model fit the potentiometric titration data best, with the $pK_a$ values of 4.25, 6.53, and 9.09, and site concentrations of $4.70 \times 10^{-3}$, $2.04 \times 10^{-3}$, and $2.99 \times 10^{-3}$ mol per gram dry mass of EPS, respectively. The FTIR results confirmed the presence of the functional groups with above $pK_a$ values on the EPS molecules, and further demonstrated that carboxylic and phosphoric groups on EPS are involved in Cu(II) binding. The calculated enthalpies and entropies of Cu(II) adsorption on EPS suggest that Cu(II) binds with anionic oxygen-bearing ligands and forms inner-sphere complexes with the EPS functional groups. The XAFS results are consistent with inner-sphere binding of Cu(II) by carboxyl sites at an average Cu-C distance of 2.96 Å. Similar extended X-ray absorption fine structure (EXAFS) spectra and Cu-C distance (2.79 Å) were also observed in Cu(II) binding on *B. subtilis*, suggesting that EPS have similar functions with bacteria in the binding of Cu(II). The molecular binding mechanisms obtained in this study will improve our understanding on the fate of heavy metals in natural environments.

**Keywords**
EPS, adsorption, heavy metal, XAFS, ITC
Diversity of 2,4-Dichlorophenol Degraders in Agricultural Soil and Drilosphere

Anja Dallinger and Marcus A. Horn

Department of Ecological Microbiology, University of Bayreuth, Bayreuth, Germany

Earthworms play an important role in processing soil organic matter and contribute to the removal of organic pollutants from soil. 2,4-dichlorophenol (2,4-DCP) represents the initial degradation product of 2,4-dichlorophenoxyacetic acid (2,4-D), one of the most widely used herbicides. Degradation occurs in soil due to aerobic and anaerobic microbial processes. Hotspots of microbial activity in soils include the drilosphere, i.e., earthworm gut content, cast, and burrows. The effect of the endogeic earthworm Aporrectodea caliginosa and/or 2,4-DCP on the 2,4-DCP degrading microbial community in soil columns was resolved by a comparative analysis of tfdB (encoding a 2,4-DCP hydroxylase) sequences derived from barcoded amplicon pyrosequencing and clone libraries. In situ relevant concentrations of 2,4-DCP (25 μg g\textsubscript{dw}$^{-1}$) were consumed in soil columns within 19 and 41 days in the presence and absence of earthworms, respectively. Pyrosequencing of tfdB yielded 23800 sequences that were assigned to 58 operational taxonomic units (OTUs) belonging to Actinobacteria, Alpha- and Betaproteobacteria and Verrucomicrobia. Most OTUs (26) were related to Mycobacteriaceae and Micrococccaceae. Sequences affiliated to Comamonadaceae were only detected in burrow walls, cast and bulk soil pre-exposed to earthworms and 2,4-DCP. The analysis of tfdB clone libraries, including 290 sequences, revealed 16 OTUs belonging to Actinobacteria, Alpha- and Betaproteobacteria. Similar to the pyrosequencing data most OTUs (9) were related to Mycobacteriaceae. Statistical analyses (i.e. non-parametric MANOVA) indicated a significant impact of 2,4-DCP on the tfdB-harboring microbial community in drilosphere and bulk soil material. The collective data indicated that (a) agricultural soil harbors diverse putative 2,4-DCP degrading bacteria, (b) 2,4-DCP rather than earthworms affects bacterial community structure of detected 2,4-DCP-degraders, and (c) "high throughput-" as well as "classical"-techniques can lead to almost identical results.
Bentazon (3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide) is a highly selective herbicide that has been used worldwide since the 70's. Bentazon is mobile and susceptible to leaching into groundwater, and consequently of environmental concern. Information on the fate of bentazon in soils are scarce and prokaryotes associated with bentazon degradation in soils are essentially unknown. Therefore, microorganisms that are potentially linked to bentazon degradation in soil were enriched and isolated from agricultural soil of Scheyern. 25 bacterial and four fungal isolates were obtained after a total bentazon consumption of 0.65 mg. Bentazon degradation capabilities of four fungal isolates and three pure cultures provided from a culture collection were tested under oxic conditions in presence and absence of additional carbon. No growth inhibition was observed when 0.01 % (w/v) bentazon was added. A pure culture of *Pae‐cilomyces lilacinus* (*Trichocomaceae, Ascomycota*) and isolate AD13 [(closely related to *Mor‐tierella elongata* (*Mortierellaceae, Zygomyco‐tata*))] transformed bentazon to 6- hydroxybentazon (6- OH- bentazon). The detected concentrations of 6- OH- bentazon after seven days of incubation were in the range of 6 % to 20 % of the initial applied bentazon. Transformation of bentazon mainly occurred in the presence of additional carbon, indicating a co- metabolic process. Cells of *Trametes versicolor*, a laccase- producing fungus affiliated to *Polyporaceae* (*Basidio‐mycota*) transformed 50 % of the initial bentazon. However, no transformation product was detected by HPLC. Cell suspensions of the remaining three fungal isolates and the pure culture showed no decrease in bentazon concentration. Investigation of the bacterial bentazon degradation potential is still in progress, however preliminary tests suggest at least a tolerance towards an elevated bentazon concentration. The collective data indicate that (a) agricultural soil of Scheyern harbors diverse bentazon- tolerant and bentazon- transforming microorganisms, (b) transformation of bentazon is a co- metabolic process, and (c) laccase- producing fungi are associated with bentazon transformation in soil.
Earthworms Rather Than 2,4-Dichlorophenol Impact on Denitrifier and Nitrifier Communities in Agricultural Soil

Anja Dallinger, Marianna M.S. Weller, Christian A. Hofmann and Marcus A. Horn

Department of Ecological Microbiology, University of Bayreuth, Bayreuth, Germany

Nitrous oxide (N$_2$O) is the third most important anthropogenic greenhouse gas with 300 times the global warming potential of carbon dioxide. The production of N$_2$O results primarily from microbial transformations of nitrogenous compounds (i.e. denitrification and nitrification). Earthworms are the predominant soil macrofauna in most terrestrial habitats and emit N$_2$O in situ, due to soil-derived denitrifying bacteria. Pesticides and their degradation products are widespread in nature and affect N$_2$O-forming processes in soils. 2,4-dichlorophenol (2,4-DCP) represents the initial degradation product of 2,4-dichlorophenoxyacetic acid (2,4-D), one of the most widely used herbicides. Soil columns were set up to assess the impact of soil feeding earthworms (Aporrectodea caliginosa) and/or 2,4-DCP on N$_2$O production. N$_2$O-formation rate was 2.5 x higher in soil pre-exposed to earthworms than in soil without earthworms. However, the application of in situ relevant concentrations of 2,4-DCP (21 μg g$_{dw}$⁻¹) showed no significant effect. Denitrifiers were quantified by qPCR and most probable number (MPN) approaches, nitrifiers were quantified by qPCR only. MPNs of denitrifiers in bulk soil of columns with and without earthworms approximated 4.9 x 10⁶ and 8.3 x 10⁵ g$_{dw}$⁻¹, respectively. MPNs of denitrifiers approximated 5.9 x 10⁸ g$_{dw}$⁻¹ in gut contents, indicating that earthworms stimulated replication of denitrifying microorganisms. 2,4-DCP pre-treatment resulted in decreasing and increasing MPNs for drilosphere and bulk soil material, respectively. Structural genes associated with (de)nitrification (i.e. narG, nirK, nirS, nosZ and amoA) tended to be more abundant in earthworm treated soil than in soil without earthworms and were not significantly affected by 2,4-DCP. Bacterial amoA genes (encoding an ammonia monoxygenase) were in general more abundant in drilosphere and bulk soil material than amoA genes of Archaea, indicating that ammonia oxidizing bacteria have an important role in the ammonia oxidizing community in agricultural soil of Scheyern. Terminal restriction fragment length polymorphism (TRFLP) analysis of nosZ (encoding a N$_2$O-reductase) revealed dominance of Bradyrhizobium japonicum affiliated TRFs in drilosphere and bulk soil material irrespective of 2,4-DCP treatment. The collective data suggest that endogeic earthworms rather than 2,4-DCP impact on (a) the N$_2$O-formation in agricultural soil, and (b) the abundance of denitrifying and nitrifying microorganisms.
Succession of Soil Microbial Communities and Enzyme Activities in Artificial Soils

Franziska Ditterich¹, Aurelia Gebala¹, Christian Poll¹, Geertje J. Pronk²,³, Katja Heister², Ingrid Kögel-Knabner²,³ and Ellen Kandeler¹

¹Institute of Soil Science and Land Evaluation, Soil Biology Section, University of Hohenheim, Stuttgart, Germany
²Lehrstuhl für Bodenkunde, Technische Universität München, Freising-Weihenstephan, Germany
³Institute for Advanced Study, Technische Universität München, Garching, Germany

Soils are heterogeneous mixtures of different minerals, organic and biological compounds which are associated in complex hierarchical structures. More than 80-90% of microorganisms are attached to mineral surfaces or mineral-organic complexes. The abundance, diversity and function of microorganism are regulated by several environmental factors such as substrate availability, habitat properties and mineral composition. Until now, less is known about the colonization and succession of different soil minerals by microorganisms. Furthermore, the effect of soil mineral composition on the microbial community structure has been rarely explored. The use of artificial soils which differ only in their mineral, but not in their organic composition, offers a unique possibility to study microbial-mineral-interactions in soils. We hypothesized that the mineral composition as well as substrate availability regulate the colonization of microbial communities of artificial soils.

Eight different artificial soils with the same soil texture (42% fine sand, 52% silt and 6% clay), but with different mineral composition were used. The artificial soils consisted of quartz + (a) one mineral component (montmorillonite; illite; ferrihydrite), (b) two mineral components (montmorillonite + illite; montmorillonite + charcoal; illite + ferrihydrite; illite + boehmite), (c) three mineral components (illite + ferrihydrite + charcoal), sterilized organic manure (carbon source) and a microbial inoculum from an Eutric Cambisol (Ultuna, Sweden). The soils were incubated 3, 6, 12 and 18 months under constant temperature (20°C) and water conditions (60% of maximum water holding capacity) in the dark. We quantified the enzyme diversity, the phospholipid fatty acids (PLFAs) and the abundance of eight bacterial groups at the phylum or class levels by using qPCR to characterize the function and structure of microbial communities. Discriminant analyses of PLFAs showed that the microbial community structure changed over a period of 18 months towards similar communities at the end of incubation, which could be probably explained by nutrient limitation. Molecular analyses for the different mineral component systems showed similar results. We detected a microbial succession of the soil microbial community from a dominance of r-strategists (e.g. β-proteobacteria) using mainly easily available organic substrates during the first six months of the incubation towards systems with a higher dominance of K-strategists (e.g. acidobacteria) using mainly recalcitrant compounds. The succession of the enzyme activities gave clear evidence that nutrient limitation occurred during the incubation. This study showed that microbial colonization and succession on mineral surfaces is affected by mineral properties and nutrient availability.
Impact of Laccases on the Decomposition of MCPA at the Soil-Litter Interface – A Soil Microcosm Experiment

Aurelia Gebala¹, Franziska Ditterich¹, Holger Pagel², Thilo Streck², Christian Poll¹ and Ellen Kandeler¹

¹Institute of Soil Science and Land Evaluation, Soil Biology Section, University of Hohenheim, Stuttgart, Germany
²Institute of Soil Science and Land Evaluation, Biogeophysics, University of Hohenheim, Stuttgart, Germany

The soil-litter interface is a biogeochemical hot spot in soil, where abundance and activity of soil microorganisms are increased and priming phenomena occur. Accordingly, it has been shown that soil organic matter turnover and the degradation of organic chemicals is enhanced at the soil-litter interface. It has been hypothesized that stimulation of fungal growth by litter-derived carbon and increased production of unspecific fungal exo-enzymes may partly explain the accelerated degradation of MCPA (4-chloro-2-methylphenoxyacetic acid) at the soil-litter interface. In particular, laccases have been reported to oxidize a wide range of xenobiotic substances. Therefore, we hypothesized that 1) MCPA degradation is immediately enhanced due to the presence of active fungal laccases and that 2) this effect is even more pronounced at the soil-litter interface due to higher availability of co-substrates. In order to test these hypotheses, we performed a microcosm experiment using a Luvisol soil from the experimental farm Scheyern (Bavaria, Germany). We set up seven different treatments: (a) Control (without MCPA and enzymes), (b) MCPA, (c) MCPA + litter, (d) MCPA + inactive laccase, (e) MCPA + active laccase, (f) MCPA + litter + inactive laccase and (g) MCPA + litter + active laccase. Treatments (b)-(g) were uniformly spiked with MCPA (50 mg kg⁻¹ DM). Treatments (c), (f) and (g) were uniformly mixed with 2-10 mm shredded maize leaf litter and stems (0.01 g kg⁻¹). In treatments (d)-(g) soil was amended with a mixture of three different laccases, either active or inactivated by autoclaving. Soil samples were taken 2, 22 and 40 days after starting the experiment. The sampling dates were selected according to ¹⁴C mineralization data measured at a parallel set of microcosms spiked with ¹⁴C-labeled MCPA. Soil samples were analyzed for residual MCPA concentrations and enzyme activity of laccases. After a period of 22 days, the results of treatments (f) and (g) indicated that addition of both active and inactive laccases in combination with litter most strongly stimulated MCPA degradation. Despite higher enzyme activities in the treatments with added active laccases, the addition of laccases without litter had no significant effect on MCPA degradation compared to the litter treatment (d). In conclusion, we must reject our hypotheses. Rather, our results suggest that the applied laccases only act as additional nutrient sources (particularly nitrogen) and do not directly stimulate MCPA decomposition. Nonetheless, the soil-litter interface is a fungal hot spot here and other unspecific fungal exo-enzymes may be responsible for stimulated MCPA degradation in this microhabitat.
Phages as Biological and Colloidal Vectors of Mass and Genetic Information in the Earth’s Critical Zone (PHAGE)

Nawras Ghanem, Anja Narr, Hauke Harms, Antonis Chatzinotas and Lukas Y. Wick

Department of Environmental Microbiology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany

Although viruses represent the most abundant entities on earth, research has focused mainly on marine ecosystems neglecting terrestrial habitats. Viruses that infect specific host bacteria, known as bacteriophages, have a vast influence on their hosts mortality, evolution, physiology and community structure, and thus on biogeochemical cycles. Despite their relevance still little is known about their transport behavior in terrestrial habitats, their interactions with biogeochemical interfaces (BGI) and the implications of (transported) phages for the genetic landscape of the terrestrial deep subsurface biosphere. Here we would like to present and discuss our recently started “PHAGE” project in the framework of the DFG Collaborative Research Center 1076 – AquaDiva. The overall aim of “PHAGE” is to study (transducing) phages as biological and colloidal vectors of mass and genetic information in the subsurface zone between the highest density of plant roots (~ 0.3 m) and the first aquifers (up to 100 m), known as the Earth’s Critical Zone. As both mobility and the ability of infection determine the contribution of phages in ecosystems, we will assess their role as drivers and indicators for microbial diversity and subsurface transport. More specifically “PHAGE” aims at: (i) Identifying bacteria participating in transduction-mediated gene transfer in different layers of the Critical Zone using Illumina sequencing of 16S rRNA genes isolated from phage heads. Moreover, using 454 shotgun sequencing we will investigate the viral functional metagenome in selected field core samples. Finally, we want to overall screen the morphological and genetic virus diversity with transmission electron microscopy and PCR-based fingerprinting techniques. (ii) Investigating the factors driving subsurface phage transport and assessing the eligibility of marine phages as specific markers of hydrological flow and reactive transport of colloidal particles along BGI and in the Critical Zone. Laboratory column experiments will be applied to test the possible effects of different factors such as phage morphology, different flow regimes as well as the role of eukaryotic (fungal, plant root) networks on phage transport.
Microbial Domains Respond Differently to Soil Minerals in Their Microhabitats as Revealed by Studies with Artificial Soils

Michael Hemkemeyer1, Frederike Imbusch1, Geertje J. Pronk2,3, Katja Heister2, Ingrid Kögel-Knabner2,3, Rainer Martens1 and Christoph C. Tebbe1

1Thünen Institute of Biodiversity, Braunschweig, Germany
2Chair of Soil Science, Department Ecology and Ecosystem Management, Technical University of Munich, Freising-Weihenstephan, Germany
3Institute of Advanced Study, Technical University of Munich, Garching, Germany

Artificial soils (AS) of different mineral compositions can be used to elucidate the importance of selected soil properties for the establishment of microbial communities. This study describes the impact of mineral compositions on Bacteria, Archaea and Fungi in soils, fractionated after incubation of 6 and 18 months into the following sizes: 63–2000 μm, 20–63 μm, and < 20 μm, respectively. Three AS were supplied with different clay minerals and iron oxide: montmorillonite (MT), illite (IL), and illite plus ferrihydrite (IL+FH). The carbon source derived from sterilised manure and the whole mixtures were inoculated with a standardised microbial soil extract. Fractionation was achieved by mild sonication, wet sieving and centrifugation, as previously described (Neumann et al., 2013). DNA was extracted from bulk (not fractionated) soil and size separates. Population sizes of the three domains were determined by quantitative PCR (qPCR) of small subunit (SSU) rRNA genes and the same genes were used for genetic profiling of the communities using terminal restriction fragment length polymorphism (T-RFLP). Gene copy numbers in bulk soil ranged between $1.1 - 2.7 \times 10^{10} g^{-1}$ soil for bacteria, $0.9 - 6.7 \times 10^8$ for archaea, and $0.6 - 11 \times 10^9$ for fungi, respectively. Illite containing mixtures supported more bacteria and archaea, while the addition of ferrihydrite fostered bacteria and fungi. The clay minerals drove the community composition of bacteria and, even more pronounced, of fungi. The latter ones also were affected by ferrihydrite after 18 months of incubation. No effect was seen for archaeal community structure. Generally, patterns of the population sizes from bulk soil were reflected in the finest fraction, but not in the coarsest fraction. The microhabitat was a common driver of community structuring. However, archaea needed 18 months to establish a community in the finest fraction distinct from the both coarser fractions. While fungi responded to the different clay minerals across most particle size separates, the prokaryotes were affected only in the finest fraction. The three domains responded in their microhabitats to the mineral compositions either in form of abundance or community structure or both. The different minerals and the particle size separates showed different selective effects and, thus, suggest that these factors contribute to niche separation. Considering the diversity of minerals in natural soils, our findings suggest that the mineral composition and heterogeneity of soils has a tremendous effect on the diversity of their residing microorganisms.

Reference
Wood ant Nests as Hot Spots of Microbial Activity in Forest Ecosystems

Veronika Jílková¹,² and Jan Frouz¹,²

¹Institute of Soil Biology, AS CR, České Budějovice, Czech Republic
²Institute for Environmental Studies, Charles University in Prague, Czech Republic

Wood ants build large and long-lasting nests from organic materials and mineral soil which have a very special structure. Nests are well-aerated due to numerous chambers and galleries and stable temperature and moisture are maintained there thanks to ant activities. These conditions together with the constant input of easily available nutrients from food of ants support microbial activity. Due to respiration of ants and microbes, wood ant nests are known as hot spots of CO₂ production in forest ecosystems. Although the main source of CO₂ is represented by ant respiration, a significant amount of CO₂ originates also from microbial decomposition of organic materials. Several conditions affect microbial respiration, such as moisture of nest material, changes in temperatures or food input. As mineral nutrients are released from organic materials, wood ant nests represent hot spots of mineral nutrients in forest ecosystems which can be exploited by other organisms, such as roots of trees, and can also cause heterogeneity in species abundance and composition.
Soil Macrofauna Webmasters of Ecosystems

Jan Frouz\textsuperscript{1,2} and Veronika Jílková\textsuperscript{1,2}

\textsuperscript{1}Institute of Soil Biology, AS CR, České Budějovice, Czech Republic
\textsuperscript{2}Institute for Environmental Studies, Charles University in Prague, Czech Republic

The role of plant roots and microflora in shaping many ecosystem processes is generally appreciated. In the contrary, the role of soil macrofauna in this context is assumed to be negligible and rather anecdotic. But more than half of the litter fall is consumed by soil fauna and soil fauna can also consume and/or translocate substantial amount of soil. Here we demonstrate on example of post mining chronosequences how site colonization by soil fauna affects composition of whole soil biota community, plant succession and soil formation. Field and laboratory experiments showed that decomposition of fauna feces may be sped up compared to litter at the very beginning but in a long term fauna feces decomposed slower than litter. This is also supported by micromorphological observation which showed that fauna feces form substantial part of soil. Fauna feces also induce lower or even negative priming effect when introduced in soil in comparison with litter that triggers positive priming effect. A laboratory experiment showed that fauna effect is context sensitive and is more pronounced in systems already affected by soil fauna. Soil mixing by soil fauna consequently affects environmental conditions in soils such as water holding capacity or nutrient availability, it also affects composition of a decomposer food web including microbial community (fungal/bacterial ratio) which feeds back in alternation of plant community composition during succession. This faunal activity is not constant everywhere, the higher effect of fauna activity on litter layer was observed in temperate soils of deciduous forests and with litter having C/N ratio between 20-30. In conclusion, soil fauna uses directly only a small proportion of energy in the litter but can substantially affect soil carbon turnover, soil formation, decomposer food web and plant community.
Gypsum and Halite Deposition on *Cyanobacteria* and Algae in Salt-Affected Soils

Loredana Canfora\(^1\), Pietro Iavazzo\(^3\), Elisa Vendramin\(^4\), Giuseppe Lo Papa\(^2\), Carmelo Dazzi\(^2\), Anna Benedetti\(^1\), Paola Adamo\(^3\) and Flavia Pinzari\(^1\)

\(^1\)Consiglio per la Sperimentazione e la Ricerca in Agricoltura, Centro di Ricerca per lo studio delle relazioni tra Pianta e Suolo, Rome, Italy (CRA-RPS)
\(^2\)Dipartimento di Scienze Agrarie e Forestali, Università degli Studi di Palermo, Italy
\(^3\)Dipartimento di Agraria, Università di Napoli Federico II, Portici, Italy
\(^4\)Consiglio per la Ricerca e Sperimentazione in Agricoltura, Centro di ricerca per la frutticoltura di Roma (CRA-FRU)

Soil surface communities are different from those of bulk soil due to the development of photosynthetic communities comprising cyanobacteria, algae, and other bacteria which contribute to the formation of biological soil crusts. The structure of ecological niches forming biological crusts in saline soil environments is characterized by communities dominated by extremophiles organisms like archea, halophilic bacteria and cyanobacteria that can have a direct or indirect role in shaping soil properties. For example gypsum and halite were found by some authors associated with the cyanobacterium *Entophysalis* (Braithwaite and Whitton, 1987); moreover the crystallization of gypsum and halite around filaments was observed in marine cyanobacterial mats of arid regions in the Persian Gulf (Golubic, 1973). In all these cases no causal relationship has been established between the crystallization of gypsum or halite and cyanobacterial or algal metabolism, and no mention is made of specific sedimentary structures. The present account describes the occurrence of gypsum and halite in a saline soil community and suggests hypothesis on how the organisms may have exerted a physical control over the distinctive structures produced. The study site is a naturally salt-affected soil located in an area, *Piana del Signore*, where some ecological variables acted as strong shaping factors in above and belowground communities distribution, driven by a spatial salinity gradient. Scanning electron microscope observations and microanalysis (SEM-EDS) coupled with X-Ray diffraction analysis (XRD) were carried out to investigate the biogeochemical interfaces in soil, with a deeper overview on the morphology of the minerals occurring in the soil surface. Soil bulk samples and selected fragments of the salted crust of the soil surface were analyzed. Three well defined minerals were identified: halite, sulfates and gypsum. Energy Dispersive Spectroscopy confirmed the cubic mineral form to be halite. The results showed a conspicuous deposition of halite and gypsum on the very superficial layers of the soil areas characterized by a 100% of salt crust cover, and the SEM-EDS analysis provided evidence of the presence of cyanobacteria and algae associated to halite and gypsum deposits. The loss of water from the soil surface due to the natural evaporation can easily explain the deposition of halite and the formation of characteristic sulfate crystals. The inner association and stratification of these minerals along cyanobacteria and algae bodies might be explained by a more complex phenomenon that involve the CO\(_2\) depletion at the biogeochemical interface, due to the algal and bacterial photosynthetic and metabolic activity.

References


Clay Minerals and Metal Oxides Strongly Influence the Structure of Alkane Degrading Microbial Communities During Soil Maturation

Annelie Steinbach1, Stefanie Schulz2, Julia Giebler1, Stephan Schulz2, Geertje J. Pronk3,4, Ingrid Kögel-Knabner3,4, Hauke Harms1,5, Lukas Y. Wick1 and Michael Schloter2,3

1Department Environmental Microbiology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany
2Research Unit Environmental Genomics, Helmholtz Zentrum München, Munich, Germany
3Department Ecology and Ecosystem Management, Chair of Soil Science, Technische Universität München, Munich, Germany
4Institute for Advanced Study, Technische Universität München, Munich, Germany
5German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Germany

The huge structural heterogeneity of soils is believed to foster an enormous microbial diversity, and soil biogeochemical interfaces (BGIs) are assumed to be hotspots of microbial diversity and activity (Totsche et al., 2010). Due to the eons of pedogenesis it is, however, difficult to infer important soil properties shaping microbial diversity and ecosystem functioning. We therefore studied temporal changes of the abundance and diversity of alkane degrading bacteria during the maturation of eight different artificial soils, and analysed their response to disturbance induced by supplementing an additional soil-litter interface as a nutrient rich BGI with high alkane content. The artificial soils contained single components or mixtures of montmorillonite, illite, charcoal, ferrihydrite or boehmite in addition to quartz sand and silt as structural elements (Pronk et al., 2012). The model soils were inoculated with a microbial inoculum from an agricultural soil and matured for three (T3) or twelve months (T12). Subsequently, soil samples from both treatments were incubated with winter wheat litter for two weeks in a microcosm experiment forming a soil-litter interface on top of the cosmos. Sampling of spatial subsamples allowed to differentiate effects in the soil layer with direct contact to litter and bulk soil without direct litter contact. Quantitative PCR (qPCR) and terminal restriction fragment length polymorphism analysis (T-RFLP) targeting a alkB gene (i.e. a marker coding for the alkane monooxygenase as key enzyme to bacterial alkane degradation) were applied to reveal quantitative and qualitative differentiation of alkane degrading bacterial communities during maturation of the different soils. Generally higher alkB gene copy numbers were detected at T3 compared to T12 in all soils. However, the communities at T12 responded much stronger to litter amendment. Concomitantly, stronger community shifts were detected after litter amendment at T12 compared to T3 with converging community compositions in response to substrate availability. In general, the alkane degrading communities of different soil types increasingly diverged with ongoing maturation and influences of different soil components (e.g. illite, charcoal and ferrihydrite) were detected at the different stages of soil development. Hence, our data suggest that the development of functional communities is strongly coupled to the complex structured BGIs. Moreover, with increasing maturation, these impacts become more prominent suggesting a dynamic interplay of the BGIs and microbial communities. Structure-diversity and structure-function relationships are emerging properties of these microhabitats.

References
Effect of Biogeochemical Interface Formation on the Microbial Abundance and Diversity in Matured Soil-Like Systems and Natural Soil During the Plant Litter Degradation

Irina Tanuwidjaja¹,², Nicolas Weithmann¹, Stefanie Schulz¹, Franz Buegger³, Annelie Steinbach⁴, Julia Giebler⁴, Geertje J. Pronk⁵,⁶, Cordula Vogel⁵, Lukas Y. Wick⁴, Hauke Harms⁴ and Michael Schloter¹

¹Research Unit Environmental Genomics, Helmholtz Centre Munich, Neuherberg, Germany
²Wissenschaftszentrum Weihenstephan, Technical University of Munich, Munich, Germany
³Institute of Soil Ecology, Helmholtz Centre Munich, Neuherberg, Germany
⁴Department Environmental Microbiology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany
⁵Chair of Soil Science, Department Ecology and Ecosystem Management, Technical University of Munich, Freising–Weihenstephan, Germany
⁶Institute for Advanced Study, Technical University of Munich, Garching, Germany

Multitude of microhabitats and biogeochemical interfaces (BGIs) make soil one of the most heterogeneous and complex ecosystems that microorganisms can inhabit. The formation of BGIs depends on the mineral composition of soil and the presence of easily available nutrients, which in turn strongly influences the establishment and development of microbial communities. In this experiment, we studied the effect of plant litter addition on the microbial abundance and diversity in well-defined soil-like systems and one natural Luvisol, which had been under agricultural use. Soil-like systems were matured for over two years to allow BGI formation. Four “artificial soils” that consisted of quartz sand and silt and varied in presence of montmorillonite, illite, charcoal and ferrihydrite, were inoculated with microorganisms extracted from an agricultural soil together with sterile manure. Manure was reapplied after 562 days to maintain microbial activities. The matured artificial soils as well as the natural Luvisol were incubated with ¹⁵N and ¹³C labelled potato and maize litter and incubated in the dark at 14°C and 60 % of the respective water holding capacity. Total nucleic acids were extracted from soil samples taken at 0, 7, 21 and 63 days after the plant litter addition. Abundance of bacteria and fungi as well as the respective community structure was assessed based on amplified ribosomal genes. The gene copy numbers for bacteria and fungi were comparable in all soils. Despite the plant litter addition no significant increase in bacterial and fungal abundance was observed over the time. rRNA (“transcripts”) values were higher in artificial soils treated with plant litter when compared to the control soils. The increase in active community abundance in artificial soils was observed directly after the litter addition, whereas in natural Luvisol possibly due to the nutrient reaction with pre-existing complex BGIs, the increase was delayed. Molecular DNA-fingerprinting suggests that both the bacterial and fungal community structure depends on soil composition as well as on litter addition and time. 16S rRNA profiles showed no significant differences in “active” bacterial communities among artificial soils. These results suggest that the soil composition influences the overall microbial structure whereas the plant litter addition conceals said effect on active bacterial community.
Biological Activity Impact on the Dynamics of Aggregates Within a Technosol: Direct Visualization and Quantification in a 14 Months Experimentation

Francoise Watteau\textsuperscript{1,2}, Nouhou Salifou Jangorzo\textsuperscript{1}, Dorian Hajos\textsuperscript{1} and Christophe Schwarz\textsuperscript{1}

\textsuperscript{1}Laboratoire Sols et Environnement, UMR INRA 1120, Université de Lorraine, Vandoeuvre-les-Nancy, France
\textsuperscript{2}UMS CNRS 3562, 15 rue Notre---Dame des Pauvres BP 20, F---54501 Vandoeuvre-les-Nancy, France

Evaluate the dynamics of soil structure, particularly under the influence of biological factors is a major challenge in an objective of their pedogenesis modeling. By using an innovative device of automatic acquisition of high-resolution images, SOILINSIGHTR, we specified in rhizotrons during 14 months the porosity and aggregation dynamics of a constructed Technosol within the rhizosphere of a leguminous plant (\textit{Lupinus albus}) in presence of earthworms (\textit{Lumbricus castaneus}). The constructed Technosol is, by definition, considered as a good candidate for the pedogenesis modeling, insofar as its initial characteristics and implementation conditions are controlled (Sere et al., 2010). A video can show the dynamics of biological agents: root system architecture from germination to senescence of plants, formation of symbiotic nodules, movements of earthworms within rhizotron. Specific image processings were used to quantify total porosity (50μm-2mm), total area of aggregates (100μm-2mm) and various descriptive parameters of pores or aggregates: number, size, diameter, form index (Jangorzo et al., 2013). “Actions” of worms-digging or filling burrows, crossing - were recorded over time. After 14 months, the pore surface is 10 times higher in rhizotrons with plant and microfauna in comparison with the controls. If the biological activity promoted the genesis of aggregates, their dynamics was irregular in that the proportion of aggregates increased or decreased depending on the actions of worms. Characterization of bioturbations on soil thin sections or at microaggregation scale by transmission electron microscopy specified their constitution and the contribution of microorganisms.

References
Fungal-Bacterial Interplays at Biogeochemical Interfaces: Co-occurrence of Fungi and Bacteria in Artificial Soils

Annelie Steinbach¹, Irina Tanuwidjaja², Julia Giebler¹, Florian Centler¹, Stefanie Schulz², Geertje J. Pronk³,⁴, Cordula Vogel¹, Tesfaye Wubet⁵, Ingrid Kögel-Knabner³,⁴, Hauke Harms¹,⁶, Michael Schloter²,⁴ and Lukas Y. Wick¹

¹Department Environmental Microbiology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany
²Research Unit Environmental Genomics, Helmholtz Zentrum München, Munich, Germany
³Institute for Advanced Study, Technische Universität München, Munich, Germany
⁴Department Ecology and Ecosystem Management, Chair of Soil Science, Technische Universität München, Munich, Germany
⁵Department Soil Ecology, Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany
⁶German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig, Germany

Contrary to bacteria, mycelial fungi do not rely on continuous water paths during colonization and foraging of spatially heterogeneous biogeochemical interfaces (BGIs) in water unsaturated zones. Thanks to their high surface to volume ratio mycelia take up nutrients and energy sources efficiently, and with hyphal lengths of up to one kilometer per gram soil build up highly complex network structures. Recent studies unraveled that mycelia resemble functional logistic dispersal networks along which bacteria (“fungal highway”) and nutrients and contaminants (“fungal pipeline”) can be transported (Harms et al., 2011). Mycelia may hence also contribute to a BGI-dependent colonization and the formation of microbial niches in soil. Such knowledge, however, still is sparse. In this study we investigated the impact of four model soil habitats on the development of fungal and bacterial communities and their interplays at BGIs. Four sterile artificial soils were inoculated with a water-extracted microbial inoculant from an agricultural soil, fertilized with sterile manure and matured for two years. The soils contained quartz sand and silt in combination with (i) montmorillonite, (ii) illite, (iii) montmorillonite and charcoal or (iv) illite and ferrihydrite. After maturation the soils were amended with maize-potato litter, incubated for another 7, 21 and 63 days and the fungal and bacterial communities analysed with molecular fingerprinting and high-throughput sequencing. Community structure analyses revealed distinct, BGI-dependent colonization patterns for the two microbial groups. Soil maturation and the addition of plant litter strongly affected the community composition of the fungi and bacteria with most explicit effect detected in charcoal containing soil. Clearly distinct patterns were also found in response to the type of clay (illite vs. montmorillonite), whereas the ferrihydrite as model metal oxide impacted bacterial communities only. Microbial community network analyses based on Fisher’s exact test further revealed distinct co-occurrence relationships between fungi and bacteria in response to the composition of the artificial soils (i.e. the abiotic microbial habitat) or the addition of the plant litter. Our data suggest that BGIs are drivers for bacteria and fungi both during colonization of new habitats, as well as their responses to environmental changes, as induced by the addition of plant litter substrates. Combinations of shared niche preferences and helper-effects (“fungal highways” effect), hence, may explain the soil type dependent community patterns and is currently enlightened via next generation sequencing analysis.

References
Effect of MCPA on N-Acetylglucosamine Degradation by Chitinolytic and Saccharolytic Bacteria under Dynamic Redox Conditions

Adam S. Wieczorek1, Stefanie A. Hetz1, Harold L. Drake1 and Steffen Kolb1,2

1Department of Ecological Microbiology, University of Bayreuth, Bayreuth, Germany
2Department of Aquatic Geomicrobiology, Institute of Ecology, Friedrich Schiller University of Jena, Jena, Germany

Pesticides, like the in agriculture widely applied herbicide MCPA (2-methyl-4-chlorophenoxyacetic acid), have the potential to impair the metabolism of soil microorganisms (Schellenberger et al., 2012). Increasing application of pesticides over the past decades in agriculture has resulted in accumulation of pesticide residues in soils that may affect microbial metabolism. Chitin, consisting of alternating β-1,4-linked N-acetylglucosamine (GlcNAc) residues, is an abundant biopolymer in soils, and is degraded by chitinolytic and saccharolytic soil microbes by sequential enzymatic hydrolysis to GlcNAc. In an aerated soil, oxygen distribution is highly heterogeneous, and dynamic on the micro- to millimeter scale due to different porosity in- and outside of soil aggregates and complex interactions in ‘Biogeochemical Interfaces’ (Totsche et al., 2010). However, chitinolytic and saccharolytic Bacteria enable continued chitin degradation despite fluctuations of oxygen concentration as they are catabolically diverse and occupy different ecological niches with regard to oxygen availability (Wieczorek et al., 2014). The aim of this study was to assess the effect of MCPA on GlcNAc degradation by chitinolytic and saccharolytic Bacteria under dynamic redox conditions. Agricultural soil slurries were sequentially flushed with synthetic air (oxic conditions) or dinitrogen gas (anoxic conditions) to establish dynamic redox conditions. Supplementations of GlcNAc (3 mM) were followed by a drop of the redox potential from positive (+ 400-200 mV) to negative (- 300 mV) values under anoxic conditions whereas the redox potential of un-supplemented controls was stable. Under oxic conditions the redox potential of supplemented slurries increased to almost initial values. GlcNAc was degraded by aerobic respiration, ammonification, and nitrification to carbon dioxide and nitrate under oxic conditions. When oxygen was absent, likely butyrate and propionic acid fermentation were along with ammonification and nitrate respiration responsible for GlcNAc degradation. Supplementation of in situ relevant concentrations (60 μM) of MCPA had no effect on the degradation of GlcNAc under dynamic redox conditions. In slurries supplemented with high concentrations of MCPA (860 μM) GlcNAc consumption was apparently not impaired. However, reduced accumulation of acetate during anaerobic degradation of GlcNAc compared to controls without MCPA suggested a potential toxic effect of MCPA on the anaerobic metabolism of chitinolytic and saccharolytic Bacteria. The effect of dynamic redox conditions and the supplementation MCPA on chitinolytic and saccharolytic Bacteria will be determined by comparative transcript analysis of 16S rRNA genes.

References
Metabolic Responses of Chitinolytic and Saccharolytic Bacteria to Oxygen

Adam S. Wieczorek¹, Stefanie A. Hetz¹, Harold L. Drake¹ and Steffen Kolb¹,²

¹Department of Ecological Microbiology, University of Bayreuth, Bayreuth, Germany
²Department of Aquatic Geomicrobiology, Institute of Ecology, Friedrich Schiller University of Jena, Jena, Germany

Chitin, consisting of alternating $\beta$-1,4-linked N-acetylglucosamine (GlcNAc) residues, is an abundant biopolymer in soils, which are 'hot spots' of production and degradation of chitin. Aerobic and anaerobic soil microbes can degrade chitin by initial hydrolyzation via exo- and endochitinases to N,N$'$/diacetylchitobiose ([GlcNAc]$_2$) and longer oligomers of GlcNAc. An alternative degradation pathway involves prior deacetylation to chitosan and the subsequent hydrolyzation to chitobiose ([GlcN]$_2$) and longer oligomers of glucosamine (GlcN). The preferred pathway of chitin hydrolysis in soil microbial communities has yet not been resolved. In an aerated soil, oxygen distribution is highly heterogeneous, and dynamic on the micro- to millimeter scale due to different porosity in- and outside of soil aggregates and complex interactions in ‘Biogeochemical Interfaces’ (Totsche et al., 2010). Therefore, different redox processes, such as fermentation or oxygen respiration, can simultaneously be active when chitin is degraded. The aim of this study was to resolve the preferred pathway of chitin hydrolysis and to assess the response of chitinolytic taxa and the processes associated with chitin hydrolysis under oxic and anoxic conditions. Chitin was degraded under oxic and anoxic conditions in agricultural soil slurries, whereas chitosan was not substantially degraded. Thus, hydrolysis of chitin was preferred to the pathway that starts with deacetylation to chitosan. $^{13}$C labelled chitin was degraded by aerobic respiration, ammonification, and nitrification to carbon dioxide and nitrate under oxic conditions. When oxygen was absent, likely butyrate and propionic acid fermentation were along with ammonification, nitrate and iron respiration responsible for chitin degradation. Chitinolytic taxa actively assimilating carbon derived from $^{13}$C labelled chitin under oxic and anoxic conditions will be identified by comparative transcript analysis of 16S rRNA genes. TRFLP analysis showed that different chitinase genotypes responded to chitin supplementation and affiliated with a novel deep-branching bacterial chitinase genotype (anoxic conditions), genotypes of Beta- and Gammaproteobacteria (oxic and anoxic conditions), and Planctomycetes (oxic conditions). The findings provide evidence that detected chitinolytic Bacteria were catabolically diverse and occupied different ecological niches with regard to oxygen availability enabling continued chitin degradation despite fluctuations of oxygen concentration in soil.

References
Session 4:  
BGIs in Changing Environments:  
BGIs Dynamics & Heterogeneity  
with Consequences for Properties & Processes
Effect of Soil Structure on Iron Oxide Colloid Mobility

Jannis Florian Carstens¹, Jörg Bachmann¹ and Insa Neuweiler²

¹Institute of Soil Science, University of Hannover, Hannover, Germany
²Institute of Hydromechanics, University of Hannover, Hannover, Germany

The mobility of iron oxide colloids in soils is strongly affected by pore structure as well as hydraulic, physical, and chemical properties of biogeochemical interfaces, fluid phase, and colloids. Colloidal iron oxides are of importance for natural soil-forming processes and human-induced processes including technical applications. The aim of this study was to investigate the effect of pore structure on iron oxide colloid mobility in goethite-coated quartz sand packings as well as in disturbed and undisturbed natural soil samples rich in naturally occurring iron oxide coatings. Moreover, the influence of dissolved organic matter (DOM) on transport and retention of iron oxide colloids was examined. By adsorption onto solid particles, DOM can modify biogeochemical interfaces and simultaneously alter soil wettability. A special emphasis was put on determining if effective physico-chemical surface parameters derived from contact angle and zeta potential measurements can be used as a tool to predict general tendencies for iron oxide colloid transport and retention in porous media. Iron oxide colloid mobility was examined in column breakthrough experiments by percolating goethite colloids (particle size: 200-900 nm) through packings of goethite-coated quartz sand (grain size: 100-300 μm) at different DOM concentrations. Furthermore, goethite colloids were percolated through flow cells filled with both disturbed and undisturbed soil samples from a forest subsoil rich in iron oxide coatings, in order to examine (i) if results of flow columns packed with goethite-coated quartz sand can be transferred to natural soil, and (ii) whether differences between the undisturbed and the disturbed soil samples occur. Additionally, sessile drop contact angles and zeta potentials of the applied materials were measured. By means of these surface parameters, both classic and extended DLVO energies including Lewis acid-base parameters were estimated. Experiments with goethite-coated quartz sand elucidate that the both the goethite colloids and the goethite-coated sand need to be coated with DOM in order to enable colloid transport. These basic interactions were transferable to the undisturbed soil: Pre-conditioning the natural soil with DOM was required to facilitate the transport of DOM-coated goethite colloids through the flow cell. As compared to the undisturbed soil, goethite colloid mobility in the disturbed soil was reduced, likely due to the destruction of the original pore structure and the concomitant loss of preferential flowpaths, as well as the modification of biogeochemical interfaces, i.e. due to abrasion of the original coatings. DLVO interaction energy calculations demonstrated that primary energy wells and energy barriers yielded by the classic DLVO approach are sufficient to predict general trends of goethite colloid mobility. Extended DLVO calculations revealed strong surface-near (~5 nm) interaction energies due to Lewis acid-base interactions that apparently do not influence goethite colloid transport. These short-range energies may have been weakened by surface roughness of sand grains and colloids. It can be concluded that the impact of DOM concentration and goethite coatings of the solid matrix are transferable from flow columns filled with goethite-coated quartz sand to flow cells filled with undisturbed soil, and furthermore that the mobility of goethite colloids is reduced in disturbed soil samples. Moreover, with restrictions for the interpretation of close-distance interactions, DLVO interaction energies are capable of predicting general trends of goethite colloid mobility.
Changes in soils water regime will be a key component of future climate change. While many recent studies focused on the effect of temperature on soil C dynamics much less studies are devoted to the impact of water regimes, although soil moisture strongly influences microbial activity (Moyano et al., 2013). Bph horizons of Amazonian podzols represent a huge stock of organic carbon, i.e., 13.6 PgC (Montes et al., 2011). The se horizons are often water–saturated, which is hypothesised to limit decomposition. Predicted changes in climate for this Area will result in drier and more variables water regimes as compared to the present situation. We investigated how heterotrophic respiration of the different soil horizons of these soils reacts to soil moisture. For this we incubated undisturbed soil cores from the OH, E, Bph, and IIM soil horizons at different matric potentials (pF 0, 1.7, 2.5, 3.5, 4.2) and monitored the C mineralisation by measuring the evolved CO$_2$ using a μGC. The results showed very little variation of C mineralization rates within the considered range of matric potentials. This is explained, for the Bph horizons, by the dominance of soil pores by very small (dia < 0.95 μm) pores, which remain water saturated even at pF 4.2. Absence of impact of matric potential variations may also be explained by other factors limiting decomposition in these soils. We discuss the possible impacts of predicted variations of the water regime of these. Soils with climate change changing climate on the stability of their C stocks.

References
Restructuring of Biogeochemical Interfaces: Role of Cations and Heat Treatment for SOM Thermal Properties

Dörte Diehl1, Marc-O. Goebel2, Tatjana Schneckenburger4,5, Jaane Krüger5, Susanne K. Woche2, Anastasia Shchegolikhina3,6, Jette Schwarz1, Bernd Marschner3, Friederike Lang5, Sören Thiele-Bruhn4, Jörg Bachmann2 and Gabriele E. Schaumann1

1Institute for Environmental Sciences, Department of Environmental and Soil, Universität Koblenz-Landau, Landau, Germany
2Institute of Soil Science, Leibniz Universität Hannover, Hannover, Germany.
3Institute of Geography, Department of Soil Science and Soil Ecology, Ruhr-Universität Bochum, Bochum, Germany
4FB VI Geography/Geosciences, Soil Science, Universität Trier, Trier, Germany
5Chair of Soil Ecology, Albert-Ludwigs-Universität Freiburg, Freiburg i.Br., Germany
6National Research Tomsk Polytechnic University, Tomsk, Russia

Molecular arrangement of soil organic matter (SOM) is subjected to continuous restructuring processes under changing environmental conditions (Piccolo, 2002) with consequences for SOM stability and matrix rigidity (Schaumann and LeBoeuf, 2005). SOM thermal stability is linked with biogeochemical stability and can be characterized via thermal combustion (Plante et al., 2011). Cations are suggested to increase SOM stability against degradation (e.g., Scheel et al., 2008) although this effect was studied only rarely in non-fractionated soil samples. SOM matrix rigidity describes the flexibility of polymer chains and influences the ability and rate of changes in supramolecular structure (Piccolo, 2002) with consequences for sorption and wetting behavior. SOM matrix rigidity is suggested to increase by cross-links between molecule chains, like cation bridges (CaB) (Kunhi Mouvenchery et al., 2012) or water molecule bridges (WaMB) (Schaumann and LeBoeuf, 2005). The present study aimed at understanding the processes occurring in SOM upon changes in cation composition, temperature treatment and aging. For this purpose, we enriched soil samples with (Na+, Ca2+, Al3+) and subjected them to different temperatures (25, 40, 60, and 105 °C). SOM matrix rigidity was determined via step transition temperature T* with DSC as a function of aging time. Thermal stability was determined at the end of aging. While cation effects on matrix rigidity evolved only slowly after 8 weeks of ageing, significant effects of treatment above 40 °C caused a nonreversible loss of water molecule bridges and above 60 °C a partly reversible melting process probably of semi-crystalline poly(methylene). In contrast, thermal stability increased with increasing cations valence and degree of protonation (desalination) whereas temperature treatment revealed no significant effect. We conclude that drying at elevated temperatures (>40 °C) may irreversibly change SOM structure via disruption of labile cross-links and melting of semi-crystalline domains.

References
Towards Further Understanding of the Soil Genesis Control on Carbon Stabilization: The Loss of Physical Protection of Carbon Along a 3000 kyr Chronosequence

Sebastian Doetterl¹, Asmeret Asefaw Berhe², Jennifer W. Harden³, Pascal Boeckx⁴ and Elisabet Nadeu⁴

¹Isotope Bioscience Laboratory - ISOFYS, Ghent University, Ghent, Belgium
²Life and Environmental Sciences, University of California at Merced, Merced (CA), USA
³Soil Biogeochemistry Group, USGS, Menlo Park (CA), USA
⁴TECLIM, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

Most studies on stability of carbon (C) in soils are conducted on time series ranging from 1 to 100 years. Annual scale (or shorter) time series typically focus on the interaction of microorganisms with the soil mineral matrix and the transformation of organic compounds in litter. In contrast, soil genesis, i.e. soil weathering, is traditionally studied on longer time-scales (centuries to millennia) by using soil chronosequences. This temporal discrepancy between C sequestration (short-term process) and soil genesis (long-term process) represents a major gap in our understanding of the interaction of mechanisms that can stabilize C in soils over longer timescales. In this study we characterize the pathways of carbon transformations and stability from the litter source into different compartments of the soil matrix in rangeland soils with similar bioclimatic characteristics along a chronosequence ranging from 0.1 – 3000 kyr derived from granitic alluvium on terraces of the river Merced (Merced County, CA, USA) (Harden 1987). In order to investigate the changing effectiveness of geochemical and/or physical protection of C along the chronosequence, we conducted (i) a series of aggregate-based soil fractionation experiments combined with (ii) a biochemical characterization of the C in the isolated fractions using the abundance of labile amino sugars as tracers for microbial residues in soils, (ii) an analysis of the radiocarbon age of the different fractions, (iii) an analysis of the geochemical composition of top- and subsoils along the sequence and (iv) temperature sensitivity incubation experiments on the bulk soil and isolated major C fractions. Our analysis shows that the distribution of aggregates and C associated with aggregate fractions as well as the potential turnover of these fractions are highly variable along the chronosequence. While soils developed in younger (<10 kyr) deposits show an increase in C stabilized with the mineral phase, soils developed in older deposits (>10 kyr) lose the ability to form aggregates and provide physical protection for C by occlusion with increasing age, leading to lower soil C content. This finding is confirmed by the abundance of amino sugars and relative changes in the ¹⁴C age of different fractions. The patterns we observe with aggregation, amino sugars, and radiocarbon co-evolve with alterations in the abundance of primary and secondary minerals of soils due to ongoing weathering. The observed effects differed between top- and subsoils most likely related to the fact that biomass C input, an important component of larger aggregates, decreases nearly tenfold from topsoils developed in the youngest compared to the oldest deposits, while the decrease is insignificant in subsoils. For further research we hypothesize that decreases in C are also related to a reduction in reactive mineral surfaces due to ongoing weathering and that this effect will be stronger in top-soils (high C input, limitation of reactive surfaces) than in sub-soils (low C input, no limitation of available surfaces).

References
This presentation provides a comprehensive overview about the formation of non-extractable residues (NER) from organic pesticides and contaminants in soil and tries classifying the different types. Anthropogenic organic chemicals are deliberately (e.g. pesticides) or unintentionally (e.g. polynuclear aromatic hydrocarbons [PAH], chlorinated solvents, pharmaceuticals) released in major amounts to nearly all compartments of the environment. Soils and sediments as complex matrices provide a wide variety of binding sites and are the major sinks for these compounds. Many of the xenobiotics entering soil undergo turnover processes and can be volatilised, leached to the groundwater, degraded by microorganisms or taken up and enriched by living organisms. Xenobiotic NER may be derived from parent compounds and primary metabolites that are sequestered (sorbed or entrapped) within the soil organic matter (type I NER) or can be covalently bound (type II NER). Especially type I NER may pose a considerably environmental risk of potential release. However, NER resulting from productive biodegradation, which means the conversion of carbon (or nitrogen) from the compounds into microbial biomass molecules during microbial degradation (type III, bioNER), do not pose any risk. Experimental and analytical approaches to clearly distinguish between the types are provided and a model to prospectively estimate their fate in soil is proposed.
Physicochemical Character of Water Molecule Bridges Stabilizing Soil Organic Matter

Jiri Kucerik¹, Alexander Jäger², Marko Bertmer² and Gabriele E. Schaumann¹

¹Institute for Environmental Sciences, Group of Environmental and Soil Chemistry, University Koblenz-Landau, Landau, Germany
²Institute for Experimental Physics II, Group MQF, University of Leipzig, Leipzig, Germany

Even in air dried soils, water is still involved in many processes. To understand them, it is beneficial to get deeper knowledge about the physicochemical character of water binding. Combination of differential scanning calorimetry (DSC), NMR and molecular modeling showed that water nanodroplets that function as water molecule bridges (WaMB), connecting and physically stabilizing soil organic matter are progressively formed in a wide range of soils (Hurrass and Schaumann, 2005; Schaumann and LeBoeuf, 2005; Kunhi Mouvenchery et al., 2013). The WaMB is supported by hydrophobic surroundings of spatially arranged polar groups (Aquino et al., 2011). WaMB is detected by its disruption, manifested as a step in heat capacity on DSC records (Hurrass and Schaumann, 2005). In this work, we report results about a progressive formation of WaMB after its disruption, separation of WaMB from accompanying processes and new approaches to analyze its physicochemical character. As a model soil, a sapric histosol was used. In the first step, using different heating protocols, the WaMB transition was separated from a parallel processes, which involved melting of aliphatic structures (Chilom and Rice, 2005). Unlike melting, WaMB responded to the heating rate and extrapolation to stationary conditions indicated its occurrence at ambient temperatures. The transition energy, which involves the energy of the H-bonds break and water diffusion, was determined ~ 54 kJ/mol. After WaMB breaking, it reforms quickly at ambient conditions, whereas at elevated temperatures, water diffuses away and WaMB reforms slowly. The experiments further reveled that formation of WaMB depends also on cooling conditions, the condensation of molecules into WaMB was manifested as an exothermal processes preceding the WaMB transition (Kucerik et al., 2014). The newly developed approach, based on the determination of soil water evaporation enthalpy, supports molecular modeling results about the occurrence of WaMB in the vicinity of hydrophobic domains. The measured enthalpies demonstrated that binding energy of WaMB nanodroplets depend on relative humidity and thermal history of soil.

References
Spatial Ecology of Bacteria at the Microscale in Soil

Xavier Raynaud\(^1\) and Naoise Nunan\(^2\)

\(^1\)Sorbonne Universités, UPMC, Institute of Ecology and Environmental Sciences – Paris, Paris, France
\(^2\)CNRS, Institute of Ecology and Environmental Sciences – Paris, Campus AgroParisTech, Thiverval-Grignon, France

Despite an exceptional number of bacterial cells and species in soils, bacterial diversity seems to have little effect on soil processes, such as respiration or nitrification, that can be affected by interactions between bacterial cells. The aim of this study is to understand how bacterial cells are distributed in soil to better understand the scaling between cell-to-cell interactions and what can be measured in a few milligrams, or more, of soil. Based on the analysis of 744 images of observed bacterial distributions in soil thin sections taken at different depths, we found that the inter-cell distance was, on average 12.46 mm and that these inter-cell distances were shorter near the soil surface (10.38 mm) than at depth (>18 mm), due to changes in cell densities. These images were also used to develop a spatial statistical model, based on Log Gaussian Cox Processes, to analyse the 2D distribution of cells and construct realistic 3D bacterial distributions. Our analyses suggest that despite the very high number of cells and species in soil, bacteria only interact with a few other individuals. For example, at bacterial densities commonly found in bulk soil (108 cells g\(^{-1}\) soil), the number of neighbours a single bacterium has within an interaction distance of ca. 20 mm is relatively limited (120 cells on average). Making conservative assumptions about the distribution of species, we show that such neighbourhoods contain less than 100 species. This value did not change appreciably as a function of the overall diversity in soil, suggesting that the diversity of soil bacterial communities may be species saturated. All in all, this work provides precise data on bacterial distributions, a novel way to model them at the micrometer scale as well as some new insights on the degree of interactions between individual bacterial cells in soils.
Changes in the Structure of Sapric Peat Induced by the Presence of Phenol

Pavel Ondruch¹, Jiri Kucerik¹, Alexander Jäger², Marko Bertmer² and Gabriele E. Schauermann¹

¹Institute for Environmental Sciences, University Koblenz-Landau, Landau, Germany
²Institute for Experimental Physics II, Group MQF, University of Leipzig, Leipzig, Germany

Pollutant sorption in soil has already been widely studied, focusing mostly on sorption kinetics and mechanisms as well as pollutant interaction with soil organic matter (SOM). Despite this effort, the effect of pollutants on soil structure is not fully understood, although it has an important influence on pollutants’ fate and soil quality in terms of soil stability and functions. In this work, we applied thermoanalytical methods, differential scanning calorimetry (DSC), thermogravimetric analysis coupled with mass spectrometry (TGA-MS), and solid-state ¹³C CPMAS NMR to study soil structure that was treated by different solvents with and without phenol. To this purpose we chose an organic matter rich sapric histosol. We focused on two soil characteristics, character of soil water molecule bridges (WaMB) and soil aliphatic composition. Formation of water molecule bridges is an important factor of stabilization of the physical structure of soil organic matter (Schaumann and Bertmer, 2008) and represents an important part in its physicochemical aging (Kucerik et al., 2014). The role of crystalline aliphatic regions is not fully clear, and it is usually connected with sorption inactivity and even solvent impermeability. Nevertheless, there are proposals that crystalline domains can reduce amorphous domain mobility in their vicinity and thus indirectly cause nonlinear sorption behavior (Deshmukh, 2003). Furthermore, the influence of phenol incorporation on soil thermal stability was investigated. Our results suggest that the effect of phenol on WaMB and their destabilization is governed by physicochemical properties of the solvent that was used for incorporation of phenol. It was observed that nonpolar solvents support WaMB stability and may increase its formation. Regarding to aliphatic composition, we detect significant melting point depression only if phenol was present in soil. It suggests changes in aliphatic crystalline domains. This was also supported by ¹³C NMR results, which indicate decrease of crystallinity in phenol spiked samples. Furthermore, we observed a decrease of onset temperature of organic matter degradation that was indicated by release of CO₂ as seen by TGA-MS analysis. In summary, our investigation proposes destabilization of soil physicochemical structure caused by phenol and solvents used. These findings may contribute to knowledge of pollutant sorption, sequestration, and their impact on environment.

References
Effective Dispersal of Degrading Bacteria Impedes Outgassing of Organic Contaminants

Sally Otto¹, Thomas Banitz², Karin Johst², Hauke Harms¹ and Lukas Y. Wick¹

¹Department of Environmental Microbiology, Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany
²Department of Ecological Modelling, Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany

Contaminants are only hazardous if they become bioavailable. The most effective remediation technique should lead to an optimal coverage with degrading microorganisms to prevent a release of contaminants bound to biogeochemical interfaces (BGI) to the environment. Here, we investigated the impact of bacterial dispersal on BGI on the outgassing of phenanthrene (PHE). Our study was performed to challenge the hypothesis that the presence of dispersal networks of bacteria leads to: (i) bacterial distribution along the transport network, (ii) efficient bacterial distribution on the surface, and (iii) an increased biomass production allowing for the degradation of PHE releasing from the system. We therefore designed a laboratory microcosm mimicking a continuous PHE release from a PHE hotspot to a model BGI (agar surface) in presence and absence of model dispersal networks which facilitated the transport of unless poorly motile PHE-degrading Pseudomonas fluorescens LP6a on agar surfaces. The presence of the glass fibres (as a laboratory mimic the widespread soil fungal networks) resulted in an (i) increased spatiotemporal spreading of bacteria, (ii) an increased bacterial coverage of and growth on the agar surface, and (iii) a subsequent effective degradation of outgassing PHE and effective reduction of PHE contamination beyond the PHE hotspot. Our data hence suggest that fungal mycelia may promote the formation of an adapted microbial biomass that will degrade contaminant molecules desorbing from that source and that such an activity potentially can result in zero emission of contaminants to the pore and groundwater and, hence, to higher organisms.
Transport of Bacterial Pesticide Degraders - An Important Process Enhancing Degradation of MCPA Close to the Soil-Litter Interface?

Holger Pagel¹, Aurelia Gebala², Christian Poll², Joachim Ingwersen¹, Franziska Ditterich², Ellen Kandeler² and Thilo Streck¹

¹Institute of Soil Science and Land Evaluation, Section of Biogeophysics, University of Hohenheim, Stuttgart, Germany
²Institute of Soil Science and Land Evaluation, Section of Soil Biology, University of Hohenheim, Stuttgart, Germany

The rate of pesticide degradation in soils depends on the spatial distribution of degrading microorganisms. In addition to solute transport, the movement of microorganisms can improve the connectivity of pesticide degraders and substrate. Input of fresh litter-carbon stimulates microbial growth and degradation of the herbicide MCPA (2-Methyl-4-chlorophenoxyacetic acid) in soil adjacent to the soil-litter interface (detritusphere). Transport of bacterial MCPA degraders enriched at the soil-litter interface might contribute there to enhanced MCPA degradation by increasing the actively degrading biomass. In particular, bacterial transport via fungal hyphae (“fungal highways”) could promote the translocation of bacterial pesticide degraders, because fungal growth is strongly enhanced at the soil-litter interface. Therefore, our objective was to elucidate i) if movement of bacterial pesticide degraders by convective and diffusive transport occurs and ii) if growth of fungal hyphae promotes bacterial transport. Both processes would enhance MCPA degradation. We set up soil cores (33 mm height, 56 mm diameter) consisting of a 30 mm subsoil layer covered by a thin topsoil layer (3 mm). The soil was a silty loam from an agriculturally used field. Maize litter was then placed on top of a portion of these soil cores. All soil was sieved (2 mm) and homogeneously amended with 50 μg g⁻¹ MCPA. The topsoil was pre-incubated either after amendment of 20 μg g⁻¹ MCPA or without MCPA amendment to obtain soil material with an increased abundance of bacterial MCPA degraders (inoculum) or without. In total, we prepared 4 treatments: i) MCPA amendment & non-inoculated topsoil (control); ii) litter addition & MCPA amendment & non-inoculated topsoil (litter); iii) MCPA amendment & inoculated topsoil (inoculated); iv) litter addition & MCPA amendment & inoculated topsoil (litter inoculated). The soil cores were incubated in microcosms, irrigated with 0.01 M CaCl₂ solution at two rates (1 mm d⁻¹ and 24 mm d⁻¹) and sampled 1 day and 10 days after a total volume of two pore volumes had been applied. During incubation we measured CO₂-production. The soil cores were separated into 9 layers, from 0-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-10, 10-15 and 15 – 33 mm, using a newly developed sampling device and analysed for abundances of three molecular markers (tfdA genes, 16S rRNA genes and fungal ITS fragments) and residual MCPA concentration. Since analyses are currently still running, first results will be presented in addition to the newly developed sampling device.
Effects of Acid Treatment on Soil Hydraulic and Transport Properties of Floodplain Soils

Sabine Schaefer and Kai Uwe Totsche

Institute of Geosciences, Friedrich Schiller University Jena, Germany

Biological and physicochemical processes in soils, like root growth, mineral precipitation and dissolution, or colloidal dispersion and flocculation may result in not only temporal changes of the soil structure. Such effects will in turn affect the pore network architecture, the hydraulic and the transport properties. Using soil column experiments, we studied the influence of mineral dissolution on the hydraulic conductivity, the water retention characteristic and the apparent dispersivity. Two undisturbed soil cores packed with a calcareous floodplain soil from the Danube were flushed with a perchloric acid solution (10-2.5 M). Before and after the acid treatment we investigated the pore network by computer tomography (CT) (UFZ Halle, Department of Soil Physics) and measure the hydraulic and the transport properties. Transport experiments (sodium chloride as tracer) show a fast increase of the solution concentration which points to dominance of preferential flow, most likely along macropores, which are related to old roots. Whereas leaching of the solution is retarded. Only weak effects on dispersivity occurred, modeling dispersivity yields changes between 3.2 cm (± 0.9 cm) and 5.3 cm (± 2.3 cm) before and after acid percolation. Because of the high standard deviations these values are less reliable. In the water retention characteristic we observe only small changes as well. A slight increase of the saturated water content was measured after acid percolation. At low tension in the range of the field capacity (pF 1.8 to 2.5) a tendency to lower water contents after acid treatment is observable. However, we can't exclude that these changes are within range of the hysteresis effect. Percolation with a high concentrated acid, for nearly a month, only leads to weak effects in the transport properties as well as in the water retention. This means the soil we used shows a high resistance against disturbance and can be referred as a good resilient water conductor.
Effects of Fresh Organic Matter Accessibility on Carbon Decomposition by Fungi

Sonja Schmidt¹, Claire Chenu², Ruth Falconer¹, Cyril Girardin³, Naoise Nunan⁴, Wilfred Otten¹ and Valérie Pouteau³

¹SIMBIOS Centre, Abertay University, Dundee, UK
²AgroParisTech, UMR 7618 Bioemco, Bâtiment EGER, Thiverval Grignon, France
³INRA, UMR 7618 Bioemco, Bâtiment EGER, Thiverval Grignon, France
⁴CNRS, UMR 7618 Bioemco, Bâtiment EGER, Thiverval Grignon, France

Fungi play an important role in carbon decomposition and sequestration but how soil structure controls their activity is still unclear. Soil structure seems to be the key factor on fungal spread in soil, in particular the size, continuity and air filled fraction of soil pores. Physical access of fungi to SOM will also depend on the abundance of decomposable SOM. Fungi are predominant involved in residues cell wall decomposition and in the priming effect (PE) where old soil organic matter (SOM) is decomposed by using fresh carbon as a source of energy. Information on how soil structure affects colonisation and decomposition of fresh organic matter and SOM by fungi could help to get a better understanding of the processes involved in carbon sequestration and CO₂ respiration. The objective of this study was to test how fungal exploration of the soil and probability of contact between OM and hyphae determines C mineralization. For this we manipulated the soil pore system by compaction and the abundance of OM by adding fresh organic matter in different amounts. Maize straw and soil were sterilised and mixed to different ratios and packed to two different bulk densities (1.3 and 1.5 Mg m⁻³). The initial water content in each sample was adjusted to an air filled porosity of 17%. Each sample was inoculated with *Rhizoctonia solani* and stored at 20°C. CO₂ concentration and the isotopic ratio of carbon were measured on day over a period of 42 days to distinguish the C-CO₂ originating from the fresh organic material (δ¹³C = 12‰) and the C-CO₂ originating from the soil organic matter (SOM δ¹³C = 27‰). Faster decomposition rates were found in the less compacted soils than in very dense soil as the fungal spread is probably hindered due to fewer pores the mycelium can grow through. Greater amounts of C CO₂ released from SOM were measured when larger amounts of fresh organic matter were added with greater differences in soil samples packed to 1.3 Mg g⁻³ than in soil samples packed to 1.5 Mg g⁻³, showing that the ability of fungi to colonize soil limited decomposition. The amount of C-CO₂ produced per mg of C-fresh organic matter decreased as their concentration increased. The addition of fresh organic matter induced a positive priming of SOM. These data will help us to calibrate an existing models of fungal growth in soil in response to native and added soil organic matter to better understand the role of fungi in carbon decomposition and sequestration.
Anecic earthworms forage on organic detritus at the soil surface and maintain permanent burrows which act as hotspots of decomposition, microbial activity and water flow in soil. The ecological importance of this earthworm group is widely recognized, but the assumption that distinct species are functionally redundant in their effects has rarely been investigated. We performed a field experiment in temperate grassland to test whether two species in this functional group, *Lumbricus centralis* and *Aporrectodea longa*, had the same impact on soil biochemical heterogeneity, protists and nematodes. We used maize litter labelled with $^{13}$C and $^{15}$N stable isotopes to detect incorporation of residue-derived C and N into soil around burrows, either occupied by one of the two species, or from which the earthworm was manually removed. After 50 days, we sampled topsoil (0–10 cm depth) at thin concentric layers around the burrow walls (up to 8 mm), representing the potential drilosphere, and at a further distance (50–75 mm), representing bulk soil. Although the drilosphere of both species had a higher C content than bulk soil, *L. centralis* incorporated more $^{13}$C, i.e. more litter-derived C, than *A. longa*. This was associated to a larger contribution of plant-derived sugars to the soil organic matter (lower \([\text{galactose + mannose}]/[\text{arabinose + xylose}]\) ratio), as well as a higher total sugar content in soil. Multivariate analyses on C, N and organic matter composition showed the drilosphere of *A. longa* to be biochemically more similar to unoccupied than to *L. centralis* drilosphere. Although we were not able to sample enough *A. longa* burrows to probe species-specific effects on protists and nematodes, we found interactive effects of *L. centralis* presence and soil microhabitat (drilosphere vs bulk soil) on some protistan clades, while the soil nematode assemblage was more homogeneous.
Wettability and Hydrophobic-Hydrophilic Components of Humic Substances of Chernozem Densitometric Fractions

Evgeny Shein and Evgeny Milanovskiy

Moscow State University, Soil Science Faculty, Moscow, Russia

Water stability of the aggregate structure is directly related to the surface properties of elementary soil particles (ESP) in the solid phase of the soil. In case of high hydrophilicity of ESP, the water flows through the capillaries in the dry aggregate and leads to an increase of water pressure in the aggregate and its destruction. When ESP are hydrophobic, the adhesion is reduced as there is no attraction between the water molecules and the non-polar surface. Contact angle (CA) is used as a wettability characteristic value; it quantifies the physicochemical interactions at the liquid-solid interface (Letey et al., 1962). The purpose of this study was to link the densitometric fractions surface wettability with the hydrophobic and hydrophilic components of humus substances (HS) contained in these fractions. The samples were taken from the two horizons (10-15, 40-45 cm) of chernozem within an oak wind-proof forest strip without grass cover (Voronezh region, Russia). We used the procedure (Golchin et al., 1994) to obtain the density fractions of soil organic matter: occluded particulate organic matter (oPOM) with a density <1.6 g cm\(^{-3}\) (oPOM\(_{<1.6}\)); 1.6–1.8 g cm\(^{-3}\) (oPOM\(_{1.6-1.8}\)); 1.8–2.2 g cm\(^{-3}\) (oPOM\(_{1.8-2.2}\)) and mineral associated OM with a density >2.2 g cm\(^{-3}\). Total organic carbon (TOC) was obtained with CN analyzer (Vario EL, Elementar, Germany). Static CA were determined by means of the sessile drop method with the help of a digital goniometer (Drop Shape Analysis System, DSA100, Krüss, Germany). Using Octyl Sepharose CL-4B HS, isolated from Densitometry fractions (extraction by solution NaOH + Na\(_4\)P\(_2\)O\(_7\)), fractionated by hydrophobic interaction chromatography (HIC) at low pressure liquid chromatograph BioLogic LP (BioRad, USA). TOC content and C/N ratio of the fractions decreased along with the increase of their density (from 47-30% to 0.6% and from 28-25 to 8 respectively). At the same time the surface of the oPOM\(_{<1.6}\) was hydrophobic (CA 90\(^{\circ}\)) while the rest were hydrophilic (CA 59-50-33\(^{\circ}\)). HIC allows to physically divide a set of HS in extract into components (5 fractions), which differ in ability to participate in hydrophobic interactions with gel matrix. It was found that a decrease in CA of wetting of densitometric fractions was accompanied by an increase of the relative content of hydrophilic components of HS (fraction 1) and the reduction of hydrophobic compounds (fraction 4). The value of the CA was highly correlated with hydrophobic components (R\(^2\) = 0.93) content, but not with the hydrophilic HS. Hydrophobic components of soil HS are indigenous formations, spatially localized with humification products of organic material in situ within the aggregates (Shein and Milanovskiy, 2003). Our results indicate the heterogeneity of surface wettability of the solid phase components of soils, caused by heterogeneous distribution of hydrophilic and hydrophobic HS within the aggregates (Urbanek et al., 2007).

References


Consequences of Organic Matter Composition on PAH Accumulation in Soils from Industrial Areas

Bozena Smreczak, Aleksandra Ukalska-Jaruga, Agnieszka Klimkowicz-Pawlas and Barbara Maliszewska-Kordybach

Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy, Poland

Soils located in industrial areas may be contaminated with polycyclic aromatic hydrocarbons (PAHs). PAHs enter soils mainly with atmospheric precipitations. Majority of them are concentrated in the top layer of soils where they subject to different processes. Soil properties play an important role in the rate and the extent of those transformations. PAHs exhibit strong sorption affinity to soil organic matter (SOM) what influence the sequestration and aging processes. Recent studies indicate that SOM composition is the key factor governing the fate of PAHs in soils. Of particular importance is the presence of fractions exhibiting strong sorption properties like dissolved organic carbon (DOC), humic substances (HS) or black carbon (BC) which can limit PAH's bioavailability and solubility and thus effect its degradability and movement within soil profile. The aim of the study was to assess the relationship between SOM content and composition and PAH concentration in historically contaminated soils with regards to properties of contaminants. Soil samples (n=9) were collected from the upper horizon (0-30 cm) of soils situated in industrial Silesia Region (Poland), exposed for a few decades to PAHs emission sources. SOM analysis included determinations of: total organic carbon content - TOC (CN apparatus), DOC content (cold water extraction, 1h, 20°C), black carbon content (lost at ignition at 375°C and CN apparatus) and HS content (calculated as a difference between TOC and BC). The determinations of PAHs included analysis of sixteen individual hydrocarbons from US EPA list (GC-MS technique). The groups of compounds of different structure and molecular weight (2+3 rings, 4 rings and 5+6 rings) were distinguished. Soils exhibited high differences in the TOC content (19.6-167.2 g·kg⁻¹) and individual SOM fractions: DOC: 0.19-2.13 g·kg⁻¹; HS: 9.5-198.6 g·kg⁻¹ and BC: 1.1-45.3 g·kg⁻¹. Humic substances accounted for 73-98% of TOC while BC covers only 2-26%. The total PAHs concentrations varied from 0.7 to 224.1 mg kg⁻¹ and were dominated by lower molecular weight fractions (≤ 4 rings). All PAHs groups (2+3-rings, 4-rings and 5+6-rings) exhibited significant (p≥0.05) positive correlation with BC (r=0.91) with the strongest link corresponded to 5+6 ring hydrocarbons. No significant relationship with HS and DOC was observed. The results suggest black carbon fraction, deriving mainly from anthropogenic sources, as being the most responsible for the retention of PAHs in soils with particular regard to higher molecular weight compounds. Higher persistence of PAHs in soils with increased content of BC may reduce the risk of the movement of those contaminants within soil profile (no relation with DOC was observed). The other dependences may be observed in soils from uncontaminated areas with limited BC content and other quantitative and qualitative PAHs contamination.
Reactivity of Ferrihydrite-Organic Matter Complexes

Karin Eusterhues¹, Anke Hädrich², Julia Neidhardt², Kirsten Küsel² and Kai Uwe Totsche¹

¹Department of Hydrogeology, Friedrich Schiller University of Jena, Jena, Germany
²Institute of Ecology, Friedrich Schiller University of Jena, Jena, Germany

The association of organic matter with minerals strongly affects mineral surface properties such as solubility, charge and hydrophobicity. This will influence their reactivity towards nutrients and pollutants, the adsorption of new organic matter, and their interaction with microorganisms. We produced ferrihydrite-organic matter associations by adsorption and coprecipitation in laboratory experiments. As a surrogate for dissolved soil organic matter we used the water-extractable fraction of a Podzol forest-floor layer under spruce. Biodegradation experiments were carried out with an inoculum extracted from the podzol forest-floor under oxic conditions at pH 4.8 to quantify the mineralization of the adsorbed and coprecipitated organic matter. These experiments showed that the association with ferrihydrite stabilized the associated organic matter, but that differences in the degradability of adsorbed and coprecipitated organic matter were small. We therefore conclude that coprecipitation does not lead to a significant formation of microbial inaccessible organic matter domains. Microbial reduction experiments were performed using *Geobacter bremensis*. We observed that increasing amounts of associated OM led to decreasing initial reaction rates and a decreasing degree of dissolution. Reduction of coprecipitated ferrihydrites was faster than reduction of ferrihydrites with adsorbed OM. Our data demonstrate that the association with ferrihydrite can effectively stabilize labile polysaccharides against biodegradation. Vice versa, these polysaccharides may protect ferrihydrite from reduction by *Geobacter*-like bacteria.
Session 5: Quantitative Understanding of BGIs: Theoretical Concepts & Models to Explain Structure, Properties, & Functions of BGIs
Microbial Degradation of Propylene Glycol: Batch Experiment, Modelling Approach and Potential of Geophysical Methods for Monitoring

Annette Dathe¹, Perrine M. Fernandez¹, Lars R. Bakken¹, Johannes C.L. Meeussen², Esther Bloem³ and Helen K. French¹,³

¹Norwegian University of Life Sciences, Department of Environmental Sciences, 1432 Ås, Norway
²Nuclear Research and Consultancy Group, 1755 Petten, The Netherlands
³Bioforsk, Norwegian Institute for Agricultural and Environmental Research, Soil and Environment Division, 1432 Ås, Norway

De-icing chemicals are applied in large amounts at airports during winter conditions to keep the runways and aircrafts ice-free. At Gardermoen airport, Norway, most of the applied chemicals can be captured, but about 10 to 20 % infiltrate into the soil along the runways and during take-off. While the commonly used propylene glycol (PG) is easily degradable by local microbial communities, its biological oxygen demand is high, anoxic zones can develop and soluble Fe⁺² and Mn⁺² ions eventually can reach the groundwater. The objectives of this study are to quantify mechanisms which control the order of reduction processes in an unsaturated sandy soil, and to test whether measured redox potentials can help to determine underlying biogeochemical reactions. The microbial induced degradation of PG follows a redox-sequence in the subsurface, and in theory electrical signatures of these reactions can be measured with geophysical methods. However, the degradation is happening at the pore scale, and measurements take place at the centimeter to meter scale. To understand and quantify underlying biogeochemical reactions batch experiments were conducted under aerobic and anaerobic conditions. The results, in agreement with field observations, suggest that iron- and manganese reducing bacteria out-number denitrifying bacteria in this soil, because anoxic incubation with ample amounts of nitrate resulted in iron- and manganese-reduction while denitrification was insignificant. Inverse modelling of PG decay under aerobic conditions reveals that not only the commonly used redox reaction but biomass growth, decay and respiration have to be taken into account. With the calibrated model we are working towards a tool to quantify microbial induced redox reactions under different soil water saturations to account for seasonal water fluxes especially during snowmelt. Additionally, geophysical signatures can be simulated and thus contribute to building a framework of monitoring redox reactions by measuring the electrical conductivity or the self-potential in the field.
Trace metals speciation in soil systems are generally dominated by minerals, organic matters and biological components. In natural environment, these ingredients are “glued” together to form a heterogeneous complex and thus the surface properties of the composites differ dramatically from their individual ones. Understanding the speciation and distribution in mineral/organic matter/bacteria composites is of critical importance in predicting the fate and transport of trace metals in biogeochemical interface (BGI) (Huang et al., 2008; Song et al., 2009; Totsche et al., 2010). In the present study, potentiometric titration, batch adsorption and isothermal titration calorimetry (ITC) were employed to investigate Cd sorption behavior on complex systems contained montmorillonite, cell of Pseudomonas putida and humic acid. Five samples were studied, including pure Mont and P. putida, binary Mont-bacteria and Mont-HA composites, ternary Mont-bacteria-HA composites. Considerable difference in the shapes and positions of the potentiometric titration curves for the 5 samples indicated diverse surface acidity and proton binding behavior of these composites. The average buffering capacity for P. putida, over the pH range of 2.5 to 10 was 6.1mmol/g, while this value was 2.5-4.6mmol/g for the binary and ternary composites, and montmorillonite was the smallest (~1.9mmol/g). Cell of P. putida displayed the strongest affinity for Cd removal from the solution due to a great quantity of negative functional groups on bacteria surfaces. Enhanced Cd adsorption was observed for Mont-HA composites as compared to pure montmorillonite at studied pH demonstrated the formation of surface complexes (metal-ligand-mineral). However, the ternary Mont-bacteria-HA complex did not show higher sorption capability than Mont-bacteria, illustrating an interaction between humic acid and bacteria cell that may mask the adsorption sites. ITC results showed that sorption of Cd ions on Mont and Mont-HA complex were exothermic processes while that on bacteria, Mont-bacteria and Mont-bacteria-HA composites were endothermic reactions with enthalpy (ΔH) changes ranging from 5.48 to 13.09 kJ mol⁻¹. Larger entropy changes (32.65-71.49 J mol⁻¹K⁻¹) of Cd adsorption on bacteria, Mont-bacteria and Mont-bacteria-HA composites suggested the formation of inner-sphere Cd complexes. Results obtained from this study revealed the dominant role of bacteria in Cd distribution at the interface of mineral-organic matter-bacteria composites.

References
Compound-Specific Isotope Analyses: A New Angle to Tracing the Fate of Micropollutants at Biogeochemical Interfaces

Shiran Qiu, Sandra Reinnicke, Kathrin Schreglmann, Michael Maier, Armin H. Meyer and Martin Elsner

Institute of Groundwater Ecology, Helmholtz Zentrum München, Neuherberg, Germany

Processes at biogeochemical interfaces like sorption, transport and degradation are controlling factors for the fate of micropollutants in the environment. To better predict the respective contributions of each novel analytical approaches are needed. Within the SPP 1315, it was our objective to establish for the first time compound-specific isotope analysis for micropollutants of environmental concern. This method analyzes changes in isotope ratios ($^{13}$C/$^{12}$C; $^{15}$N/$^{14}$N) of organic compounds at natural abundances which enables to differentiate degradation processes from sorption or transport (Schmidt et al., 2004). In the course of the SPP1315 we optimized enrichment methods and subsequent GC-IRMS (gas chromatography isotope ratio mass spectrometry) analysis of important herbicides: atrazine (Meyer et al., 2008, Schreglmann et al., 2013), isoproturon (Penning and Elsner, 2007), dichlobenil, bentazon (Reinnicke et al., 2010) and phenoxy acids (Maier et al., 2013). In batch studies we could successfully link changes in $^{13}$C/$^{12}$C and $^{15}$N/$^{14}$N ratios to microbial degradation (Reinnicke et al., 2011; Penning et al., 2010) For atrazine in particular, we could even demonstrate the power of two-dimensional isotope plots to decipher different natural degradation pathways (Meyer and Elsner, 2013) (Figure 1). In a recent combined approach of enantiospecific gas chromatography–isotope ratio mass spectrometry (ESIA) and enantiomer analysis of phenoxy acids (Qiu et al., 2014), contrasting carbon isotope and enantiomer fractionation enabled distinction of bottlenecks in biodegradation on the mechanistic level (mass transfer in solution vs. uptake into the cell vs. enzymatic reaction). To match such insight on isotope fractionation during degradation, ongoing work targets changes in isotope ratios during sorption.

![Figure 1. Two dimensional C and N isotope plots reflect different natural degradation processes of atrazine. Blue line biotic hydrolysis and black line biotic oxidation.](image)

References


Hydrodynamic Parameter Estimation of 1D and 2D Axial Symmetric Transport Simulations and Consequences For the Reactive Transport

Johanna Lippmann-Pipke1, Christin Stuhlfauth1,2, Holger Lippold1, Johannes Kulenkampff3, Frieder Enzmann2 and Laurin Wissmeier3

1Institute of Resource Ecology, HZDR Research Site Leipzig, Germany
2Institute for Geosciences, Johannes Gutenberg University, Mainz, Germany
3AF Consult, Baden, Switzerland

With 1D and axial symmetric 2D finite element simulations of tracer transport in porous media columns, we conducted systematic studies of increasing heterogeneity on the resulting breakthrough curves (BTC). While preferential flow can still have comparably little effect on the BTC of non-reactive tracer substances, for strongly adsorbing tracer preferential flow can significantly shift the break-through towards earlier arrival times by reducing the reactive surface area. Motivation for conducting this systematic simulation study is our unique GeoPET method (Positron Emission Tomography) that allows the visualization of the spatio-temporal tracer distribution in geologic media (Richter et al., 2000; Gründig et al., 2007; Kulenkampff et al., 2008). The real complexity of thus directly observed flow fields is always surprising. Even for non-reactive tracers quantitative transport simulations typically remain a challenge due to the need for detailed knowledge of hydrodynamic parameter values in 3D with a certain critical spatial resolution. Here we show simulation results obtained by the COMSOL Multiphysics code coupled with PHREEQC (Wissmeier and Barry, 2011) and compare them with measurement results (BTC) from reactive transport (herbicide MCPA on goethite/sand). CD-MUSIC adsorption model parameter were obtained from Kersten et al., (2014). The underlying structural heterogeneity of the simulated column experiments reflects preferential flow along the column boundaries caused by locally elevated permeability in otherwise homogeneous sand packing as verified by the GeoPET images from both conservative and reactive tracer experiments.

References
Colloidal particles can facilitate the transfer through the vadose zone of adsorbed contaminants or be themselves contaminants (e.g. bacteria, viruses). Mechanisms leading to colloid retention have been thoroughly studied, essentially in homogeneous model soils (sand, glass beads). However, results of these studies cannot be transposed directly to undisturbed soils, when preferential flow occurs through a small number of macropores, bypassing most of the soil matrix. In these soils, colloid retention has received a scarce attention, and is still poorly understood and modeled. In a 2009 study, Cey et al. (2009) showed that particles were retained (i) in the first few centimeters below soil surface, (ii) at the macropore walls, and (iii) in the immediate vicinity of the macropores. The matrix potential gradient between active macropores and the neighboring soil matrix drives water redistribution from these macropores towards the matrix. We hypothesized that the retention pattern observed by Cey et al. (2009) is caused by this water redistribution. We tested this hypothesis and quantified the importance of this retention process performing successive and identical rainfalls onto undisturbed soil cores. To vary the water content of the matrix next to active macropores, rainfalls were separated by rain interruptions of increasing durations (5 to 1200 hours). The rainwater contained fluorescent microspheres dyed with a different fluorophore for each rainfall. Microsphere concentration in the effluents and the number fraction of these microspheres adsorbed to natural soil colloids were analyzed by flow cytometry. We found that during a rainfall occurring after a 5 hours pause, 45 % of the microspheres were retained in the core. This fraction increased with pause duration for the subsequent events until it became constant (70%) for rains occurring after interruptions longer than 350 hours. Between 0,2 and 1% of microspheres retained during rainfall n were recovered in the effluents of rainfall n+1, and 10 to 45% of them were adsorbed to natural soil particles; recovery and association to soil particles being inversely (respectively directly) correlated with pause duration before rain n. In this contribution, we will propose and discuss a retention mechanism compatible with these experimental results, as well as the requirements to implement it in a numerical colloid fate model. We will also discuss the benefits of flow cytometry to investigate colloid fate in soils.

Acknowledgement
This research was funded by the ANR 10 Blanc 605-Agriped project

Reference
Effect of Bacterial biofilms (Extracellular Polymeric Substances) in Geosorbents Mobility and Reactivity

Sneha Pradip Narvekar and Kai Uwe Totsche

Chair of Hydrogeology, Institute of Geosciences, Friedrich-Schiller-Universität Jena, Jena, Germany

Biofilms and their component are one of the important components of the soil, and also the soil organic matter pool. They impact various soil properties like soil architecture, mineral formations and dissociations etc. The aim of our work is to study the effect of biofilms on the colloidal transport of natural geosorbents like Fe- and Mn-oxhydroxides that can lead to lead to mobility and solubility of nutrients and pollutant. The mobility of these particles is mainly dependent on colloidal stability and aggregation of these particles, which in turn is affected by pH, ionic strength, and the presence ions. Biofilms and EPS can alter the physical and colloidal properties of geosorbents by redox effects or also by producing compounds like acids and alkalies. Biofilm and EPS may also interact with the porous material altering the transport of geosorbents. EPS and its components are known to form coating of sub μm spaced protein-rich and lipid-rich domains with iron oxide which will affect adsorption and co-precipitation (Liu et al., 2013). In this study we used column experiments to study the mobility of hematite nanoparticles through biofilm coated porous media columns. EPS coated porous media was also studied. The porous media was coated with Bacillus subtilis biofilm and with EPS extracted from, liquid cultures of Bacillus subtilis. The attachment efficiency of glass beads coated with biofilms decreased significantly from 2.103x10⁻³ to 5.36x10⁻³ on coating with biofilm. Hematite was colloidal stable and mobile in EPS and biofilm coated porous media, whereas uncoated porous media, hematite nanoparticles lose its colloidal stability and are deposited on the porous media. Also the zeta potential of hematite changes from positive values to negative values indicating coating of hematite nanoparticles with EPS. The reactivity of hematite particles to the porous medium is reduced due to the masking of the reactive surface sites on the porous media with EPS. Also the reactive site on hematite may be altered by EPS depositions. EPS also leads to remobilization of sorbed hematite. 8% of sorbed hematite was remobilized by EPS.

References
There have been various attempts to improve the quality and sorption characteristics of clays by modifying them with different techniques. One of common techniques in this regard is intercalation and pillaring. However, the interactions of the metals and pillared clays in the environment may differ from that predicted by laboratory experiments because of the presence of a variety of inorganic and especially organic ions in natural solutions. Adsorption of Pb in the absence or presence of low molecular organic acids with different functional groups: citric and lysine onto a Na-bentonite and Al-pillared bentonite at the increasing concentrations of the organic acids and various sequences of addition of the trace element and the organic substances was studied. Our data shows that Na form of bentonite is more effective sorbent for Pb than Al-pillared bentonite. During sorption experiments final pH increased sufficiently, but at high the metal concentration in lower extent that shows the presence of ion exchange mechanism. Adsorption of Pb by Na form of bentonite was strongly affected by citric acid. The amount of Pb fixed by Na form of bentonite decreased from 174 mmol kg⁻¹ in the absence of the organic ligand up to 18 mmol kg⁻¹ at simultaneous addition of citric acid and practically zero adsorption in the case of preliminary addition of the acid at acid/metal ratio 8/1. Citric acid slightly changed adsorption of Pb by Al-pillared bentonite. At adsorption of Pb on Na bentonite in the presence of citric acid added as mixture or preliminary pH decreased with increasing of citric acid concentrations. At adsorption by Al-pillared bentonite pH initially rise (up to molar ratio 2/1) and then decreased. However, pH changes practically don’t connect with Pb adsorption. Our data shows strong competition between Pb and citric anion for adsorption sites of Nabentonite and completely different mechanism of Pb and citric acid adsorption on the Al-pillared bentonite. During experiment with Al-pillared bentonite high amount of Al was released that shows not stable structure of the pillared material. Lysine is basic polar amino acid with isoelectric point (IEP) at 9.7. At pH below of IEP it has positive charge. However, when we add Pb and lysine simultaneously to Na bentonite and Al pillared bentonite it practically does not affect Pb adsorption at any lysine concentrations (except slight changes at highest rations) that shows their occupation of different sorption sites of the minerals. Lysine additions two hours before the metal decrease lead adsorption at ratio 1/1 and then slightly increase at ratio 8/1 for Al-pillared bentonite only. This decreasing may illustrate amount of sorption sites for nonspecific adsorption of the metal and organic ligand. Final pH does not depend from Pb doses (except R=8/1 for Na bentonite) and was lower in the case of first acid addition for both mineral So reactions between trace elements and natural and modified clay minerals in soils are affected by many factors, such as pH of soil solution, presence and concentration of organic ligands, including humic and fulvic acid, root exudates, microbial metabolites and nutrients.
Indications For an Alternative Sorption Mechanism For the Binding of Acetate to Goethite

Thomas Wach and Kai Uwe Totsche

Institute of Geosciences, Friedrich Schiller University of Jena, Jena, Germany

Sorption is one of the major processes that contribute to the "filter function" of soil. A thorough understanding of the mechanisms behind sorption is thereby the basis for design of appropriate, efficient and site-specific clean-up and remediation strategies. In this study we explore the interaction of the carboxylic moiety frequently with goethite, a secondary iron phase of primary importance in natural porous media like soil, sediments and aquifers. The carboxylic group is not only frequently found in a large number of natural and anthropogenic organic substances, but is known to compete with a large variety of inorganic pollutants including toxic metals, thereby affecting mobilization and transport. As model organic solute we use acetate as it persists both in protonated and deprotonated states at environmentally relevant pH-values. Sorption was explored with both batch and column techniques, thereby taking into account the important role of the solid/liquid ratio for the extent of sorption (Wang et al., 2009). We interpret our results and the pH-dependent adsorption of acetate to goethite as presented by Norén and Persson (2007) with a cooperative inner surface complexation of the acetate/acetic acid complex to different hydroxo-groups of the goethite. Based on these findings, a sorption model has been developed takes into account the S/L-ratio, also. We tested the performance of our model with the data of Norén and Persson (2007). We were also able to successfully describe the findings on the attachment of carbonate (Villalobos and Leckie, 2000; Rahnemaie et al., 2007) and MCPA (Iglesias et al., 2010), respectively, to the goethite surface. Based on that we hypothesize that both carbonates and MCPA adsorb according to the same adsorption mechanism. This implies that this adsorption mechanism may be general important for the adsorption of solutes with carboxylic moieties to surfaces providing hydroxo-groups, like manganese or aluminium oxides.

References:
List of Participants
ACHTENHAGEN, Jan
Department of Environmental Biotechnology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany

BABIN, Doreen
Institute for Epidemiology and Pathogen Diagnostics
Federal Research Center for Cultivated Plants-Julius Kühn Institute
Messeweg 11/12, 38104 Braunschweig
Germany

BACHMANN, Jörg
Institute of Soil Science Gottfried Wilhelm Leibniz University of Hannover
Herrenhäuser Str. 2, 30419 Hannover
Germany

BAVEYE, Philippe
Department of Civil and Environmental Engineering
Rensselaer Polytechnic Institute
110 8th street, New York Troy
United States

BERTMER, Marko
Institute for Experimental Physics
University of Leipzig
Linneweinstr. 5, 04103 Leipzig
Germany

BORISOVER, Mikhail
Institute of Soil, Water and Environmental Sciences
Agricultural Research Organization
The Volcani Center
POB 6, 50250 Bet Dagan
Israel

BRAX, Mathilde
Institute for Environmental Sciences
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

BUCHMANN, Christian
Institute for Environmental Sciences
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

CAI, Peng
Huazhong Agricultural University
430070 Wuhan
China

CARSTENS, Jannis Florian
Institute of Soil Science
Herrenhaeuser Str. 2, 30419 Hannover
Germany

CEPÁKOVÁ, Šárka
Institute of Soil Biology
Na Sádkách 7
370 05 České Budějovice
Czech Republic

CHENU, Claire
AgroParisTech
Av. de Brétignières
78850 Thiverval-Grignon
France

DALLA VALLE, Nicolas
Institute for Biogeochemistry
Max Planck Institute
Hand Knöll Str. 10, 07745 Jena
Germany

DALLINGER, Anja
Department of Ecological Microbiology
University of Bayreuth
Dr. Hans-Frisch-Str. 1-3, 95440 Bayreuth
Germany

DATHE, Annette
Department of Plant and Environmental Sciences
Norwegian University of Life Sciences
Ekebergveien 22, 1440 Drøbak
Norway
DECHESNE, Arnaud
Department of Environmental Engineering
Technical University of Denmark
Miljoevej, 2100 Kgs. Lyngby
Denmark

DIEHL, Dörte
Institute of Environmental Sciences
Environmental and Soil Chemistry
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

DITTERICH, Franziska
Institute of Soil Science and Land Evaluation
University of Hohenheim
Emil-Wolff-Str. 27, 70593 Stuttgart
Germany

DOETTERL, Sebastian
Department of Applied Analytical and Physical Chemistry
ISOFYS–Isotope Bioscience Laboratory
Coupure Links 653, 9000 Gent
Belgium

DU, Huihui
Huazhong Agricultural University
Shizishan No.1, Hongshan District, 430070 Wuhan
China

EICKHORST, Thilo
The Faculty of Biology/Chemistry
University of Bremen
Leobener Str./UFT 0530, 28359 Bremen
Germany

VAN ELSAS, Jan Dirk
Department of Microbial Ecology
University of Groningen
Nijenborgh 7, 9747 AG Groningen
The Netherlands

ELSNER, Martin
Institute of Groundwater Ecology
German Research Center for Environmental Health
Helmholtz Centre Munich
Ingolstädter Landstraße 1
85764 Neuherberg
Germany

FLAVEL, Richard
Department of Agronomy Soil Science
University New England
2351 Armidale, NSW
Australia

GHANEM, Nawras
Department of Environmental Microbiology
Helmholtz Center for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany

GÖBEL, Marc-Oliver
Institute of Soil Science
Wilhelm Leibniz University of Hannover
Herrenhäuser Str. 2, 30419 Hannover
Germany

HABERHAUER, Georg
Institute of Soil Research
University of Natural Resources and Life Sciences
Peter-Jordan-Str. 70, 1190 Vienna
Austria

HANZEL, Joanna
Department of Hydrogeology
Friedrich Schiller University of Jena
Burgweg 11, 07749 Jena
Germany

HARMS, Hauke
Department of Environmental Microbiology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany
HEISTER, Katja
Chair of Soil Science
Technische Universität München
Emil-Ramann-Str. 2, 85354 Freising-Weihenstephan
Germany

HEMKEMEYER, Michael
Johann Heinrich von Thünen Institute
Bundesallee 50, 38116 Braunschweig
Germany

HORN, Marcus A.
Department of Ecological Microbiology
University of Bayreuth
Dr. Hans-Frisch-Str. 1-3, 95440 Bayreuth
Germany

HUANG, Qiaoyun
Huazhong Agricultural University
Shizishan No.1, 430070 Wuhan
China

JÄGER, Alex
Institute for Experimental Physics
University of Leipzig
Linnestr. 5, 04103 Leipzig
Germany

JILKOVÁ, Veronika
Institute of Soil Biology AS CR
Na Sádkách 7
37005 České Budějovice
Czech Republic

KAISER, Michael
The Faculty of Organic Agricultural Sciences
University of Kassel
Nordbahnhofstr. 1a
37213 Witzenhausen, Germany

KALTENBACH, Robin
Institute of Environmental Sciences
Environmental and Soil Chemistry
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

KANDELER, Ellen
Institute of Soil Science and Land Evaluation
University of Hohenheim
Emil-Wolff-Str. 27, 70593 Stuttgart
Germany

KÄSTNER, Matthias
Department Environmental Biotechnology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany

KELLEHER, Brian
School of Chemical Science
Dublin City University
9 GLASNEVIN
Ireland

KHAN, Faisal
Institute of Geosciences
Johannes Gutenberg University
Becherweg 21, 55099 Mainz
Germany

KIESEL, Bärbel
Department of Environmental Microbiology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany

KOLB, Steffen
Department of Ecological Microbiology
University of Bayreuth
Dr.-Hans-Frisch-Str. 1-3 95448 Bayreuth
Germany

KOWALCHUCK, George
Department of Microbial Ecology
Netherlands Institute of Ecology
P.O.Box 50 6700 AB Wageningen
The Netherlands
KÖGEL-KNABNER, Ingrid
Chair of Soil Science
Technische Universität München
Am Hochanger 2, D-85350 Freising-Weihenstephan
Germany

KÖNIG, Claudia
Institute for Radioecology and Radiation Protection
Leibniz Universität Hannover, IRS
Herrenhäuser Str. 2, 30419 Hannover
Germany

KRÜGER, Jaane
Institute of Soil Science and Forest Nutrition
University of Freiburg
Bertodlstr. 17, 79085 Freiburg
Germany

KUBICKI, James
Department of Geosciences
Penn State
335 Deike Building
University Park, PA 16802
United States

KUČERIK, Jiří
Institute of Environmental Sciences
Environmental and Soil Chemistry
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

LANG, Friederike
Institute of Soil Science and Forest Nutrition
University of Freiburg
Bertodlstr. 17, 79085 Freiburg
Germany

LEHMANN, Robert
Department of Hydrogeology
Friedrich Schiller University of Jena
Wöllnitzer Str.7, 07749 Jena
Germany

LEHOUX, Alizee
INRA
228 route de l’aerodrome, CS 40 509
84914 Avignon cedex 9
France

LIPPMANN-PIPKE, Johanna
Institute of Radiochemistry
Reactive Transport Division
Research Centre Dresden-Rossendorf
Permoserstr. 15, 04318 Leipzig
Germany

LIU, Xing
Huazhong Agricultural University
Shizishan 1st, 430070 Wuhan
China

MA, Wenting
Huazhong Agriculture University
Shizishan 1st, 430070 Wuhan
China

MATTHIES, Michael
Institute for Environmental System Sciences
University of Osnabrück
Barbarastr. 12, 49076 Osnabrück
Germany

MICHEL, Eric
INRA
228 route de l’aerodrome, CS 40 509
84914 Avignon cedex 9
France

MILANOVSKIY, Evgeny
Lomonosov Moscow State University
Leninskie Gory, 119991 Moscow
Russian Federation

MILTNER, Anja
Department Environmental Biotechnology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany
MOGUSU, Emmanuel
Institute of Groundwater Ecology
German Research Center for Environmental Health
Helmholtz Centre Munich
Ingolstädter Landstraße 1
85764 Neuherberg
Germany

MUNCH, Jean Charles
Chair for Soil Ecology
Technische Universität München
Ingolstädter Landstr. 1
85758 Oberschleißheim
Germany

KUNHI MOUVENCHERY, Yamuna
Department of Chemistry
NSS College Manjeri
(University of Calicut)
Malappuram, Kerala
India

NANNIPIERI, Paolo
Department of Plant, Soil and Environmental Sciences
University of Florence
28 Piazzale delle Cascine, 50144 Florence
Italy

NAPOLI, Rosario
CRA-Research Centre of the Soil-Plant System
Via della Navicella 2-4, 00184 Roma
Italy

NARR, Anja
Department of Environmental Microbiology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany

NARVEKAR, Sneha
Department of Hydrogeology
Friedrich Schiller University of Jena
Wöllnitzer Str.7, 07749 Jena, Germany

NIESSNER, Reinhard
Institute for Hydrochemistry
Technische Universität München
Marchioninistr. 17, 81377 Munich
Germany

NUNAN, Naoise
UMR 7618 CNRS - ENS PARADISI Paola
46 rue d'Ulm, 75005 PARIS
France

ONDRIUCH, Pavel
Institute of Environmental Sciences
Environmental and Soil Chemistry
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

OOSTENBRINK, Chris
Institute of Molecular Modeling and Simulation (MMS)
Muthgasse 18, 1190 Wien
Austria

OR, Dani
Soil and Terrestrial Environmental Physics
ETH Zürich
Universitätstrasse 16
CHN F 29.1, 8092 Zürich
Switzerland

O'Rourke, Sharon
US dy Department of Environment and Agriculture
University of Sydney
Rm 116A, Level 1, Biomedical Building
1 Central Avenue, ATP, Eveleigh
NSW 2006 Sydney
Australia

OSWALD, Sascha
Institute of Earth and Environmental Science
University of Potsdam
Karl-Liebknecht-Str. 24-25
14476 Potsdam
Germany
OTTO, Sally
Department of Environmental Microbiology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr. 15, 04318 Leipzig
Germany

PAGEL, Holger
Institute of Soil Science and Land Evaluation
University of Hohenheim
Emil-Wolff-Str. 27, 70593 Stuttgart
Germany

PEDERSEN, Lasse Lu
Technical University of Denmark
Majkøvej 113, building 115
2800 Kgs. Lyngby
Denmark

PERELOMOV, Leonid
Tula State University
Lenin avenue, 92, 300012 Tula
Russian Federation

PINZARI, Flavia
Consiglio per la Ricerca e la sperimentazione in Agricoltura Centro di Ricerca per lo studio delle relazioni tra pianta e suolo
CRARPS
Via della Navicella 2-4, 00184 Rome
Italy

POHL, Lydia
Department of Hydrogeology
Friedrich Schiller Universität Jena
Wöllnitzer Straße 7, 07749 Jena
Germany

POLL, Christian
Institute of Soil Science and Land Evaluation
University of Hohenheim
Emil-Wolff-Str. 27, 70593 Stuttgart
Germany

PRONK, J. Geertje
Chair of Soil Science
Technische Universität München
Emil-Ramann-Straße 2, 85354 Freising-Weihenstephan
Germany

PROSSER, James
Institute of Biological and Environmental Sciences
University of Aberdeen
St Machar Drive, Aberdeen AB24 2UU
United Kingdom

RAYNAUD, Xavier
Sorbonne Universités, UPMC-Paris6
46 rue d’Ulm, 75230 Paris
France

RAZAVIDEZFULY, Baharsadat
Department of Agricultural Soil Science
Georg August University Göttingen
Büsgenweg 2, 37077 Göttingen
Germany

REICHEL, Katharina
Department of Hydrogeology
Friedrich Schiller University of Jena
Wößnitz Str. 7, 07749 Jena
Germany

RIEDE, Beate
Institute for Radioecology and Radiation Protection
Leibniz Universität Hannover-IRS
Herrenhäuser Str. 2, 30419 Hannover
Germany

RITSCHEL, Thomas
Department of Hydrogeology
Friedrich Schiller University of Jena
Wöllnitzer Str. 7, 07749 Jena
Germany

RITZ, Karl
Environmental Science and Technology Department
School of Applied Sciences
Cranfield University National Soil Resources Institute
Cranfield, Bedfordshire MK 34 Oal
United Kingdom

RUDOLPH-MOHR, Nicole
Institute of Earth and Environmental Science
University of Potsdam
Karl-Liebknecht-Str. 24-25
14476 Potsdam
Germany

SANAULLAH, Muhammad
Institute of Soil Science
Georg-August-Universität Göttingen
Büsgenweg 2, 37077 Göttingen
Germany

SCHAAF, Wolfgang
BTU Cottbus-Senftenberg
Konrad-Wachsmann-Allee 6
03046 Cottbus
Germany

SCHAUermann, Gabriele E.
Institute for Environmental Sciences
Environmental and Soil Chemistry
University of Koblenz-Landau
Fortstr. 7, 76829 Landau
Germany

SCHÄFER, Sabine
Department of Hydrogeology
Friedrich Schiller University of Jena
Wöllnitzer Str. 7, 07749 Jena
Germany

SCHÄFFER, Andreas
Institute for Environmental Research (Biology V)
Environmental Biology and Chemodynamics
RWTH Aachen University
Worringerweg 1, 52074 Aachen
Germany

SCHMIDT, Sonja
Abertay University
40 Bell Street

DD1 1HG Dundee, United Kingdom
SCHMIDT, Olaf
University College Dublin
School of Agriculture and Food Science
Dublin 4, Dublin
Ireland

SCHLOTER, Michael
Chair for Soil Ecology
Technische Universität München
Ingolstädter Landstr. 1
85758 Oberschleißheim
Germany

SCHURING, Christian
Technische Universität München
WTT/Environmental Biotechnology
Emil-Ramann-Str. 2, 85354 Freising-Weihenstephan
Germany

SCHWEIGERT, Michael
Department Environmental Biotechnology
Helmholtz-Centre for Environmental Research
Permosserstr. 15, 04318 Leipzig
Germany

SHEIN, Evgeny
Lomonosov Moscow State University
Leninskie Gory
119991 Moscow
Russian Federation

SENESI, Nicola
Department of Agroforestal and Environmental Biology and Chemistry
University of Bari, 70126 Bari
Italy

SMALLA, K.
Institute for Epidemiology and Pathogen Diagnostics
Federal Research Center for Cultivated Plants-Julius Kühn Institute
Messeweg 11/12, 38104 Braunschweig
Germany
WATTEAU, Françoise
Laboratoire Sols et Environnement
2 avenue de la forêt de Haye TSA 40602
54518 Vandœuville-les- Nancy, France

WICK, Lukas, Y.
Department of Environmental Microbiology
Helmholtz Centre for Environmental Research-UFZ
Permoserstr.15, 04318 Leipzig
Germany

WIECZOREK, Adam
Department of Ecological Microbiology
University of Bayreuth
Dr.-Hans-Frisch-Str. 1-3, 95448 Bayreuth
Germany

WOCH, Susanne K.
Institute of Soil Science
Wilhelm Leibniz University of Hannover
Herrenhäuser Str. 2, 30419 Hannover
Germany

WUTZLER, Thomas
Institute for Biogeochemistry
Max Planck Institute
Hand Knöll Str. 10, 07745 Jena
Germany

VOELKNER, Amrei
Institute of Plant Nutrition and Soil Science
Hermann-Rodewald-Str. 2, 24118 Kiel
Germany

VOGEL, Hans-Jörg
Department of Soil Physics
Helmholtz Centre for Environmental Research-UFZ
Theodor-Lieser-Straße 4 06120 Halle (Saale)
Germany

YOUNG, Iain M.
School of Environmental and Rural Sciences Natural Resources
University of New England
Bilduing W55 Armidale NSW 2351 Australia

ZÜHLKE, Sebastian
Institute of Environmental Research Faculty of Chemistry (INFU)
Dortmund University of Technology
Otto-Hahn-Str. 6, 44227 Dortmund
Germany