X-ray microtomographic investigation of soil aggregate microbial and pore structure

K. M. Kemner1*, S. O’Brien2, M. D. Whiteside3, D. Sholto-Douglas4, O. Antipova1, V. Bailey5, M. I. Boyanov6, A. Dohnalkova5, D. Gursoy1, L. Kovarik5, B. Lai1, C. Roehrig1, S. Vogt1, P. Shevchenko1, F. Marin1


kemner@anl.gov

Soil is a highly complex network of pore spaces, minerals, and organic matter (e.g., roots, fungi, and bacteria), making it physically heterogeneous over nano- to macro-scales. Such complexity arises from feedbacks between physical processes and biological activity that generate a dynamic, self-organizing 3D complex. Since we first demonstrated the utility of synchrotron-based transmission tomography to image internal soil aggregate structure [Kemner et al., 1998*], we and many other researchers have made use of and have advanced the application of this technique. However, our understanding of how microbes and microbial metabolism are distributed throughout soil aggregates is limited, because no technique is available to image the soil pore network and the life that inhabits it. High energy x-ray transmission microtomography can provide highly detailed 3D renderings of thick and opaque soil structure but cannot easily distinguish cells from other electron-light material such as air or water. However, the use of CdSe quantum dots (QDs) as a reporter of bacterial presence enables us to overcome this constraint, instilling bacterial cells with enough contrast to detect them and their metabolic functions in their opaque soil habitat, with hard x-rays capable of penetrating 3D soil structures at high resolution. Previous transmission tomographic imaging of soil aggregates with high energy synchrotron x-rays has demonstrated ~700 X 700 X 700 nm³ voxel spatial resolution. These and recent results from tomographic x-ray fluorescence imaging of bacterial distributions within soil aggregates to determine rates of microbial colonization of the soil aggregate will be presented. A discussion of the critical role to be played by the upgrade of the Advanced Photon Source (APS-U) for 100-1000X increases in hard x-ray brilliance will also be presented.