Biogeochemical Transformations at Critical Interfaces Science Focus Area: An Overview

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Subsurface Biogeochemical Research Program: ORNL Mercury SFA (PI: E.M. Pierce)

After making substantial progress over the past 6 years in understanding the processes that govern mercury transformation in contaminated systems, the ORNL SFA program is poised to make new transformational advances in mercury research and, more broadly, subsurface biogeochemistry in the program's subsequent phase. This next phase seeks to address the following science challenge and goal:

- **9-Year Science Challenge:** *Determine the coupled hydrobiogeochemical processes that control mercury fate and transformation in low-order freshwater stream systems* and
- **9-Year Science Goal:** *Process-rich predictive capability that integrates field, laboratory, and modeling studies of mercury fate and transformation dynamics across broad spatiotemporal scales in low-order streams*.

Low-order freshwater streams, such as EFPC (the project's representative use case), constitute nearly 90% of the total stream length in the United States and are the most frequently occurring stream type (>85%; Pierson et al. 2008). Furthermore, because of their low hydraulic radius (cross-sectional area and wetted perimeter) and low average water velocity, these stream systems have high water–sediment contact times, which promote in-stream biogeochemical cycling (Haggerty, Wondzell, and Johnson 2002). Numerous studies indicate that low-order streams play a dominant role in the flow, biogeochemistry, and water quality of downstream higher-order reaches (Alexander et al. 2007; Bernhardt et al. 2003; Waldron et al. 2009; Milliman and Syvitski 1992; Jeong et al. 2012). Additionally, these streams play a prominent role at the terrestrial-aquatic interface because they represent the first aquatic environment encountered by terrestrially derived materials (solutes and particles).

Developing a predictive understanding of mercury and trace metal transport and fate in environmental systems, such as terrestrial surface and subsurface ecosystems, is a formidable challenge that requires deciphering complex processes (i.e., physical, chemical, and biological), deconvoluting how these processes interact with one another, and understanding the factors that control system response over broad spatiotemporal scales.

Exchange and feedback processes at critical interfaces are central for determining fluxes, stocks, and transformation rates of key constituents that control mercury speciation, distribution, and bioavailability, such as oxygen, nutrients, and dissolved organic matter (DOM). Therefore, over the next 3 years, the ORNL SFA program will focus on: *Determining the fundamental mechanisms and environmental factors that control mercury biogeochemical transformations at key interfaces in terrestrial and aquatic ecosystems.* The research outlined in **Phase I** of the ORNL SFA plan comprises collaborative and complementary research activities that support four research thrusts: Ecosystem features influencing mercury transformation, Biogeochemical mechanisms controlling mercury uptake and methylation, Microbial community functions and geochemical influences on mercury transformations, and Molecular structure, dynamics, and mechanisms of mercury transport and transformations.

This presentation will summarize progress made to-date, which represents the initial 9-month period following the program's triennial peer review (April 2015) and acceptance of a renewal science plan, which occurred in August 2015 by the U.S. Department of Energy's (DOE) Office of Biological and Environmental Research.