Mercury Challenges in the Environment: A Technical Summit

U. S. Department of Energy
Office of Groundwater and Soil Remediation

Background

The U.S. Department of Energy (DOE) is interested in mercury in the environment because this element was used extensively at the Y-12 National Security Complex in Oak Ridge, TN during the 1950s and early 1960s as part of a lithium separation process. During this period, large quantities of mercury were released to the environment, resulting in the contamination of buildings, soils, sediments, groundwater, and surface water. The behavior of mercury in the environment is complex and remediation presents major challenges, not only at Oak Ridge but at sites around the world.

The DOE "Integrated Facilities Disposition Project" (IFDP) at Y-12 includes the deactivation and decommissioning of buildings as well as associated environmental remediation activities. IFDP plans were examined in 2008 by an External Technical Review (ETR) panel consisting of a facilities team and a mercury team. The ETR final report identified the mercury team's observations and recommendations concerning the remediation of mercury-contaminated environmental media. Key observations include the following:

- While mercury source reduction is a regulatory driver, no direct linkage exists between mercury source reduction and emerging stream protection endpoints such as mercury levels in fish tissue.
- The technical basis and defensibility of waste characterization and segregation and technology selection should be a primary focus of future IFDP planning.
- Estimates of mercury-contaminated materials will likely increase as buildings are decontaminated and decommissioned.

Mercury Summit

DOE has planned a technical summit to facilitate information exchange on mercury-related environmental issues and potential remediation approaches that have applicability at Oak Ridge and other sites. This meeting will be held at Vanderbilt University in October 2009. Participants will include representatives from government, academia, industry, state and federal regulatory agencies, and other stakeholders. Development of the meeting is guided by a steering committee that includes Skip Chamberlain (DOE Office of Environmental Management), Jim Clarke (Vanderbilt/CRESP), Rich Landis (DuPont), Brian Looney (Savannah River National Laboratory), and Dawn Kaback (AMEC/Geomatrix).

The Mercury Summit will focus on best practices for mercury characterization, site assessment, and remediation, as well as on the development of research priorities related to mercury in the environment. Presentations will be given by experts and practitioners in areas including:

- mercury-related regulatory issues
- Oak Ridge site needs and remediation technology evaluation and planning
- modeling and characterization of potential mercury source areas and associated fluxes
- mercury biogeochemistry and characterization in environmental media

- new technologies for mercury removal or control, including soil and sediment amendments
- assessment of toxicity and ecological risk for mercury-contaminated media
- remediation case studies from a variety of mercury-contaminated sites.

Mercury Summit products

The primary product of the meeting will be a compendium organized by topic. Each topic area will include a summary that identifies data gaps, research needs and priorities, and the major conclusions and recommendations derived from presentations and discussions held during the meeting. The compendium will also include presentation materials provided by speakers at the Mercury Summit. This document will be prepared in the weeks following the meeting and distributed to the participants. The ultimate goal of the meeting is the prioritized identification of research needs and associated budget requirements; improved communication among research teams, site personnel, and regulators; and potentially the development of a partnership that includes representatives from DOE, regulatory agencies, academia, and industry to facilitate addressing the needs identified during the meeting. It is expected that the Mercury Summit will lead to follow-up meetings that will foster continued communication, collaboration, technology development and transfer, and identification of emerging needs in the area of environmental mercury-related research.

Mercury Challenges in the Environment: A Technical Summit

Meeting location:
Vanderbilt University
Featheringill Hall
Jacobs Believed in Me Auditorium
400 24th Avenue South
Nashville, TN 37212

Thursday, October 22, 2009

7:15 – 8:00	Continental breakfast outside the auditorium. *NOTE TO PRESENTERS:* Please provide an electronic copy of your presentation to the meeting coordinators during the breakfast or lunch period before your talk.

Topic 1. DOE's Groundwater and Soil Remediation program and overview of Oak Ridge mercury issues
Host: Dave Kosson or Chuck Powers

8:00 – 8:10	*Dave Kosson* or *Chuck Powers* (Vanderbilt University) Welcome from CRESP
8:10 – 8:25	*Skip Chamberlain* (U.S. Dept. of Energy, Office of Groundwater and Soil Remediation) Introduction to the Mercury Summit and overview of DOE's groundwater and soil remediation program
8:25 – 8:45	*Ralph Skinner* (DOE Oak Ridge Operations) "The Oak Ridge Cleanup Program"
8:45 – 9:05	*Elizabeth Phillips* (DOE Oak Ridge Operations) "Goals of the Y-12 Mercury Remediation Strategy"
9:05 – 9:15	Q & A

Topic 2. Regulatory and public issues related to mercury
Host: Jim Clarke

9:15 – 9:35	*Katherine (Katie) Sciera* (USEPA Region 4, Water Protection Division) "EPA's Methylmercury Water Quality Criterion and Implementation"
9:35 – 9:55	*Bob Alexander* (Tennessee Dept. of Environment and Conservation, TDEC) "Regulatory and Public Issues Related to Mercury"
9:55 – 10:20	Q & A and short break

Topic 3. Oak Ridge Reservation site history, regulatory drivers, and remediation history
Host: Brian Looney

10:20 – 10:40 *Scott Brooks* (Oak Ridge National Laboratory, ORNL)
"Brief History of Mercury Use at the Oak Ridge Y-12 Plant"

10:40 – 11:00 *Mark Peterson* (ORNL)
"Mercury in Fish: Status Report for the Oak Ridge Reservation"

11:00 – 11:20 *John Kubarewicz* (Bechtel Jacobs/RSI)
"Upper East Fork Poplar Creek Past and Planned CERCLA Remediation"

11:20 – 11:40 *David Lind* (B&W Y-12)
"Y-12 Plant Storm System Remediation for Reducing Mercury Flux into East Fork Poplar Creek"

11:40 – 12:00 Q & A

Topic 4. Lunch and a featured speaker
Host: Skip Chamberlain

12:00-12:40 Lunch served

12:40 – 1:20 *Cyndi Gilmour* (Smithsonian Environmental Research Center)
"Biogeochemical Controls on Methylmercury Production"

Topic 5. Overview of DuPont's mercury research and remediation program
Host: Rich Landis

1:20 – 1:50 *Nancy Grosso* (DuPont)
"South River Science Team: Remedial Options Program for Mercury in the South River, Virginia"

Topic 6. Other mercury case studies
Host: Rich Landis

1:50 – 2:40 *Ralph Turner* (RT Geosciences, Inc.)
"Nature and Effectiveness of Soil and Groundwater Remediation at a Large Mercury-Contaminated Site"

2:40 – 3:00 Q & A and short break

Topic 7. Mercury biogeochemistry and environmental behavior
Host: Dawn Kaback

3:00 – 3:20 *Baohua Gu* (ORNL)
"A Comprehensive Study of the Biogeochemical and Molecular Mechanisms of Mercury Transformation at a Contaminated Site in Oak Ridge, Tennessee, USA."

3:20 – 3:50 *Gary Gill* (Battelle Marine Sciences Laboratory)
"Determination of the Sediment-Water Exchange of Mercury and Monomethyl Mercury: Approaches, Limitations and Observations"

3:50 – 4:10 Q & A and discussion of research needs and priorities

Topic 8. Mercury toxicity and ecological risk assessment

Host: Jim Clarke

4:10 – 4:30 *Yi Su* (Mississippi State University)
"Mercury Uptake, Phytotoxicity and Field Sample Analysis"

4:30 – 4:50 *Joanna Burger* (Rutgers University) and *Michael Gochfeld* (N.J. School of Medicine and Dentistry)
"Ecological Implications of Mercury Exposure"

4:50 – 5:30 Group discussion of ecological risk, led by Joanna Burger and Michael Gochfeld

Day 1 closing remarks

5:30 *Jim Clarke*

Friday, October 23, 2009

7:15 – 8:00 Continental breakfast outside the auditorium.

NOTE TO PRESENTERS: Please provide an electronic copy of your presentation to the meeting coordinators during the breakfast or lunch period before your talk.

Topic 9. Site conceptual model for mercury at Y-12 National Security Complex

Host: Skip Chamberlain

8:00 – 8:30 *Brian Looney* (Savannah River National Laboratory, SRNL)
"Through a Looking Glass: Conceptual Models of Mercury at a Complex Real-World Site"

Topic 10. Modeling mercury in watersheds and the subsurface

Host: Brian Looney

8:30 – 8:50 *Dave Watson* (ORNL)
"Overview of ORNL's Mercury-Related Modeling Program: A Systems Analysis Approach"

8:50 – 9:10 *Georgio Tachiev* (Florida International University)
"Integrated Flow and Transport Model of East Fork Poplar Creek for Evaluation of Mercury Remediation Alternatives"

9:10 – 9:30 *Reed Harris* (Reed Harris Environmental, Ltd.)
"Modeling Mercury Cycling and Bioaccumulation in Aquatic Systems: An Update"

9:30 – 9:45 Q & A

9:45 – 10:00 Break

Topic 11. Mercury characterization for sites, soils, and wastes
Host: Brian Looney

10:00 – 10:20 *Carol Eddy-Dilek* (SRNL)
"Development of a Direct Push/Membrane Interface Probe Technique for Rapid Characterization of Mercury-Contaminated Sediments"

10:20 – 10:40 *David Kosson* (Vanderbilt University)
"Draft EPA Methods for Alternative Assessment of Leaching of Solid Materials"

10:40 – 11:00 *Fengxiang X. Han* (Mississippi State University)
"Mercury Speciation, Bioavailability and Characterization of Contaminated Soils"

11:00 – 11:20 Q & A and discussion of technology development needs

Topic 12. Mercury remediation technologies, part 1
Host: Rich Landis

11:20 – 11:40 *Brian Looney* (SRNL)
"Mercury Treatment Technologies: 2007 Baseline"

11:40 – 12:00 *George Southworth* (ORNL)
"Flow Manipulation and Chemical Reduction: Air Stripping to Lessen Mercury Export from the Oak Ridge Y-12 Complex"

12:00 – 12:20 *Paul Kalb* (Brookhaven National Laboratory)
"The Mercury Treatment Challenge: Returning a Toxic Material Back to Its Roots"

Topic 13. Lunch and a featured speaker
Host: Skip Chamberlain

12:20 – 1:00 Lunch served

1:00 – 1:40 *Dave Krabbenhoft* (U.S. Geological Survey, USGS)
"Strategies for Reducing Net Methylmercury Formation in the Environment"

Topic 14. Mercury remediation technologies, part 2
Host: Dawn Kaback

1:40 – 2:00 *Carol Ptacek* (University of Waterloo)
"Investigations of Stabilization Methods for Mercury-Contaminated Sediments"

2:00 – 2:20 *Shas Mattigod* (Pacific Northwest National Laboratory)
"SAMMS Technology for Effective Removal of Mercury from Aqueous and Non-aqueous Wastes"

2:20 – 2:40 *Upal Ghosh* (University of Maryland-Baltimore County)
"Low-impact Delivery System for In Situ Treatment of Sediments Contaminated with Methylmercury"

2:40 – 3:00 *Ganesh Skandan* (NEI Corp.)
"Nanoscale Treatment Media for Efficient Mercury Remediation"

3:00 – 3:20 *Zhong Xiong* (AMEC Geomatrix)
"An Innovative Nanotechnology for In Situ Mercury Immobilization"

3:20 – 3:35 Q & A

3:35 – 3:45 Break

Topic 15: Group discussion led by Steering Committee panel

3:45 – 5:00 *Skip Chamberlain* (DOE EM), *Jim Clarke* (Vanderbilt/CRESP), *Rich Landis* (DuPont), *Brian Looney* (Savannah River National Laboratory), *Dawn Kaback* (AMEC/Geomatrix)

- Discussion of research and technology development needs for remediation
- Observations, other research needs, future interactions with regulatory authorities

Adjourn general meeting

5:00 *Jim Clarke*

Topic 1. DOE's groundwater and soil remediation program and overview of Oak Ridge mercury issues

The Oak Ridge Cleanup Program

Ralph Skinner
U.S. Dept. of Energy, Oak Ridge, TN

The Oak Ridge Cleanup Program has been effective for 20 years at advancing the cleanup state on the Oak Ridge Reservation (ORR). In partnership with our stakeholders, both local citizens and regulatory agencies, Oak Ridge Environmental Management has completed several noteworthy projects on the ORR at all three major plant sites, including the East Tennessee Technology Park (ETTP, the former K-25 Gaseous Diffusion Plant), Oak Ridge National Laboratory, and the Y-12 National Security Complex. These projects have included significant legacy material and equipment removal projects at ETTP, involving the old former GDP buildings (K-29, 31, and 33), and now the K-25 Building D&D project; significant risk reduction at ORNL's Melton Valley Watershed cleanup project; the Legacy Waste Disposition Project; the DUF6 Cylinder Disposition Project; and the Molten Salt Reactor Experiment defueling project. With the December 2008 approval of Critical Decision 1 for an integrated cleanup program for significant additional excess facilities to transfer to EM in the next 10 years, and with the acceleration of several projects with ARRA funding, Oak Ridge looks to incorporate into its baseline the remaining cleanup scope in the future.

RALPH SKINNER works for the U.S. Department of Energy's Office of Environmental Management as Deputy Federal Project Director for Y-12 Projects at the Oak Ridge Office. He has been part of Oak Ridge Environmental Management for most of its existence in Oak Ridge. He served as a Project Manager on the Integrated Facilities Disposition Project during the CD-1 planning and preparation phase. He was the DOE Project Manager for the ORNL Melton Valley Closure Project and also served as Project Manager during CERCLA planning and decision-making for the Melton Valley Project. Mr. Skinner has previous experience in waste management line item construction projects at both Oak Ridge National Laboratory and the Y-12 National Security Complex, and 16 years of experience in DOE waste management, environmental restoration, and D&D projects. Prior to his service at DOE, he was a project manager for 14 years at the Tennessee Valley Authority, with various responsibilities in TVA's electrical power generation program. Mr. Skinner earned a Bachelor's degree in engineering from the University of Alabama.

Goals of the Y-12 Mercury Remediation Strategy

Elizabeth Phillips
U.S. Department of Energy, Oak Ridge Operations

Large amounts of mercury were used to make nuclear weapons at the Y-12 National Security Complex in Oak Ridge, TN. As a consequence of the historical use of mercury, two million pounds of mercury are unaccounted for at Y-12. It is located in soils, sediments, storm sewers and old process buildings. The risk that mercury poses is mainly to the fish in Upper East Fork Poplar Creek (UEFPC) from methylmercury. DOE has two signed Interim Records of Decision (RODs) that prescribe actions to be taken under CERCLA to clean up the mercury-contaminated areas. Since those RODs have been signed, new scope has been added to the existing Environmental Remediation Scope by the Integrated Facilities Disposition Project (IFDP). Some of that new scope is in the Former Mercury Use Area at Y-12. The addition of the new scope creates an opportunity to perform a more comprehensive and less "surgical" cleanup as prescribed in the existing RODs. The DOE Office of Science has also funded a multi-million dollar study to understand the biological mechanisms of mercury methylation. The study is progressing in parallel with IFDP planning activities and may lead to important findings to consider while planning a remediation project of this complexity and magnitude. A Mercury Remediation Strategy (Strategy) being developed by DOE Environmental Management (EM) will link the various actions that are being taken and will serve as the integrative planning tool for successful execution of the EM mercury cleanup. The Strategy is a comprehensive approach for remediation of mercury contamination at the UEFPC watershed to facilitate planned remedial actions identified in the RODs and to allow compliance with water quality regulations during and after decommissioning and deactivation of unneeded facilities.

ELIZABETH PHILLIPS has over 29 years of experience in the environmental field as a program manager, technology developer, and lead scientist for the United States Department of Energy (DOE) and the private sector. At DOE, where she has worked for 18 years, Ms. Phillips has held many positions, including Dense Non Aqueous Phase Liquids Product Line Manager for the Subsurface Contaminants Focus Area. She has been working primarily in the area of Technology Development since 1995. Present responsibilities include the mercury remediation at Y-12 and technology development planning for the IFDP. Prior to joining DOE, Elizabeth worked as a private mining consultant, regulator for the State of Tennessee, and government contractor with Martin Marietta Energy Systems. Ms. Phillips graduated from Vanderbilt University with a B.S. in Geology. She received her M.S. in Environmental Engineering in 1999 from Kennedy-Western University. In her spare time, she is a full-time soccer mom to two goalies, President of the local Chapter of Women in Nuclear Engineering, Science Club school champion for Bearden Elementary School, and advocate for exposing young people to science in a way that makes it cool and fun.

Topic 2. Regulatory and public issues related to mercury

EPA's Methylmercury Water Quality Criterion and Implementation

Katherine Sciera
USEPA Region 4, Water Protection Division, Atlanta, GA

Water quality assessments have shown that there are fish consumption advisories for mercury in fish for 883,000 river miles and 14.2 million lake acres, in 48 states and 1 territory. Based on recommendations by EPA's Science Advisory Board, EPA recommended a new fish tissue-based criterion in 2001. Currently, there is draft implementation guidance by EPA, which provides technical assistance to states and authorized tribes as they develop their own water quality standards for methylmercury. The guidance presents the recommended implementation approach for standards, monitoring, total maximum daily loads (TMDLs), and National Pollutant Discharge Elimination System (NPDES) permitting.

KATHERINE SCIERA, Ph.D., is a TMDL coordinator in the Water Protection Division at EPA Region 4 in Atlanta, Georgia. She completed her Bachelor's degree in Environmental Science at Purdue University and continued on to a Master's degree in Environmental Toxicology at Clemson University. She recently earned her Ph.D. in Environmental Toxicology at Clemson University, where her research focused on quantifying the effects of land use and urbanization on water quality. Previously, she had worked at EPA Region 6 in Dallas, Texas as an ecological risk assessor in the Superfund program. Her expertise includes ecological risk assessment, aquatic toxicology, and land use impacts on water quality.

Regulatory and Public Issues Related to Mercury

Bob Alexander
Tennessee Department of Environment and Conservation (TDEC)

Under the Water Quality Control Act, Tennessee's water quality criteria and stream use classifications establish in-stream concentrations for total mercury in the water column. Tennessee's 2008 303(d) report identified thirty stream segments with documented effects from mercury, most from atmospheric deposition. Three streams are known to be affected by mercury point source discharges, most notably East Fork Poplar Creek near Oak Ridge. Tennessee's regulatory approach through the NPDES permitting program will use EPA's 2009 methylmercury guidance for determination of water column concentrations of total mercury necessary to meet the EPA fish tissue guidelines. This approach is still under development, in light of Tennessee's consideration of a fish tissue-based mercury standard.

BOB ALEXANDER serves as a Permit Writer in the Tennessee Division of Water Pollution Control, with specific responsibility for the USDOE Oak Ridge permit renewals at Oak Ridge National Laboratory (ORNL), East Tennessee Technology Park (ETTP), and Y-12. His recent work on permit renewals for these major facilities have required interaction with CERCLA Core Teams and close coordination with the TDEC Division of DOE Oversight. A native of Roane County, TN, Bob graduated as a Civil Engineer from Tennessee Tech and with a MSCE from NC State University. Bob has operated an environmental cleanup contractor operation and managed the NPL site at Marine Corps Base, Camp Lejeune, NC. His additional duties are to serve as an Emergency Services Coordinator for spill responses when called upon by the TN Emergency Management Agency.

Topic 3. Oak Ridge Reservation site history, regulatory drivers, and remediation history

Brief History of Mercury Use at the Oak Ridge Y-12 Plant

Scott Brooks
Environmental Sciences Division, Oak Ridge National Laboratory

Between 1950 and 1963 approximately 11 million kilograms of mercury (Hg) were used at the Oak Ridge Y-12 Plant (now known as the Y-12 National Security Complex, Y-12 NSC) for lithium isotope separation processes. About 3% of the mercury was lost to the air, soil and rock under facilities, and East Fork Poplar Creek (EFPC) which originates in the plant site. Smaller amounts of Hg were used at other Oak Ridge facilities with similar results. Although the primary mercury discharges from Y-12 NSC stopped in 1963, small amounts of mercury continue to be released into the creek from point sources and diffuse contaminated soil and groundwater sources within Y-12 NSC. This presentation describes mercury use at the Y-12 Plant in its historical and geographical context, summarizes known losses of Hg to the environment, and describes present day sources of Hg to East Fork Poplar Creek. Finally, relevant examples of national, regional, and local patterns of mercury concentrations in fish will be presented.

SCOTT BROOKS, Ph.D., joined the Environmental Sciences Division at Oak Ridge National Laboratory in 1994 as a postdoctoral research associate and is currently a Senior Research Scientist and Team Leader for the Hydrogeochemical Dynamics team in the Earth and Aquatic Sciences Group. He conducts research on the biogeochemical processes that influence the fate and transformation of contaminants in the environment. Projects span a range of spatial and temporal scales from molecular investigations and processes operating on the time scales of seconds to hours to field-scale investigations operating on time scales of days to years. He has served on a number of proposal review panels, as an associate editor for the AGU journal *Water Resources Research*, and serves as an ad hoc reviewer for the Department of Energy and a number of journals. Dr. Brooks received M.S. (1991) and Ph.D. (1995) degrees in Environmental Sciences from the University of Virginia and is a member of the American Geophysical Union, American Chemical Society (Geochemistry and Environmental Chemistry Divisions), and Sigma Xi. In 2003 he was awarded the Environmental Sciences Division’s Distinguished Scientific Achievement Award.

Mercury in Fish: Status Report for the Oak Ridge Reservation

Mark J. Peterson, George R. Southworth, and Theresa J. Mathews
Environmental Sciences Division, Oak Ridge National Laboratory

Mercury concentrations in fish near the Department of Energy's (DOE) Oak Ridge facilities have been monitored on an annual basis since the mid 1980s, as part of Oak Ridge National Laboratory's Biological Monitoring and Abatement Program. Objectives of this monitoring include addressing the DOE facilities' NPDES permit requirements, providing data for CERCLA-driven human and ecological risk assessments, assessing the impact of plant operations and identifying sources, and monitoring the effectiveness of remedial actions. Many remedial and abatement actions have occurred over the last twenty-plus years to reduce mercury levels in the Oak Ridge environment, including storm drain rerouting and relining, stream bank stabilization, floodplain soil removal, and groundwater treatment using activated charcoal. These actions have been successful at significantly reducing total mercury concentrations in stream water near the facilities; however, fish mercury concentrations in most cases have not responded commensurately. For example, water mercury concentrations in upper East Fork Poplar Creek have decreased 10-fold over the last decade, and are approaching previously established remediation goals for water, but fish mercury concentrations have not changed and remain around 0.9 µg/g (wet weight) throughout the creek. Regulatory guidance to a fish-based criterion of 0.3 µg/g mercury presents a significant remediation challenge for the DOE facilities, as current fish concentrations near the sites would have to decrease substantially, and the target level is only slightly higher than "background" levels in fish in east Tennessee. Given the many and complex challenges related to mercury, the DOE is supporting a number of basic and applied research programs that ultimately may help address the mercury issue.

MARK PETERSON is the Leader of the Ecological Assessment Science Team in the Environmental Sciences Division at Oak Ridge National Laboratory, and the program manager of the Biological Monitoring and Abatement Program, a long-term multidisciplinary monitoring program implemented primarily in Oak Ridge, Tennessee. He has over 25 years of environmental assessment experience, with a major research focus on the bioaccumulation of contaminants near Department of Energy and Department of Defense sites. Related to mercury, he has provided research and development support to large-scale mercury remediation projects in lower and upper East Fork Poplar Creek in Oak Ridge, Tennessee, helped to develop new technologies and strategies for mercury remediation as part of the DOE's Groundwater and Soils Remediation Program, and participated in atmospheric mercury studies in Alaska and Ontario, Canada. Since 1988 he has evaluated changes in mercury accumulation in stream fish near the Y-12 Complex, which is the topic of his presentation at the DOE's Mercury Summit.

Upper East Fork Poplar Creek Past and Planned CERCLA Remediation

John Kubarewicz
Bechtel Jacobs/RSI, Oak Ridge, TN

Remediation of the Upper East Fork Poplar Creek (UEFPC) watershed (Oak Ridge, TN) is being conducted in stages using a phased approach. Early actions were conducted to address offsite contamination and onsite releases that contribute to offsite migration. The Phase 1 UEFPC Record of Decision (ROD) addresses interim source control actions for the remediation of mercury-contaminated soils, sediments and groundwater discharges that directly contribute to contamination of surface water (principal-threat wastes). The initial project of the Phase 1 ROD, construction of the Big Springs Water Treatment System, addressed the largest remaining point source of mercury contamination to surface water. The system has been fully operational since 2006, removing mercury from local spring and sump waters that discharge to UEFPC.

The focus of the second phase is remediation of the balance of contaminated soils, scrap and buried materials within the Y-12 National Security Complex (NSC). The actions of the Phase 1 and Phase 2 RODs are sequenced to follow construction logic and avoid recontamination. As the Y-12 NSC is an active facility undergoing modernization, implementation of remedial actions must address challenges associated with the mission and security requirements of the Y-12 NSC. Access to contaminated media is restricted by existing facilities and infrastructure; however, American Reinvestment and Recovery Act funding is accelerating the demolition of inactive facilities and access to contaminated media.

Once the Phase 1 and 2 actions are completed and their effectiveness evaluated, final decisions on additional remediation needs will be evaluated and determined in UEFPC surface water and groundwater RODs.

JOHN KUBAREWICZ is a professional engineer with over 30 years of experience in the remediation of hazardous waste sites. He has managed the preparation of Y-12 CERCLA decision documents including the Phase 1 and 2 RODs and the identification and testing of innovative technologies for the remediation of hazardous waste including mercury.

Topic 6. Other mercury case studies

Nature and Effectiveness of Soil and Groundwater Remediation at a Large Mercury-Contaminated Site

Ralph Turner
RT Geosciences Inc., Squamish, British Columbia

A large (120 mT Cl/d) mercury cell chlor-alkali plant operated between 1965 and 1991 at the head of a fjord in southern British Columbia. Over this period an estimated 40 mT of mercury were lost to local atmospheric, aquatic and terrestrial environments. Most of this loss occurred prior to implementation of various controls in 1970. Demolition of facilities began in the late 1990s, followed by remediation of site soils and groundwater over a 4-year period ending in 2003. Over 300,000 mT of site soils were excavated for further classification, off-site landfill disposal (150,000 mT), on-site washing for reuse as backfill (24,000 mT) or on-site stabilization for offsite disposal (10,000 mT). No off-site soils or sediments were excavated as part of the remediation. BC Provincial numerical standards for mercury based on-land use (40 mg/kg commercial, 15 mg/kg residential) were applied in classifying soils for excavation, treatment and/or reuse as backfill. Soils for off-site disposal had to meet leachate standards (TCLP) only and some had to be stabilized to achieve these standards. Some soils at depths greater than 3 to 5 meters exceeded Provincial standards, could not be effectively excavated due tidal influence on groundwater levels at these depths and were dealt with by risk management (deed restrictions).

An initial groundwater extraction program was implemented in July 2001 and halted in September 2002 after 50,000 m^3 of contaminated groundwater had been extracted and treated. At this time mercury concentrations in boundary wells had decreased below 1 μg/L, an interior plume had virtually disappeared and most soil remediation was nearing completion. However, within a few months mercury in boundary wells had returned to former levels and by 2006 mercury in foreshore (intertidal) groundwater was exceeding established “trigger” levels. A new program of groundwater extraction and treatment was initiated in 2007 focused on maximizing mercury capture instead of complete plume capture. Monitoring results since 2006 have demonstrated both effectiveness of the renewed groundwater extraction as well as a “superimposed” longer term trend of decreasing mercury concentrations in intertidal groundwater, surface water and biota. This work illustrates both the complexity of tracking mercury transport in intertidal groundwater and the challenges of assuring acceptable restoration of Hg-contaminated sites, few of which are monitored sufficiently following remediation to identify/confirm effective remedies.

In general the technologies and practices employed at this site were developed in-house and adapted as necessary to achieve targets. The project was completed relatively quickly and inexpensively (~40 million USD) due to a motivated management team, a synergistic mix of chemists and engineers and fully engaged stakeholders.

RALPH TURNER, Ph.D., has diverse experience spanning more than 30 years in the field of biogeochemistry of terrestrial and aquatic ecosystems. After completing his Ph.D. in 1975, he became a researcher in the Environmental Sciences Division of Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. During his 22-year tenure at ORNL he conducted extensive research and characterization at two large mercury-contaminated sites: a defunct chlor-alkali plant and a nuclear weapons plant. In 1997 he joined Frontier Geosciences, a specialty research and analytical services company in Seattle, Washington. In February 2000, he formed his own company, RT Geosciences Inc., in Squamish, British Columbia. Consultant activities with this company include project planning (mainly sampling and analysis), conduct of special field and laboratory projects (e.g., mercury treatability studies, measurement of soil and water fluxes of mercury vapor, sediment pore water extraction and analysis, dendrochemistry to reconstruct historic atmospheric mercury releases, building decontamination, mercury immobilization studies, soil/sediment mercury speciation studies, thermodynamic modeling of mercury behavior, and groundwater tracing studies). For one of the major environmental remediation projects in British Columbia (Squamish Hg chloralkali site) he was the Environment, Health and Safety manager between 2000 and 2003 and subsequently designed and supervised post-remediation monitoring of this large site. Dr. Turner has served on numerous expert panels related to mercury in the environment. Betweeen 2001 and 2004 he served on a panel concerned with mercury in sediments in the St. Lawrence River near Cornwall, Ontario. Recently he has been a member of expert panels concerned with mercury in the Shenandoah River system in Virginia, East Fork Poplar Creek in Tennessee and the Penobscot River in Maine.

Topic 7. Mercury biogeochemistry and environmental behavior

A Comprehensive Study of the Biogeochemical and Molecular Mechanisms of Mercury Transformation at a Contaminated Site in Oak Ridge, Tennessee, USA.

Baohua Gu
Environmental Sciences Division, Oak Ridge National Laboratory

Biogeochemical factors controlling mercury transformation and methylmercury (MeHg) production present a serious knowledge gap at the U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) and many other contaminated sites globally. ORR field data show that reduction in Hg levels does not necessarily lead to a decrease in aqueous MeHg or to mercury bioaccumulation in biota. This presentation will provide an overview of an integrated research program at the Oak Ridge National Laboratory (ORNL) that combines the field- to molecular-scale chemical and microbiological studies to understand various biogeochemical factors that control the net production of methylmercury. The main objectives are to elucidate the rates, mechanisms and controls of abiotic and microbial processes affecting Hg speciation and transformation; to resolve the critical Hg precursors that are produced and subsequently methylated at the sediment-water interface; and to develop and validate subcellular models to understand the biochemical and biophysical mechanisms of transformation between Hg species and MeHg. Laboratory and microcosm experiments are being performed to understand fundamental processes that control Hg speciation, reactivity and methylation using chemical, spectroscopic and stable isotope techniques. Functional genomics are being used to determine key microbial groups that influence MeHg production under varying geochemical conditions. Structural biology combined with molecular simulation is also being applied to known demethylation processes to provide an atomic-detail understanding of key reaction pathways, and it will be extended to elucidate microbial methylation mechanisms identified by advanced genomic techniques. These studies will form the basis of understanding of the reduction-oxidation and methylation-demethylation transformations that determine the fate of Hg in sediment-water environments.

BAOHUA GU, Ph.D., is a distinguished Senior Research Staff at the Oak Ridge National Laboratory and an adjunct professor at the University of Tennessee, Knoxville. He received his Ph.D. from the University of California, Berkeley in 1991 and has authored or co-authored more than 130 peer-reviewed journal publications. His current research is focused on mercury biogeochemical transformation and mechanisms, transformation and transport of contaminant metals and radionuclides, nanomaterials, and spectroscopy and its novel applications.

Determination of the Sediment-Water Exchange of Mercury and Monomethyl Mercury: Approaches, Limitations and Observations

Gary A. Gill
Pacific Northwest National Laboratory, Marine Sciences Laboratory, Sequim, WA

Several approaches exist to estimate the sediment-water exchange of mercury (Hg) and monomethyl mercury (MMHg) in the environment and each approach has its advantages and disadvantages. Choice of which technique to use largely depends on the goals of the project and the spatial and temporal scales of interest. Limitations and advantages of three sampling approaches will be presented: an indirect approach based on measurements of interstitial pore water, a direct approach based on use of benthic flux chambers, and a "whole-ecosystem" approach based on time series monitoring of water flowing through a well-delineated wetland area. Major limitations in the indirect method involving collection of interstitial pore water include the ability to resolve near-surface gradients, the inability to account for bio-irrigation, the assumption of (long term) steady-state conditions, and spatial (horizontal) heterogeneity issues in sediments. Use of benthic flux chambers has the major advantage that it is a direct measurement of flux, including any biological pumping that enhances transport. A major limitation in the use of chambers is that this approach may require intensive field efforts (e.g., SCUBA teams and diurnal studies) in order to get good spatial and temporal coverage. Where benthic chambers can be utilized is limited by the ability to seal the chamber over an uneven, vegetated or rocky bottom. Matching hydraulic conditions within the chamber to the conditions outside can also prove problematic in systems experiencing significant water flow (e.g., rivers). Monitoring of water flowing on and off a wetland with the tide can provide an alternative method to the discrete point sampling methods represented by interstitial pore water collections and benthic flux chambers. This approach integrates over large (whole ecosystem) surface areas and minimizes sediment heterogeneity issues associated with discrete point sampling.

GARY GILL, Ph.D., joined the Pacific Northwest National Laboratory in 2005 as the manager for the Marine and Environmental Chemistry Group at the Marine Sciences Laboratory in Sequim, Washington. Prior to coming to MSL, Dr. Gill was a full professor in the Department of Marine Sciences at Texas A&M University at Galveston. Dr. Gill also held a joint appointment in the Department of Oceanography at the main campus of Texas A&M University in College Station, Texas. Dr. Gill received his B.S. degree in oceanography and chemistry (dual major) from the University of Washington in 1976. He earned his Doctorate degree in (chemical) oceanography from the University of Connecticut in 1986. Following graduate work, Dr. Gill was a post-doctoral investigator at the University of California Santa Cruz where he worked with Dr. Kenneth Bruland and Dr. A. Russell Flegal. Dr. Gill's personal research interests include studies of the biogeochemistry of trace elements in natural waters, with particular experience and interest in environmental and analytical studies concerning mercury.

Topic 8. Mercury toxicity and ecological risk assessment

Mercury Uptake, Phytotoxicity and Field Sample Analysis

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Mercury uptake and phytotoxicity by different plant species, including a grass, three ferns, two cultivars of Indian mustard and a water plant, will be presented in this talk. Different mercury uptake channels through root and leaf were investigated. Mercury-induced oxidative stress was studied for fern and mustard species (*Brassica juncea*). Internal leaf structure changes, reduction of biomass and leaf relative water content due to mercury uptake were observed. Spectral reflectance was also applied to monitoring the mercury uptake process. Mercury uptake through root and translocation to leaf by Chinese brake fern (*Pteris vittata*) were observed with HgS contaminated soil. Mechanisms and processes that control/contribute to bioavailability of mercury contaminants in the rhizosphere warrant further and systematic studies. Some of these vegetation species exhibit efficient metabolic defense and adaptation systems to mercury-induce oxidative stress and hence might be considered as potential candidates for phytostabilization/phytofiltration of mercury-contaminated soil and water. Different approaches and challenges for analyzing field plant, soil and water samples will also be reviewed and discussed.

YI SU, Ph.D., is currently a research professor at the Institute for Clean Energy Technology, Mississippi State University. Dr. Su received his Ph.D. in Physical Chemistry from Wayne State University in 1996. His current and previous research areas include environmental sensing and remediation; diagnostics, measurement, and chemical detection with optical and spectroscopic technologies; atmospheric chemistry; and remote sensing.

Ecological Implications of Mercury Exposure

Joanna Burger[1,3] and Michael Gochfeld[2,3]
[1]Rutgers University [2]UMDNJ-RWJ Medical School [3]Consortium for Risk Evaluation with Stakeholder Participation

Mercury has the potential to affect eco-receptors, including humans, and to thus impact the food chain and ecosystem dynamics. Methylmercury poses the greatest risk to biota and to humans, and it enters the food chain after inorganic mercury is methylated by bacteria in the sediment. Dietary uptake varies by species and groups of aquatic organisms, but in fish, dietary uptake accounts for about 90%; assimilation ranges up to 80 %, and toxicity for the fish themselves is associated with levels of 5-20 ppm in their tissues. Toxicity levels for mammalian predators (0.1 ppm) and avian predators (0.02 ppm) differ. Long-term trends in mercury levels in some organisms have declined, while in other species at other locations they have not. Mercury levels in some fish in the Clinch River are relatively low, although they are higher in fish from East Fork Poplar Creek, especially Stonerollers. While risk for fishermen can be partly managed with fish consumption advisories, this is not possible with eco-receptors that live there, and have the opportunity for bioaccumulation and biomagnification. Key ecological issues for mercury at Oak Ridge involve 1) science research needs, 2) conflicts between different regulatory requirements, and 3) human health/ecosystem risk balancing considerations.

JOANNA BURGER, Ph.D., is an ecologist specializing in ecotoxicology. She is Distinguished Professor in the Division of Life Sciences and Environmental and Occupational Health Sciences Institute at Rutgers University, and a professor at the UMDNJ-School of Public Health. Over her 30+ years at Rutgers she has taught undergraduate and graduate students ecology, ecological risk, and animal behavior. She is one of the founding members of the Consortium for Risk Evaluation with Stakeholder Participation (CRESP), and has conducted research on stakeholder involvement and perceptions, ecotoxicology, human exposure, risk, and long term biomonitoring around several Department of Energy sites. A major emphasis of this research has been on fishing behavior, perceptions, fish consumption and risk. Her main research has focused on metals and developmental neurotoxicology, ecological risk, environmental assessment, and biomonitoring at contaminated sites, as well the effects of humans on animal behavior. She has authored over 300 peer-reviewed papers in the biomedical literature as well as several books and book chapters. She has served on several national and international committees, including the National Academy of Science's Board on Biology and Board of Environmental Studies and Toxicology, and the Scientific Committee on Problems of the Environment, as well as on advisory committees for EPA, NOAA, and Department of Interior.

MICHAEL GOCHFELD, M.D., Ph.D., is an environmental toxicologist and occupational physician who is Professor in the Department of Environmental and Occupational Medicine at UMDNJ-Robert Wood Johnson Medical School in the Environmental and Occupational Health Sciences Institute. He is one of the founding members of CRESP. His research has focused on ecological and human health consequences of occupational and environmental exposure to heavy metals, particularly mercury. From 1999 to 2001 he chaired New Jersey's Mercury Task Force. He has also chaired the international Cadmium Working Group and the Scientific Group on Methodology for Safety Evaluation of Chemicals for the Scientific Committee on Problems of the Environment. He is a clinician seeing patients exposed to heavy metals and other contaminants in their home, community, or workplace environments. He is author of over 200 peer-reviewed papers on environmental and occupational health and has contributed book chapters on toxicology and risk assessment.

Topic 9. Site conceptual model for mercury at Y-12 National Security Complex

Through a Looking Glass: Conceptual Models of Mercury at a Complex Real-World Site

Brian Looney[1], Mark Peterson[2], George Southworth[2], Carol Eddy-Dilek[1] , and Dave Watson[2]
[1]Savannah River National Laboratory, Aiken, SC [2]Oak Ridge National Laboratory, Oak Ridge, TN

Effective and efficient environmental management is predicated on developing a crisp and succinct understanding of key processes, collecting diagnostic and actionable characterization data, and evaluating potential remediation and restoration actions. These various activities are linked through the development of conceptual models. The behavior of mercury in the environment near the Y-12 Complex on the Department of Energy Oak Ridge Reservation in Tennessee has been the subject of several conceptual models over the past several decades. These conceptual models have provided valuable insights into the transport, transformation, and clean-up options for a site impacted by relatively large quantities of elemental mercury released into a complex hydrologic and biogeochemical setting. Further, these conceptual models provide an initial basis for improving remedial objectives and may provide for developing and implementing more creative, more effective and lower cost environmental management solutions.

BRIAN B. LOONEY, Ph.D., received his Bachelor of Science degree in Environmental Science from Texas Christian University in 1978, and earned his doctorate degree in Environmental Engineering from the University of Minnesota in 1984. Dr. Looney is a senior advisory engineer at the Department of Energy Savannah River National Laboratory (SRNL) in Aiken, SC and an adjunct professor in the Environmental Engineering Science Department at Clemson University. He coordinates development and deployment of innovative environmental characterization and clean-up methods at the Savannah River Site and provides technical support to the DOE Environmental Management Program. Dr. Looney has worked at SRNL for 25 years, during which time he has developed, tested and deployed a wide variety of technologies to creatively, efficiently and sustainably address challenges associated with organic and inorganic contaminants and radionuclides.

Topic 10. Modeling mercury in watersheds and the subsurface

Overview of ORNL's Mercury-Related Modeling Program: A Systems Analysis Approach

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The Oak Ridge Integrated Facilities Disposition Program (IFDP) will include demolishing 5.3 million square feet of excess facilities, disposing of legacy materials/wastes, and completing environmental cleanup of the Oak Ridge Reservation in Tennessee. There is significant risk of contaminant releases (especially mercury) during decontamination and decommissioning (D&D) implementation as well as changes in site hydrology and flow paths due to alteration of sumps, drains, and recharge and dewatering activities. Characterization and remediation activities at most contaminated sites are subject to uncertainty. However, this uncertainty is even greater at industrial facilities like the Department of Energy (DOE) Y-12 National Security Center (Y-12), where subsurface hydrogeologic conditions have been modified by plant construction and operations. When industrial facilities are constructed, high permeability gravel may be used to fill in building foundations and other structures, the course of surface water channels may be altered, and some areas may be cut or filled to level the site. These site alterations may create ill-defined conduits and preferred pathways for groundwater and migration of contaminants like mercury. Process lines and storm drains may also create preferred pathways and the operation of sump pumps used to dewater basements may alter groundwater flow directions.

A systems analysis approach has been employed and demonstrated at the Y-12 site in which the bounds of known and suspected transport pathway features are documented using geographic information system (GIS) technology (ARCGIS 9.2™) and assigned a value associated with their risk of migration. Preferred pathway layers that were determined to have an effect beyond their boundaries (e.g., sumps) were buffered with a multi-part buffer tool and assigned a rating for vulnerability and a weight for the buffer distance. Buffered and non-buffered preferred pathway layers were combined using an overlay tool (Union). The union overlay tool computes the geometric intersection of the polygon features. All polygons from the features are split at their intersections and preserved in the output layer. Each new polygon has all the attributes of all the preferred pathway layers and their buffers that contributed to the new polygon. For each polygon in the union overlay layer migration vulnerability was calculated by multiplying the rating for each contributing preferred pathway layer by its distance weight and then summing all the vulnerabilities for each polygon. The result is a map of the facility showing the risk of migration due to the presence of the pathway features. Existing soil and groundwater mercury contamination information was similarly processed in GIS, overlain and compared with the pathway maps to further refine the assessment of likely contaminant migration pathways. The pathway analysis results can be used directly to make decisions on additional site investigation and remedial activities or as input to more sophisticated groundwater and surface water 3-D flow and transport models.

We propose to use HydroGeoChem V5.0 (HGC5) (Yeh et al., 2004), a comprehensive 3-D subsurface numerical code of fluid flow and reactive chemical transport, to evaluate and predict the impact of D&D activities and potential remedial actions on groundwater. HGC5 is currently being used to conduct watershed modeling at the Office of Science Integrated Field

Research Challenge (IFRC) Project located on the west end of Y-12. The IFRC HGC5 model could easily be extended to the main Y-12 Plant area for IFDP evaluation purposes.

WASH123D (Yeh et al., 2005) is a watershed model to simulate water flow, contaminant and sediment transport in 1-D stream-river network, 2-D overland regime and 3-D subsurface media. This model has been chosen and endorsed by US EPA and US Army Corps of Engineers (ACE) as a tool for watershed management. A case study of WASH123D was conducted for Upper East Fork Poplar Creek (UEFPC) to simulate flow, sediment and reactive mercury transport. The special feature of HGC5 and WASH123D is their capability in handling transport together with complex reactions. A new paradigm of reaction-based approaches is employed to describe biogeochemical processes in terms of reaction networks. To make the biogeochemical module quite general, any kinetic reaction can be formulated based on elementary rate laws or by user-specified rate equations. For equilibrium reactions, the governing equation is given by a mass action formulation or may be specified by the user with an algebraic equation. Both models are designed for generic application to reactive transport problems controlled by both kinetic and equilibrium reactions.

Use of these models would improve the efficiency and cost-effectiveness of remediation and reduce overall technical risk and uncertainty. Information gained from the use of this systems analysis approach also would increase understanding and contribute to the development of cost-effective groundwater and surface water remediation decisions for Oak Ridge facilities.

DAVID WATSON has an M.S. in hydrology from New Mexico Tech. (1983) and a B.A. in Geology from the University of Vermont (1978). Mr. Watson has over 25 years of experience working with DOE, EPA and other government agencies and private companies remediating hazardous waste sites and managing large multi-million dollar Federal and State Superfund projects. Since 1993, he has been a hydrogeologist at Oak Ridge National Laboratory and was the technical lead for the Y-12 Remedial Investigations and Feasibility Studies. He is currently the Field Manager of the Oak Ridge Field Research Center located on the west end of Y-12 conducting research on contaminant fate and transport and remediation of source zones.

Integrated Flow and Transport Model of East Fork Poplar Creek for Evaluation of Mercury Remediation Alternatives

Georgio Tachiev
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An integrated river/surface/subsurface and flow and transport watershed model was developed using MIKE-SHE and MIKE 11 software to determine the contaminant transport within the East Fork Poplar Creek (EFPC) watershed. The model couples flow in rivers (MIKE 11), overland flow, surface and subsurface flow (MIKE-SHE), and advection-dispersion and sorption/desorption laws, to provide an understanding of the mechanisms of water and mercury transport within the model domain. The modeling system (MIKE-SHE/MIKE 11) relies on standard GIS information for model input/output, thus shortening the model development and providing researchers with a standard model platform. Measured spatial and temporal parameters for the subsurface and surface subdomains (precipitation, evapotranspiration) and river flow and transport are used for boundary conditions. The model is calibrated using stream discharge data from USGS and DOE stations, groundwater table measurements at monitoring wells within the watershed, and mercury concentrations measured in the streams of EFPC. The coupling of the hydrological cycle within the EFPC domain with the transport model provides an engineering modeling framework which is used to analyze the impact of remedial activities on water and mercury interactions within the hydrologic domains (saturated flow, vadose zone, overland flow, and stream flow). The results show that based on the large retardation factor of mercury, source control strategies which rely on removal of contaminated soil have the greatest effect in short term reduction of mercury levels when applied in the vicinity of a stream. Furthermore, the numerical results show that heavy storm flow events may increase the mercury contamination levels in streams through interactions of overland flow with subsurface zones resulting in transfer of dissolved mercury to surface water. In addition, flow diversion is an efficient alternative for limiting the contact of storm water infiltrating contaminated soil and for preventing mercury transport into streams. The project is a collaborative effort with DOE's Office of Groundwater and Soil Remediation and US DOE-ORO to develop remediation alternatives for mercury contamination in soil, sediment, and water.

GEORGIO TACHIEV, Ph.D., P.E., is a Senior Research Scientist at the Applied Research Center (ARC), Florida International University (FIU). He joined ARC as a Project Manager in 2003 and led numerous research and engineering projects for the public and private industry for clients including DOE, NASA and SFWMD. Dr. Tachiev received a Ph.D. degree in Environmental and Water Resources Engineering in 1998 and a master's degree in Chemical Engineering in 1997, both from Vanderbilt University. Prior to his graduate study in the U.S., Dr. Tachiev received a master's degree in Environmental Engineering and a bachelor's degree in Civil Engineering from the University of Architecture and Civil Engineering in Sofia, Bulgaria. Dr. Tachiev's experience spans over 20 years of designing, managing, and guiding numerous projects related to environmental engineering research and development. The main focus of his projects is regional hydrology and analysis of natural and built environmental systems and sustainability, and more specifically numerical modeling for surface and subsurface flow and transport of contaminants related to environmental problems, including remediation, nutrient analysis, and management of water resources. He has conducted numerical analysis of large-scale physical problems utilizing high performance computing and massively parallel computers and led development of parallel codes. Additional areas of expertise include advanced oxidation and biotransformation processes for remediation of organic and inorganic pollutants, environmental aqueous chemistry, remediation technologies, kinetic and thermodynamic modeling of environmental processes, wastewater reuse and GIS applications for environmental problems. He is a registered Professional Engineer in Florida. Dr. Tachiev has been a Graduate Faculty member at FIU since 2003 and serves as committee member for students' dissertations and thesis work. He is a member of the Science Committee of the Climate Change Task Advisory Force for Miami-Dade County.

Modeling Mercury Cycling and Bioaccumulation in Aquatic and Terrestrial Systems: An Update

Reed Harris
Reed Harris Environmental, Ltd., Oakville, Ontario

The current capabilities of mercury cycling and bioaccumulation models are reviewed for aquatic and terrestrial systems. The ability to predict the response of ecosystems to changes in mercury loading is reviewed in particular. Field data and modeling results from the METAALICUS project, where mercury was experimentally added to an ecosystem for 7 years, are used to highlight some of the findings of models and remaining uncertainties. These uncertainties include the bioavailability of different inorganic mercury pools (via atmospheric deposition, terrestrial runoff, industrial point sources).

REED HARRIS has over 30 years of experience in the environmental engineering field, including predicting water quality and the transport and fate of contaminants in the environment. Since the late 1980s, Mr. Harris has specialized in the behavior of mercury in aquatic environments, developing models for lakes, reservoirs, wetlands, marine and terrestrial systems. Reed is currently managing a joint Canadian-U.S. whole-ecosystem mercury addition experiment (METAALICUS) in Ontario that is examining the relationship between atmospheric mercury deposition and fish mercury concentrations.

Topic 11. Mercury characterization for sites, soils, and wastes

Development of a Direct Push/Membrane Interface Probe Technique for Rapid Characterization of Mercury-Contaminated Sediments

Carol A. Eddy-Dilek and Brian B. Looney
Savannah River National Laboratory

One of the most effective approaches for rapid characterization of subsurface contamination uses a direct push method, such as cone penetrometers or Geoprobes, configured with appropriate sensors and samplers. These approaches typically result in efficient and robust characterization by collecting a large amount of screening data that can be used to delineate the nature and extent of contamination. The permeable membrane interface probe (MIP) was developed to allow for near real-time evaluation of subsurface volatile contaminants. The MIP consists of a thin composite (metal and polymer) membrane that is mounted along the outside of a push rod. The membrane is in contact with a carrier gas line within the probe, and the carrier gas line is connected to a detector located at the surface. The membrane is typically heated to 80 to 125°C as it is advanced, volatile contaminants partition into and move through the membrane by diffusive flux, and the contaminant is picked up by the carrier gas and swept to the surface. We are proposing to develop an approach for subsurface detection of free phase mercury that uses MIP techniques combined with standard detectors such as soil classification sensors to support environmental management and restoration activities at DOE sites such as the Y-12 facility at Oak Ridge.

CAROL EDDY-DILEK, Ph.D., is a research scientist in the Environmental Restoration Technology Section at the Savannah River National Laboratory, the research and development laboratory supporting the Savannah River Site. Her responsibilities have included many aspects of applied research related to characterization of hazardous waste sites and monitoring and performance assessment of remedial technologies. She was the lead investigator for the DOE's cone penetrometer sensor testing and evaluation program and has been actively involved in the development, evaluation, and application of new sensors and approaches for site characterization and monitoring. During 1998-1999, she led the site characterization efforts for the Interagency DNAPL Consortium Program at the Cape Canaveral Air Station, Florida, a joint EPA-NASA-DoD-DOE program for evaluation of innovative technologies for DNAPL remediation.

Mercury Speciation, Bioavailability and Characterization of Contaminated Soils

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We will briefly review our previous and current research on mercury speciation, bioavailability studies and characterization of contaminated soils. The primary goal of this project is to investigate the mechanisms and major biogeochemical processes controlling mercury speciation, transformation and fate in contaminated soils, with special focuses on the floodplain soils and sediments of the Oak Ridge ecosystem. We have conducted pilot scale experiments to study the bioavailability of mercury in selected soils and sediments at low, intermediate and high loading levels. Redistribution and transformation of mercury in solid phase components of soils contaminated with various sources (such as mercury as nitrate, sulfide and chloride) have been investigated. The impact of growing plant species and the effect of incubation time on bioavailability and chemical stability of mercury contaminants (especially of mercury sulfide) in soil have been examined. Dissolution dynamics of mercury sulfide contaminated soils have been measured using various extractants. Biogeochemical conditions (pH, Cl^- concentrations, presence of organic molecules, and iron and manganese oxide minerals) triggering an increase in mercury solubility and bioavailability in floodplain soils have been studied. Future directions of proposed work will also be discussed.

FENGXIANG HAN, Ph.D., is an Associate Research Professor in the Institute for Clean Energy Technology at the Mississippi State University. Dr. Han received a Ph.D. in Soil and Water Sciences from the Department of Soil and Water Sciences at the Hebrew University of Jerusalem, Israel in 1998. Dr. Han's current research covers a wide range of soil science, environmental chemistry, environmental geology and remediation technology, carbon sequestration and global warming. Dr. Han has been appointed to the Editorial Board of *Water, Air and Soil Pollution*, *Water, Air and Soil Pollution, Focus*, and *Soil and Sediment Contamination*. In 2007 Dr. Han published a book entitled *Biogeochemistry of Trace Elements in Arid Environments* through Springer Verlag. Dr. Han has also published more than 50 peer-reviewed articles in international refereed scientific journals, 6 book chapters, 25 conference proceedings, and 39 presentations at national and international conferences.

Topic 12. Mercury remediation technologies, part 1

Mercury Treatment Technologies: "2007 Baseline"

Brian Looney
Savannah River National Laboratory

The 2007 Environmental Protection Agency report, "Mercury Treatment Technologies in Soil, Waste and Water" (available at http://clu-in.org/542R07003) identified and described the state of practice for mercury treatment; the evaluation included selection criteria to help match technologies to site-specific needs, descriptions and evaluations of past demonstrations/implementations, and historical cost experiences. The various technologies in the report can be organized into broad categories and subcategories. For treating soil and solid wastes, the technologies either: 1) stabilize, immobilize or detoxify mercury (e.g., solidification, precipitation or amalgamation) or 2) remove the mercury from the waste (e.g., thermal treatment or soil washing). For water, the technologies all remove mercury from the aqueous phase (using precipitation, sorption, etc.). Reasonable criteria for selecting a preferred technology category and the site conditions that favored a particular exemplar within the category were addressed (along with conditions that might hinder or preclude use of a technology). EPA also identified and provided an initial assessment of a list of emerging-research technologies including various nanotechnologies, air stripping and in situ thermal desorption. This work serves as an important "2007 baseline" of treatment and sets the stage for the technology innovation and technology development during the past few years.

BRIAN B. LOONEY, Ph.D., received his Bachelor of Science degree in Environmental Science from Texas Christian University in 1978, and earned his doctorate degree in Environmental Engineering from the University of Minnesota in 1984. Dr. Looney is a senior advisory engineer at the Department of Energy Savannah River National Laboratory (SRNL) in Aiken, SC and an adjunct professor in the Environmental Engineering Science Department at Clemson University. He coordinates development and deployment of innovative environmental characterization and clean-up methods at the Savannah River Site and provides technical support to the DOE Environmental Management Program. Dr. Looney has worked at SRNL for 25 years, during which time he has developed, tested and deployed a wide variety of technologies to creatively, efficiently and sustainably address challenges associated with organic and inorganic contaminants and radionuclides.

Flow Manipulation and Chemical Reduction: Air Stripping to Lessen Mercury Export from the Oak Ridge Y-12 Complex

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Inputs of dissolved inorganic mercury to the surface flow of East Fork Poplar Creek (EFPC) within the Y-12 NSC in Oak Ridge, Tennessee arise from three localized sources. The largest of these is the discharge of the subsurface storm drain network at Outfall 200. This source drains the West End Mercury Area (WEMA) where most of the use and loss of mercury (Hg) occurred. It represents the beginning of EFPC and contributes 6 - 8 g Hg per day to the stream under baseflow conditions. Metallic mercury within a relatively short reach of armored soft sediments 100 m downstream from Outfall 200 generates high concentrations of dissolved Hg within streambed interstitial water. Diffusion and advection from that source adds 1 -2 g Hg per day to EFPC. Mercury contamination within the karst system underlying upper EFPC contributed 2 - 6 g of Hg per day via an artesian spring 1000 m farther downstream, but construction and operation of a treatment system has reduced inputs from the karst system to less than 0.5 g/d. Two studies conducted for DOE EM-22 showed promise for reducing inputs of Hg to the flow of EFPC from the two largest localized sources. Advection of Hg from the streambed source was found to be sensitive to the volumetric flow of EFPC in that reach, and reducing discharge by re-routing 50% of the water added by a flow augmentation system at Outfall 200 produced about a 50% decrease in Hg input from that source. Mercury in the larger Outfall 200 point source was found to be maintained in a highly reactive dissolved state by the presence of residual chlorine in potable water from single-pass cooling water discharges. After dechlorination, that mercury was found to be reducible by trace additions of stannous chloride, converting the dissolved Hg(II) to highly volatile dissolved Hg(0). A field test using ascorbic acid as dechlorinating agent and 5 ppb Sn(II) was able to convert >90% of the Hg in the Outfall 200 discharge to Hg(0). A preliminary engineering evaluation found that off-the-shelf air stripping technology with a footprint similar in size to the existing concrete apron at Outfall 200 could effectively remove the Hg(0) from the streamflow and capture it on activated carbon. In concert with planned remedial actions within WEMA, these two technologies combined have the potential to decrease waterborne inorganic Hg concentrations in upper EFPC into a range consistent with fish Hg concentrations below the 0.3 ppm regulatory criterion.

GEORGE SOUTHWORTH is a Senior Research and Development Staff scientist in the Ecological Assessment Science Team of Environmental Sciences Division of ORNL. He has worked for 25 years on biological monitoring of methylmercury bioaccumulation, and has participated in efforts to establish cleanup goals and to reduce mercury inputs to surface waters draining contaminated Dept. of Energy facilities in Oak Ridge. He has worked on mercury-related research at industrial sites and remote field stations across North America. He holds an M.S. from the University of Michigan and has published extensively on the environmental transport of mercury and other contaminants.

The Mercury Treatment Challenge: Returning a Toxic Material Back to its Roots

Paul D. Kalb
Brookhaven National Laboratory (BNL), Upton, NY

Despite great progress toward the environmental remediation of current and former sites, the U.S. Department of Energy (DOE) still faces a large challenge when it comes to the cleanup of mercury contamination. Mercury, in its many chemical forms, can be found in soils, groundwater and stored wastes at numerous DOE sites, but most notably at the Oak Ridge complex. Until recently, mercury was also used widely in industry, e.g., chlor-alkali production, fluorescent lighting, electrical switches, and thermometers, resulting in additional environmental releases; thus mercury cleanup issues are international in scope. The U.S. Environmental Protection Agency (EPA) has reviewed a number of existing and promising mercury treatment technologies and each has advantages and disadvantages (Chattopadhyay and Condit, 2002; U.S. EPA, 2007). The overall objective of all mercury treatment processes, however, is to reduce contaminant mobility and thereby minimize potential pathways for environmental and human exposure. With this in mind, BNL developed and patented several treatment technologies that convert various types of mercury back to a less soluble, more stable, and less toxic form, similar to the natural mineral cinnabar, the most stable form of mercury in nature.

Sulfur Polymer Stabilization/Solidification (SPSS) is a two stage ex situ process that converts elemental or ionic mercury to the chemically stable sulfide form and then physically encapsulates the product in a sulfur-based solid monolith. In the initial stage, sulfur polymer and other reagents are mixed with the mercury waste to form a stable mercury sulfide powder with low solubility (i.e., leachability) and low vapor pressure. The mix can then be heated to about 135°C to melt the sulfur without releasing mercury vapor, blended to form a homogeneous mixture and then cooled back to a solid. The combination of chemical and physical treatment results in a solid form of mercury sulfide, a product that resembles the element cinnabar in both chemical and physical form.

A U.S. patent was received and SPSS was demonstrated on a pilot-scale for a number of forms of mercury waste including liquid elemental mercury and mercury contaminated soil, sludge, and debris. The resulting treated products were shown to pass EPA Toxicity Characteristic Leaching Procedure (TCLP) testing (200 ppb) and Universal Treatment Standard (UTS) protocol (25 ppb) depending on processing conditions and waste loading parameters (Bowerman et al., 2003; Fuhrmann, 2002). Further testing of SPSS-treated sludge that was contaminated with 5,000 ppm of mercury using a constant pH protocol resulted in mercury concentrations below the UTS limits at all pH ranges from 2 through 10 (Fed. Reg., 2003). The pH conditions are below 10 in over 90% of landfills. To put these data in further perspective, the SPSS-treated samples leached 3 – 4 orders of magnitude lower than untreated mercury. SPSS was licensed by Newmont Mining Corp., the largest gold mining company in the world, for possible treatment of residual mercury that is generated from processing of gold ores. Advantages of SPSS include relatively high waste loadings (up to 33 wt% pure elemental mercury and 60 wt% mercury contaminated soil), very low leachability and stability over time, and fixation of dispersible contamination. Due to cost and logistics, ex situ technologies such as SPSS are not optimal for very large volumes of soil that are not highly contaminated.

BNL developed In Situ Mercury Stabilization (ISMS) as a means of cost-effectively treating large volumes of minimally contaminated soils (Kalb, 2008). Similar to SPSS, ISMS is based on the reaction between mercury and sulfur, but it is conducted passively by the insertion of sulfur-based treatment rods into the mercury contaminated soil. Mercury surrounding the treatment rod reacts with the reagents in the treatment rod and forms a zone depleted in mercury around the rod. The resulting concentration gradient causes mercury in the soil to migrate toward the treatment rod and the process is repeated until the concentration of mercury in the soil has been reduced to acceptable levels. The treatment rods can then be removed and treated by SPSS for final disposition. ISMS has been developed and demonstrated at proof-of-principle and laboratory-scale. A U.S. patent was recently received and BNL is seeking opportunities to scale-up and demonstrate the technology under field conditions. Advantages of ISMS include low cost, passive remediation leading to eventual removal of mercury to acceptable levels. The process is not appropriate where fast cleanup is required and where high concentrations of mercury are better treated by removal and ex situ treatment.

Both technologies developed by BNL can result in stable, solid mercury sulfide, with low leaching and vapor pressure, similar in chemical and physical properties to cinnabar. These treated products can then be returned back to the earth in monitored disposal facilities or at former mine sites. For soils containing >260 ppm of mercury, this option would require a regulatory rule change by EPA, which currently only allows thermal desorption and recycling for this type of waste.

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PAUL KALB is a Senior Research Engineer at Brookhaven National Laboratory. He has a bachelor's degree in mechanical engineering from the State University of NY at Binghamton and a master's degree in nuclear engineering from Polytechnic Institute of NY. Paul has been employed at BNL for more than 29 years and has concentrated his efforts in the areas of hazardous/radioactive waste management, environmental restoration, and health and safety aspects of emerging energy technologies. His current responsibilities include serving as Division Head for the Environmental Research and Technology Division in BNL's Environmental Sciences Department and as Principal Investigator (PI) for programs on waste form development for the U.S. Department of Energy and industry. He is a co-inventor on nine U.S. patents, including his patents on processes for both ex situ and in situ treatment of mercury. He has served as a member of several national technical support groups on waste encapsulation for the US DOE and EPA (including the Mercury Working Group of DOE's Office of Groundwater and Soil Remediation), co-authored several books and numerous publications on innovative technologies, and is a member of the Program Advisory Committee for Waste Management Symposia, Inc.

Topic 14. Mercury remediation technologies, part 2

SAMMS Technology for Effective Removal of Mercury from Aqueous and Non-aqueous Wastes

Shas Mattigod
Pacific Northwest National Laboratory

Self Assembled Monolayers on Mesoporous Supports (SAMMS) material was developed to fill a critical gap in conventional mercury treatment technologies in that these technologies are not capable of meeting very stringent discharge limits established by for instance by Great Lakes Initiative (≤ 1.3 parts per trillion). SAMMS material for specific adsorption of mercury consists of thiol- functionalized monolayers assembled on the internal pore surfaces of very high surface area (600 – 1000 m^2/g) ceramic substrates. The process uses Green Chemistry in that the functionalization is accomplished using supercritical carbon dioxide medium with byproducts consisting of useable methanol and water. Extensive laboratory testing with mercury-contaminated aqueous and non-aqueous wastes indicated that SAMMS had high adsorption capacity (up to ~600 mg/g), very high specificity (K_d: 1x 10^3 – 1 x 10^6 mL/g), fast kinetics (~99.9% adsorption in 5 min), and was also capable of adsorbing complexed and organo-mercury species[1]. Mercury-loaded SAMMS materials also pass the TCLP test therefore can be disposed of as stable wasteforms without additional stabilization treatment. In 2006, the SAMMS material was licensed for commercial manufacture and deployment to Steward Advanced Materials of Chattanooga, Tennessee. Since then, Steward has used its Continuously-Stirred Tank Reactor (CSTR) System to conduct a number of pilot-scale demonstrations of mercury removal from diverse wastes such as spent leach solution from a silver mine, contaminated groundwater from a chloralkali plant site, and FGD sludge effluents. In all cases, the SAMMS-based Steward CSTR System has demonstrated that effluent mercury concentrations can be reduced to parts per trillion levels. Steward, in partnership with Veolia Water Solutions & Technologies and Siemens Water Technology, is currently developing SAMMS-based mercury high flow (~400 gpm) treatment systems to achieve effluent levels well below 10 parts per trillion.

[1]*http://samms.pnl.gov/*

SHAS MATTIGOD, Ph.D., is a Staff Scientist at Pacific Northwest National Laboratory. His work during the last 25 years has focused on characterizing and developing remediation methods for liquid and solid effluents, leachates, RCRA wastes, contaminated soil, and groundwater from CERCLA sites. He has a master's degree in Civil Engineering from University of New Hampshire and obtained his doctorate in Environmental Chemistry from Washington State University. His current research interests include synthesis of novel nanoporous metal phosphate materials and development of stable wasteforms for radioactive wastes. During the last ten years, he led the testing and contributed to the commercialization of SAMMS adsorbents.

Low-Impact Delivery System for In Situ Treatment of Sediments Contaminated with Methylmercury

Upal Ghosh
University of Maryland, Baltimore County

Important needs in in situ sediment remediation are the selection of efficient sorbent amendments, improvement of scientific understanding of how amendments reduce biouptake, and the development of efficient delivery methods of amendments into contaminated sediments. The first aspect of this research involved selection and testing of various sorbent amendment materials for a range of organic and metal contaminants. Activated carbon-based sorbents, organoclays, and a thiol-amended mesoporous silica (Th-SAMMS) were tested for effectiveness of reducing the bioavailability of mercury and methylmercury in sediments. This talk will present results from laboratory treatability studies using a range of field sediments that demonstrate the effectiveness of the treatment amendments in binding mercury and methylmercury in sediments and reducing the biouptake of the contaminants in a benthic worm. Toxicity studies were also conducted to evaluate the effect of the treatment amendments on sensitive benthic organisms. The second aspect of this research that will be discussed is the development of a pelletized composite product containing the treatment amendments that can be conveniently administered on sediment through a water column. The agglomerate (named SediMiteT) is comprised of a treatment agent (typically activated carbon), a weighting agent (to enable it to sink and resist resuspension), and an inert binder. Sorbents delivered through SediMiteT can be used to treat sediments contaminated with PCBs, mercury, methylmercury, dioxins, furans, PAHs, DDT, and other hydrophobic chemicals. The use of SediMiteT limits the impacts and difficulties with conventional in situ treatment methods and can provide an alternative to dredging and capping. Use of SediMiteT also limits ecological impacts and natural resource damages that could occur when aggressive removal or capping methods are employed.

UPAL GHOSH, Ph.D., teaches Environmental Engineering at the University of Maryland Baltimore County. Prof. Ghosh's research explores fundamental process mechanisms that control contaminant fate in soils, sediments, and aquatic environments. His research uses multidisciplinary tools to investigate exposure and bioavailability of organic and metal contaminants to organisms. The new understanding is used to develop novel remediation technologies and site-specific risk assessment and remediation goals. His recent work has involved monitoring effectiveness of novel technologies to reduce the impacts of pollutants in stormwater runoff. He has also developed an in situ remediation technology to reduce the impacts of legacy contaminants in sediments. Prof. Ghosh is involved in several field trials of this new in situ sediment remediation technology. He has a M.S. and Ph.D. in Civil and Environmental Engineering, and a B.Tech. in Chemical Engineering.

Nanocomposite Treatment Media for Efficient Mercury Remediation

Ganesh Skandan, Mohit Jain, and Jamie McCarthy
NEI Corporation, Somerset, NJ

The presentation will discuss our preliminary work on the development of a new class of nanoparticle-based treatment media where the reaction sites are highly accessible to mercury ions present in contaminated water, thereby leading to efficient and fast removal of mercury. The NEI sorbent was found to have high removal rate as well as high mercury capture capacity in simulated contaminated waters, despite having only a modest surface area as compared to activated carbon. The performance of the sorbent at two mercury concentrations, 100 ppb and 200 ppm, with and without competing ions (e.g., Cu^{2+}, Pb^{2+}), will be described. Further, two different particle morphologies will be described, keeping in mind that the NEI sorbent particles will need to be incorporated in conventional filters and columns without significant changes to their design. The work presented here was done under a Phase I SBIR grant from the Department of Energy, Award Number: DE-FG02-08ER85144, and in collaboration with Prof. D. Bhattacharyya and his group at the University of Kentucky, Lexington.

GANESH SKANDAN, Ph.D., CEO, earned his Ph.D. in Materials Science and Engineering from Rutgers University, having worked on nanomaterials for his doctoral work. As a graduate student he co-developed and patented two processes for producing nanoparticles, and received the Hoechst Celanese award for Graduate Excellence. Shortly after his graduate work, Dr. Skandan co-founded NEI Corporation. As Vice President R&D for six years at NEI Corporation, he led the development of an array of Nanomaterials Synthesis technologies that today constitutes the technology platform that NEI is built on. He was successful in utilizing federally funded programs for technology development. As CEO of for the past five years, he transitioned funded technology development programs into commercial products, and assembled a strong management team to grow the company. His technical prowess, management skills and business acumen have enabled NEI to grow over the years into a financial stable Nanomaterials company. He led the formation of a joint venture with the United Credit Group in Kolkata, India, to form United Nanotech Products Limited (UNTPL), based in Kolkata, India. UNTPL currently manufactures battery electrode materials for commercial use. Dr. Skandan was recognized as outstanding alumnus of the Graduate School at Rutgers University at its 50th anniversary. His undergraduate education at Indian Institute of Technology, Bombay, India, was funded by Yule Scholarship Fund, India. Dr. Skandan has been instructor for graduate and undergraduate courses on Materials Science at Rutgers University and Stevens Institute of Technology, New Jersey. He is frequently invited to speak at technical and business conferences, and is associated with the National Academy of Engineering through the Frontiers of Engineering Series Symposia. He is often called upon to review proposals for the National Science Foundation and review papers for publication in scientific journals. He has co-authored encyclopedia articles, edited conference proceedings, has been awarded nine patents, and has co-authored several technical articles. Dr. Skandan has also been director of an industry-oriented course on nanotechnology organized by the Center for Professional Advancement.

An Innovative Nanotechnology for In Situ Mercury Immobilization

Zhong (John) Xiong[1], Yanyan Gong[2], Dongye Zhao[2], Dawn Kaback[3], and Bruce Wielinga[3]
[1]AMEC Geomatrix, Inc., Newport Beach, CA; [2]Environmental Engineering Program, Department of Civil Engineering, Auburn University; [3]AMEC Geomatrix, Inc., Denver, CO

Mercury (Hg) is one of the most pervasive and bioaccumulative contaminants. Once Hg is released to water and sediments, it can be transformed by bacteria to methylmercury, which is a potent neurotoxin and can accumulate along the aquatic food chain. An innovative technology has been developed to immobilize Hg in contaminated water or soil by using iron sulfide (FeS) nanoparticles. The nanopartices were prepared using a low-cost, food-grade, and biodegradable cellulose (sodium carboxymethyl cellulose, CMC) as the stabilizer. The hydrodynamic diameter of freshly prepared FeS nanoparticles was measured to be 38.4±5.4 nm based on Transmission Electron Microscope (TEM) and Dynamic Light Scattering (DLS) tests. Batch and column tests showed that FeS nanoparticles can effectively immobilize Hg in sediment. The distribution coefficient for the nanoparticles was determined to be 8,930±1,480 L/g, which is >4 orders of magnitude greater than that for the sediment. When the Hg-laden sediment was treated at an FeS-to-Hg molar ratio of 26.5, the Hg concentration leached into water was reduced by 97% and the TCLP (toxicity characteristic leaching procedure) leachability of Hg was reduced by 99%. Column tests showed that water-leachable mercury from the sediment containing 3120 mg/L Hg was reduced by 67% and the TCLP leachability by >77% when the sediment was treated with 67 pore volumes (PVs) of a 0.5 g/L FeS nanoparticle suspension. Column tests also proved that the stabilized FeS nanoparticles were highly mobile in the sediment and full breakthrough occurred at about 18 pore volumes, indicating that FeS nanoparticles may be injected into the subsurface to treat Hg-contaminated areas. This innovative technology may serve as a powerful in situ remediation alternative for mitigating toxic impacts of Hg in sediments, soil, and groundwater.

ZHONG XIONG, Ph.D., is a staff engineer with AMEC Geomatrix's Newport Beach, CA office. He received his BS and MS degrees in Environmental Engineering from Chongqing University in China, and his Ph.D. degree in Civil Engineering from Auburn University. His research interests and work experiences are in the areas of environmental remediation, especially the development and application of innovative nanoscale materials for remediation and site clean-up.

Biographies of Mercury Summit steering committee members

Skip Chamberlain, P.E., is the Acting Office Director for the U.S. Department of Energy's Office of Groundwater and Soil Remediation. He is responsible for coordinating, funding, and overseeing DOE's national applied subsurface research program. Major programmatic focus areas include remediation of metals, radionuclides, and chlorinated solvents; subsurface modeling and characterization; and contaminant fate and transport in saturated and vadose zone environments. During his 17 years at DOE, Mr. Chamberlain has been involved in all aspects of the agency's applied subsurface science activities, including research program development, field-scale technology demonstrations, and technology transfer to DOE sites and to other agencies. Before joining DOE, he worked for the U.S. Geological Survey, the U.S. Department of Agriculture, and an engineering consulting firm. Mr. Chamberlain earned a bachelor's degree in agricultural engineering from the University of Maryland and is a registered Professional Engineer in Maryland. He is based at DOE Headquarters in Germantown, MD.

Jim Clarke, Ph.D., is Professor of the Practice of Civil & Environmental Engineering, Professor of Earth & Environmental Sciences and Director of Graduate Studies for graduate degree options in environmental engineering, environmental science and environmental management at Vanderbilt University. His research interests include risk analysis and risk-informed regulation; investigation, remediation and long term management of legacy hazardous chemical and radioactive waste sites and assessment of the risks and environmental impacts of conventional and emerging energy technologies and approaches. Prior to joining Vanderbilt University, Jim spent 25 years in private practice leading a nationally known consulting and engineering firm specializing in the investigation and remediation of contaminated sites, risk analysis and industrial wastewater treatment. Dr. Clarke is a consultant to the Nuclear Regulatory Commission (NRC) Advisory Committee on Reactor Safeguards and was a member of their former Advisory Committee on Nuclear Wastes and Materials. He received a B.A. in Chemistry with honors from Rockford College and a Ph.D. in Theoretical Chemistry from The Johns Hopkins University.

Dawn S. Kaback, Ph.D., is a Principal Geochemist at AMEC Geomatrix and has more than 30 years of experience in technical and management roles with emphasis on research and technology development for environmental and energy issues. She has successfully implemented innovative solutions for a wide range of environmental problems primarily focused on contaminated groundwater and soil investigation/remediation. Dr. Kaback has dedicated significant efforts to transfer of innovative technologies from government laboratories to commercial practice and holds three patents for an innovative remediation system based upon directional drilling for in situ groundwater treatment. She has served as a technical advisor for a broad range of environmental problems at numerous DOE sites and has participated/led several technical working groups supporting DOE's innovative technology program. Dr. Kaback served 6 years on a National Academy of Sciences Committee for U.S. Geological Survey Water Resources Research. She has taught numerous workshops for the National Ground Water Association, served on their Board of Directors, as editor of *Ground Water Monitoring and Remediation Journal*, as technical editor of the Ground Water News and Views column in *Ground Water Journal*, and received the Keith O. Anderson Award for service to the organization.

RICHARD C. LANDIS is an Engineer Associate with over 30 years of engineering experience with DuPont. His primary career focus has been on research and development of innovative and sustainable technology. Over the past 19 years, his research efforts have been directed to development of environmental remediation technologies. His interests range from reductive dehalogenation of chlorinated and fluorinated compounds, to innovative physical and hydraulic containment methods, to improved methods of measuring contaminant mass flux from sediments, and safe handling and separation of unexploded munitions in soils using remote controlled equipment. Through the DuPont program, he has had long involvement in public-private collaborative programs focused on remediation technology development, and has developed and led training through RTDF and ITRC on such topics as reductive dehalogenation. DuPont has recognized Mr. Landis with its Corporate Sustainable Growth Excellence Awards for development of permeable reactive barrier technology as well as a passive soil vapor extraction system. He has been awarded two patents related to vibratory emplacement technology for in-situ groundwater treatment zones and has contributed to several books and publications on physical barrier containment technologies. Currently Mr. Landis is a contributing member of a multi-functional team studying mercury fate and transport in the South River watershed of Virginia.

BRIAN B. LOONEY, Ph.D., received his Bachelor of Science degree in Environmental Science from Texas Christian University in 1978, and earned his doctorate degree in Environmental Engineering from the University of Minnesota in 1984. Dr. Looney is a senior advisory engineer at the Department of Energy Savannah River National Laboratory (SRNL) in Aiken, SC and an adjunct professor in the Environmental Engineering Science Department at Clemson University. He coordinates development and deployment of innovative environmental characterization and clean-up methods at the Savannah River Site and provides technical support to the DOE Environmental Management Program. Dr. Looney has worked at SRNL for 25 years, during which time he has developed, tested and deployed a wide variety of technologies to creatively, efficiently and sustainably address challenges associated with organic and inorganic contaminants and radionuclides.