2001 International Containment & Remediation Technology Conference and Exhibition

10-13 June 2001 - Orlando, Florida, USA

Containment & Remediation 2001
Florida State University
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Web site: www.containment.fsu.edu

10-13 June 2001 - Orlando, Florida, USA

Sponsoring Organizations:

Cooperating Partner:
Dear Conference Participant:

Welcome to the 2001 International Containment & Remediation Technology Conference and Exhibition. Through Workshops, Plenary Sessions, Technical Sessions, Poster Presentations, an Exhibition and an Off-Site Seminar, this conference will address issues related to:

• Thermal & Chemical Remediation Technologies
• Biological Remediation Technologies
• Modeling
• Barriers, & Permeable Reactive Walls
• Characterization/Monitoring/Verification
• Vadose Zone Issues Influencing Remediation
• Regulatory Acceptance of Technologies
• Multi-Agency Remediation Strategies
• Sediments Remediation
• Long-Term Stewardship

The purposes of the 2001 International Containment & Remediation Technology Conference and Exhibition are to advance the deployment of innovative technologies and to showcase the many R&D efforts used to develop technologies. This conference will accomplish its objectives by:

• disseminating information on successful technology deployments (case studies);
• discussing state of the art methods for solutions to contaminated sites;
• discussing “lessons learned” associated with technology deployments, including regulatory hurdles; and
• identifying opportunities to transfer knowledge to site managers with similar remediation challenges.

The Conference also will address new R&D efforts related to remediation and containment for organic, heavy metals and radioactive contaminants.

In addition to the Exhibition, the Conference will include four workshops and an off-site seminar at the Kennedy Space Center’s Launch Complex 34, which is the site of an on-going multi-agency DNAPL source remediation technology demonstration. These activities will provide conference delegates with additional opportunities to discuss the use of containment and remediation technologies. Experts will be available to discuss and demonstrate equipment and technologies during the Exhibition. The Conference has been organized to facilitate interactions among the conference delegates, exhibitors and sponsoring organizations. The conference hotel, which offers excellent facilities for conferences and guest accommodations, is conveniently located to the many diverse attractions in the Orlando area.

We hope that you will find the 2001 International Containment & Remediation Technology Conference and Exhibition to be an informative, thought-provoking and productive experience.

Sincerely,

Skip Chamberlain
U.S. Department of Energy

Lorne Everett
The IT Group

Annette Gatchett
U.S. Environmental Protection Agency

Paul Lefebvre
U.S. Navy

Jacqueline Quinn
National Aeronautics & Space Administration

Stephen Shoemaker
DuPont Company

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Sixth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe

23-26 September 2002
Prague, Czech Republic

Contact information:
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Sponsoring Organizations:

U.S. Department of Energy
E.I. du Pont de Nemours & Co., Inc.
U.S. Environmental Protection Agency
National Aeronautics & Space Administration
The IT Group
U.S. Navy

Cooperating Partner:

Florida State University
Installation of a permeable reactive barrier at an AFB in South Carolina.
Conference Overview

Registration
Registration will begin on Sunday morning, 10 June at 7:00 AM and will continue throughout the conference in the Convention Registration Lobby.

Welcome Reception
A Welcome Reception will be held on Sunday, 10 June from 5:00 PM – 6:00 PM in the Exhibition Hall of the Radisson Orlando Hotel.

Workshops
Four workshops will be conducted on Sunday, 10 June. Additional information concerning the workshops is provided on pages 6 - 9 of the Conference Program.

Exhibits & Posters
Exhibits and Poster Presentations will be on display in the Exhibition Hall during the conference. Exhibits will be staffed and open during regular conference hours and during all breaks and social activities. Poster Session I will be held on Monday, June 11th from 5:30 – 7:30 PM. Poster Session II will be held on Tuesday, June 12th from 5:30 – 7:30 PM. Refreshments will be served near to the poster presentation area during both Poster Sessions, and authors will be available to discuss their poster presentations during these times.

Concurrent Sessions
Presentations will be made during the technical sessions on Monday, 11 June through Wednesday, 13 June. A listing of sessions and presentations can be found on pages 12-27 of this program. The Conference Schedule lists session titles, locations and times.

Breakfast and Breaks
Continental breakfasts and refreshment breaks for morning and afternoon will be provided in the Exhibition Area.

Lunches
Lunches are not included in the conference fee. Participants are to make their own arrangements for lunch. A lunch cart will be available in the Exhibition Area for quick meals with a variety of sandwiches and snacks from 11:00 AM – 2:00 PM on Monday, 11 June and Tuesday, 12 June. Alternatively, the Radisson’s Food Court offers a variety of fast food including: Pizza Hut, TCBY, deli sandwiches, salads, deserts, flavored coffees, juices and other beverages. The Food Court is open daily 6:00 AM to 2:00 AM. The Radisson’s Palm Court Restaurant serves Florida regional cuisine - breakfast, lunch and dinner. An American breakfast buffet is available daily.

Proceedings
The 2001 International Containment & Remediation Technology Conference and Exhibition Proceedings will be published following the conference. The proceedings will include three-page extended abstracts of the papers and posters presented during the conference. One copy of the conference proceedings will be provided to each registrant at no additional charge. Additional copies of the proceedings can be ordered at the Registration Desk or from the conference organizers.

Relief well installation at base of gypsum stack.
Conference Floorplan

Registration:
Convention Registration Lobby

Exhibition:
Exhibit Hall

Poster Presentations:
Exhibit Hall

Slide Check Room:
Palm Beach

Lunch - Cash Food Cart:
Exhibit Hall

Radisson Hotel in Orlando
Seminar on DNAPL Source Removal Technology Demonstrations
at NASA’s Launch Complex 34
Wednesday, 13 June 2001
12:30 PM - 6:30 PM

NASA’s Launch Complex 34 at Cape Canaveral Air Station is the site of a unique and on-going multi-agency DNAPL source remediation technology demonstration. The three technologies deployed at the site are attempting to remove or destroy over 30,000 kg of trichloroethylene from beneath a building at the Complex. These technologies include *In Situ* Chemical Oxidation with Potassium Permanganate, Six Phase Resistive Soil Heating and Dynamic Underground Stripping with Co-Air Injection. During this conference, a seminar addressing the status of the three technologies will be conducted at NASA’s Launch Complex 34. This seminar will include bus service from the conference hotel, a boxed lunch and the opportunity to see the steam flood system in operation and meet with vendors from all three of the technologies.
Join industry professionals for a one-day intensive workshop as they demonstrate the manufacturing, fabrication, field installation, design, analysis, specification and testing of PVC geomembranes. PVC geomembranes are being used in a wide variety of applications, including waste containment facilities, waste ponds, decorative ponds, canals, and mining facilities. This workshop will present the information required to design, specify, and construct PVC geomembranes for these applications.

For more than a decade, the PVC Geomembrane Institute (PGI) has been advancing the use of PVC geomembranes through education and research. The PGI-Technology Program (PGI-TP), established at the University of Illinois at Urbana-Champaign in 1998, conducts research and disseminates technical information about PVC geomembranes.

David E. Daniels is Dean of the College of Engineering at the University of Illinois and his research over the last twenty years has focused on the containment aspects of landfill lining and cover systems. Timothy D. Stark is a Professor of Civil and Environmental Engineering at the University of Illinois and his research over the last ten years has focused on the shear strength and stability of landfill lining and cover systems.
In situ thermal remediation processes have been developed to address recalcitrant compounds such as chlorinated solvent DNAPLs, creosote, heavy oils and PAHs. Such contaminants, particularly in high dissolved concentration or NAPL-phase source regions are difficult or impossible to treat with other remedial techniques such as soil vapor extraction (SVE), air sparging, bioremediation or groundwater pump and treat. Recalcitrant compounds, which have vapor pressures less than the practical limits of soil vapor extraction (SVE) and air sparging techniques and/or have high viscosity at ambient temperatures, are not amenable to remediation using these commonly applied techniques, even though they are commonly described as preferred alternatives in remedial action plans and finalized RODs for solvents, fuels and semi-volatile compounds.

In comparison, in situ thermal remediation processes are highly effective for the recovery of volatile, and semi-volatile contaminants from the subsurface. Historically, the petroleum engineering literature has documented a large amount of research and application of in situ thermal processes to enhance oil recovery. The use of in situ thermal processes to enhance remediation of recalcitrant contaminants is relatively new and has only been applied since the mid 1980's. The more widespread use of these in situ thermal processes as an effective mechanism for source term removal has developed during the last decade.

The process of in situ heating enhances extraction and in situ destruction processes in several ways, including:

* increasing vapor pressure and volatilization rates of volatile and semi-volatile compounds;
* reducing viscosity and increasing thermal desorption of semi-volatile and nonvolatile compounds resulting in greater mobility of liquid-phase hydrocarbons (LPH); and
* physical displacement of mobilized LPH in both unsaturated and saturated conditions.

There are several ways to apply heat to the subsurface including radio frequency (RF) heating, hot air injection, steam injection, electrical resistance heating and electrical conductive heating.

**Advantages of Thermally Enhanced Remediation**
Remediation of subsurface materials with VOC contamination is enhanced through one or more of the following mechanisms:

* Volatilization and increased recovery rates due to increased vapor pressure;
* Dissolution due to increased solubility;
* Liquid flow due to reduced viscosity and/or density;
* Desorption due to decreased solid-phase adsorption and organic-matter absorption;
* Molecular diffusion in aqueous and gaseous phase due to increased diffusion coefficients;
* Distillation; and
* Hydrous Pyrolysis/Oxidation.

These mechanisms can significantly shorten the duration of source term removal. In most cases, removal rates are increased by orders of magnitude, consequently reducing remediation time from decades to months.

The purpose of this workshop is to introduce the regulatory conditions governing thermal source term removal strategies; the principles of the various in situ thermal remediation approaches, including Dynamic Underground Stripping, Steam Enhanced Extraction, electrical resistance and electrical conductive heating; and to provide examples of field applications and “lessons learned”. A panel discussion will be held at the close of the workshop to facilitate questions/answers for the workshop participants.
Workshop III

In Situ Chemical Oxidation Using Permanganate (Colorado School of Mines)
Sunday, 10 June, 1:00 PM - 5:00 PM, Osceola and Lake

Workshop Organizer: Robert L. Siegrist
Colorado School of Mines

This workshop is focused on the application of permanganate-based chemical oxidation processes for in situ treatment of contaminated soil and groundwater. Chlorinated solvents, petroleum products, PAH’s, and pesticides are commonly encountered contaminants and, in many environmental settings, they are difficult to biodegrade. However, many of these organic contaminants are amenable to rapid and complete destruction by chemical oxidation and/or to partial chemical degradation as an aid to subsequent biodegradation. Chemical oxidation technologies using KMnO$_4$ or NaMnO$_4$ have been developed and effectively employed for in situ remediation by coupling the oxidation chemistries with alternative process delivery systems. Experiences have involved KMnO$_4$ or NaMnO$_4$ delivered into subsurface regions as liquids or solids through vertical and horizontal injection probes and wells, hydraulic fracturing with permanganate solids, and enhanced soil mixing. This workshop will present an overview of in situ chemical oxidation including comparisons between permanganate and peroxide and ozone oxidants, and then describe the principals and practices of in situ chemical oxidation using permanganate. The workshop will be patterned after a forthcoming book on the subject by Siegrist et al. to be published by Battelle Press.
Characterization and remediation of residual industrial solvents, primarily Dense Non-Aqueous Phase Liquids (DNAPLs), represent a significant challenge for the successful completion of many large groundwater and soil cleanup projects. Slowly dissolving DNAPLs can provide a major source of groundwater contamination for hundreds of years. At waste sites where DNAPLs are suspected, an accurate conceptual model of the nature and extent of the non-aqueous phase contamination must be a key component of any comprehensive remediation strategy. Traditional sampling approaches generally are not effective for locating DNAPLs. Precise delineation of DNAPL areas will facilitate the design of the most effective remediation strategies and help keep cleanup costs from escalating. This informal, interactive two-hour workshop will be focused on developing a working understanding of effective DNAPL site characterization approaches and site conceptual model development. Innovative baseline and innovative technologies for DNAPL characterization will be described along with examples of successful field applications and “lessons learned”.

Course Outline

Introduction
• Definition
• Behavior of DNAPL in the subsurface
• Implications for characterization and cleanup

Baseline Characterization Methods
• DNAPL characterization basics
• Conceptual model development
• Geology and the value of depth-discrete data
• Data integration and weight of evidence approach

Baseline and Innovative Methods
• Baseline soil gas, groundwater and sediment sampling
• Geophysical methods
• Innovative tools and cone penetrometer-based methods

Instructors
Joe Rossabi, Carol Eddy-Dilek, and Brian Looney have been researching solutions to characterization and remediation for the past 10 years at DOE’s Savannah River Site. During this time they have developed or deployed more than 50 characterization and remediation technologies including many cone penetrometer-based tools. Their experience encompasses all aspects of site investigation from access methods to analytical and sensing techniques to 3D visualization and conceptual model development.
The U.S. Department of Energy's Office of Environmental Management is responsible for addressing the environmental legacy of nuclear weapons research, production and testing and of DOE-funded nuclear energy and basic science research in the United States. As Assistant Secretary for the Office of Environmental Management, Dr. Carolyn Huntoon has managed this program which addresses some of the most technically challenging work of any environmental program in the world.

Dr. Huntoon will officially open the 2001 Containment and Remediation Technology Conference.

Dr. Carolyn Huntoon  
Acting Assistant Secretary  
U.S. Department of Energy
Science, economics and political considerations are critical factors when determining the need for as well as the extent and practicality of cleaning up environmental contamination. These factors are faced regularly by public and private entities worldwide. The role of science in environmental remediation will be addressed in this opening plenary session. Critical scientific needs, considerations and unknowns limit the remediation of many types of environmental contamination. These issues will be identified and posed as the basis for the subsequent panel discussion.

Alternatives to Excavation and Storage: The Role of Science

Dr. Ernest Moniz
Professor, Department of Physics
Massachusetts Institute of Technology
(former) Under Secretary, U.S. Department of Energy

Following Dr. Moniz’s presentation, the following panel will address the key scientific issues associated with environmental cleanup.

Moderator
Dr. Jacqueline W. Quinn
Kennedy Space Center
National Aeronautics & Space Administration

Panelists
Mr. John J. Barich
Office of Research and Development/Region 10
U.S. Environmental Protection Agency

Mr. Gerald Boyd
Deputy Assistant Secretary
U.S. Department of Energy

Mr. Stephen E. Eikenberry
Head, Environmental Department
Naval Facilities Engineering Service Center
U.S. Navy

Mr. Robert Perciasepe
Senior Vice President
The IT Group
In the U.S., we are reorienting national cleanup programs (e.g., RCRA corrective action, Superfund) from process-oriented to results-based measures of progress. As sites are brought into “stable” conditions with regard to human health risk and waste migration, an important remaining issue is how to define success in the context of environmental cleanup. What are the appropriate “results” that we hope to achieve? Under what conditions should we attempt to restore sites that could be made protective through exposure control? How do we ensure effective long-term stewardship of these sites? Panelists representing various stakeholder perspectives will discuss these and other important public policy issues and field questions from the audience.

Panel Discussion:
In Quest of the “Final Remedy”: What’s Next for Cleanup Programs?

Moderator
Lorne G. Everett, Ph.D., D.Sc.
Chief Scientist, The IT Group
Chancellor, Lakehead University

Panelists
Mr. Stephen D. Luftig
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency

Dr. Hugh J. Campbell, Jr.
Environmental Manager
E.I. DuPont De Nemours & Co., Inc.

Mr. Mark J. O’Brien
Senior Vice President
Marsh Risk & Insurance Services
Session 1
Barriers, Caps and Liners: Materials, Testing and Development
Monday, 11 June, 1:00 PM - 3:00 PM, Seminole A

Session Chairs: Jeffrey C. Evans
Bucknell University
Richard C. Landis
E.I. du Pont de Nemours & Co., Inc.

1:00 PM
Asphalt Barriers for Waste Containment [7]
J.J. Bowders, J.E. Loehr, D. Neupane, University of Missouri-Columbia, Columbia, Missouri, USA;
A.M. Bouazza, Monash University, Melbourne, Victoria, Australia

1:20 PM
A New Technique for Building In Situ Sub-Surface Hydrologic Barriers: NBT [192]
C.L. Waring, Australian Nuclear Science and Technology Organization, Menai, Sydney,
New South Wales, Australia; J.R. Taylor, Earth Systems Pty Ltd, Kew, Melbourne, Victoria, Australia

1:40 PM
Unique Hydraulic Conductivity Test Results from a Self-Hardening Slurry [222]
G.E. Thomas, URS Corporation, Totowa, New Jersey, USA; G.R. Tallard, Liquid Earth Support, Inc.,
Pelham, New York, USA

2:00 PM
Shale as a Sorbent Additive to Increase Containment Barrier Efficiency [249]
R.W. Gullick, American Water Works Service Company, Inc., Voorhees, New Jersey, USA;
W.J. Weber, Jr., University of Michigan, Ann Arbor, Michigan, USA

2:20 PM
Compatibility of Soil/Bentonite Slurry Wall Backfill with Coal Tar at a Former Mid-Western MGP Site [290]
E.P. Zimmerman, Harding ESE, Inc., Nashua, New Hampshire, USA

2:40 PM
Permeability: A Dynamic Property of Barrier Materials [427]
S.A. Jeffers, University of Surrey, Surrey, England

Session 2
Programs for Facilitating Regulatory Acceptance of Technologies
Monday, 11 June, 1:00 PM - 3:00 PM, Seminole B

Session Chair: Brent Hartsfield
Florida Department of Environmental Protection

1:00 PM
Interstate Technology and Regulatory Cooperation Work Group [468]
C. Diehl, Southern States Energy Board, Norcross, Georgia, USA

1:20 PM
State Coalition for the Remediation of Drycleaners [16]
R. De Zeeuw, Oregon Department of Environmental Quality, Portland, Oregon, USA;
R.R. Steimle, U.S. Environmental Protection Agency, Washington, DC, USA

1:40 PM
RFI to CMS: An Approach to Regulatory Acceptance of Site Remediation Technologies [92]
M.A. Rowland, Lockheed Martin Space Systems Company, New Orleans, Louisiana, USA

2:00 PM
EPA SITE Program: Facilitating Technology Transfer and Regulatory Acceptance [454]
A. Gatchett, U.S. Environmental Protection Agency, Cincinnati, Ohio, USA

2:20 PM
The Environmental Technology Verification (ETV) Program: Striving to Achieve Acceptance of Innovative Environmental Technologies [437]
E. Koglin, U.S. Environmental Protection Agency, Las Vegas, Nevada, USA

2:40 PM
Health and Safety Evaluations of Field Environmental Technologies [247]
R.J. Lovett, A.S. Roberts, NEETC, Inc, Indiana, Pennsylvania, USA;
K.R. Miezio, K. Proch, Indiana University of Pennsylvania, Indiana, Pennsylvania, USA

concurrent sessions 1 & 2
Session 3
Bioremediation of Chlorinated Solvents
Monday, 11 June, 1:00 PM - 3:00 PM, Osceola

Session Chairs: Terry Hazen Kent Sorenson
Lawrence Berkeley Idaho National Engineering
National Laboratory and Environmental Laboratory

1:00 PM Bioremediation: The Hope and the Hype [321]
T.C. Hazen, Lawrence Berkeley National Laboratory, Berkeley, California, USA

1:20 PM Combining Biostimulation for Source Area Treatment with Monitored Natural Attenuation for Restoration of a Large TCE Plume [335]
K.S. Sorenson, Jr., L.N. Peterson, INEEL, Idaho Falls, Idaho, USA; R.L. Ely, Yale University, New Haven, Connecticut, USA

1:40 PM Time-Release Electron Donor Technology: Results of Forty-Two Field Applications [116]
S.S. Koenigsberg, C.A. Sandefur, K.A. Lapus, Regenesis, San Clemente, California, USA

2:00 PM Case Studies in Enhanced Reductive Dechlorination [263]
F.C. Payne, ARCADIS Geraghty & Miller, Novi, Michigan, USA; N.A. Gillotti, ARCADIS Geraghty & Miller, Columbus, Ohio, USA; F.C. Lenzo, ARCADIS Geraghty & Miller, Langhorne, Pennsylvania, USA; J.J. Reid, ARCADIS Geraghty & Miller, Columbus, Ohio, USA

2:20 PM Remediation of Chlorinated Solvent Groundwater Plume Using NoVOCs Recirculating Well Technology - A Field Study [274]
G. Frearson, B. Koenig, Metcalf & Eddy, Inc., Miramar, Florida, USA; B.D. Hartsfield, W.E. Burns, Florida Department of Environmental Protection, Tallahassee, Florida, USA

2:40 PM Bioremediation of Solvents in Fractured Rock Groundwater Resulting in Significant VOC Reductions [72]
G.L. Carter, Earth Tech, Roanoke, Virginia, USA

Session 4
Innovative Approaches to Characterization of Sites Contaminated with DNAPL or Volatile Organic Compounds I
Monday, 11 June, 1:00 PM - 3:00 PM, Lake

Session Chairs: Carol Eddy-Dilek Carl Keller
Savannah River Flexible Liner Underground Technologies
Technology Center

1:00 PM Characterization of DNAPL-Contaminated Sites - Past, Present and Future [469]
C. Eddy-Dilek, Savannah River Technology Center, Aiken, South Carolina, USA

1:20 PM Drycleaning Solvent Contamination in Florida [96]

1:40 PM Demonstration of Rapid In Situ Detection of VOCs by Membrane Introduction Mass Spectrometry [83]
J. Costanza, Naval Facilities Engineering Service Center, Decatur, Georgia, USA; W.M. Davis, U.S. Environmental Protection Agency, Atlanta, Georgia, USA

2:00 PM Site Characterization with the Membrane Interface Probe [160]
C.E. Hudson, CH2M Hill Constructors, Inc., Orlando, Florida, USA

2:20 PM Innovative Techniques to Investigate Contamination in Fractured Bedrock [155]

2:40 PM Locating DNAPLs with Flexible Liners [202]
C. Keller, Flexible Liner Underground Technologies, Santa Fe, New Mexico, USA
Session 5
Barriers, Caps and Liners: Case Studies and Demonstration Projects
Monday, 11 June, 3:15 PM - 5:15 PM, Seminole A

Session Chairs: Stephan A. Jefferis
University of Surrey
Steven R. Day
Geo-Solutions Inc.

3:15 PM Self-Healing Soft Grouts Form In Situ Bottom Barrier In EarthSaw Field Demo [25]
E.E. Carter, Carter Technologies Co., Sugar Land, Texas, USA

3:35 PM Closure of an Underground Tunnel with Long Distance Grouting [133]

3:55 PM Deployment of a Colloidal Silica Barrier at Brookhaven National Laboratory [134]
M.A. North-Abbott, MSE Technology Applications, Butte, Montana, USA; J. Heiser, Brookhaven National Laboratory, Upton, New York, USA; K.R. Manchester, J.M. Trudnowski, M.J. Moe, J.L. Bickford, MSE Technology Applications, Butte, Montana, USA

H. Ahmad, D. Leszczynska, FAMU-FSU College of Engineering, Tallahassee, Florida, USA; S. Thevanayagam, State University of New York, Buffalo, New York, USA

4:35 PM Operation and Maintenance of the Frozen Barrier at the HRE Pond [305]
E. Yarmak, AFI Permafreeze, Anchorage, Alaska, USA; E. Phillips, U.S. Department of Energy, Oak Ridge, Tennessee, USA

4:55 PM Side-Slope Considerations for Above-Grade Earthen Covers [75]
A.L. Ward, G.W. Gee, Battelle, Pacific Northwest National Laboratory, Richland, Washington, USA

Session 6
Treatment of Contaminants by Extraction or Stabilization
Monday, 11 June, 3:15 PM - 5:15 PM, Seminole B

Session Chairs: A. Lynn Wood
U.S. Environmental Protection Agency
Thomas O. Early
Oak Ridge National Laboratory

3:15 PM Field Demonstration of Surfactant-Enhanced DNAPL Remediation: Case Studies [346]
B.J. Shiau, M.A. Hasegawa, Surbec-ART Environmental, L.L.C., Norman, Oklahoma, USA; D.A. Sabatini, R.C. Knox, J. Harwell, University of Oklahoma, Norman, Oklahoma, USA; R. Lago, Tetra Tech EMI, San Francisco, California, USA

3:35 PM Deployment of Chemical Extraction Soil Treatment on Uranium Contaminated Soil [308]
J. Kulpa, Earthline Technologies, Ashtabula, Ohio, USA

3:55 PM Immobilization of Radionuclides in Soil Minerals After Thermal Treatment [56]
B.P. Spalding, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

4:15 PM Demonstration of Non-Traditional (Sub-Surface) In Situ Vitrification Technology at Los Alamos National Laboratory [270]

4:35 PM In Situ Soil Stabilization of a Former MGP Site using Shallow Soil Mixing (SSM) [252]
V. Jayaram, R.M. Schindler, M. Marks, Geo-Con, Tampa, Florida, USA; E. Walsh, Lyme Properties LLC, Cambridge, Massachusetts, USA; T.J. Olean, ThermoRetec Corporation, Concord, Massachusetts, USA

4:55 PM Containment of Phenolic Contaminants in Soils by Peroxidase Addition [356]
A. Bhandari, F. Xu, Kansas State University, Manhattan, Kansas, USA
Session 7
Bioremediation & Phytoremediation of Other Contaminants
Monday, 11 June, 3:15 PM - 5:15 PM, Osceola

Session Chairs: Anthony Palumbo William T. Stringfellow
Oak Ridge National Laboratory Lawrence Berkeley National Laboratory

3:15 PM Resolving Problems Associated with the Biological Treatment of MTBE Contaminated Groundwater [277]
W.T. Stringfellow, K.C. Oh, Lawrence Berkeley National Laboratory, Berkeley, California, USA

3:35 PM Case Study of Monitored Natural Attenuation of Dissolved Chlorinated Hydrocarbons at a Former Railroad Maintenance Facility [235]
P.J. Lacko, R.N. Leins, Gannett Fleming, Tampa, Florida, USA; K. Brinker, CSX Transportation, Inc., Jacksonville, Florida, USA

3:55 PM Oxygen Release Compound Stimulation of Biodegradation Following Landfill Excavation [55]
K. Brown, D. Williams, P. Linley, B. Norton, IT Corporation, Knoxville, Tennessee, USA; J. Mosher, CDM Federal Programs Corporation, Lenexa, Kansas, USA

4:15 PM Aerated Landfills, Changing the Subtitle D Dry Tomb Paradigm [320]
T.C. Hazen, Lawrence Berkeley National Laboratory, Berkeley, California, USA

4:35 PM Use of Engineered Wetlands to Phytoremediate Explosives Contaminated Surface Water at the Iowa Army Ammunition Plant, Middletown, Iowa [416]
D.D. Moses, R.P. Sellers, U.S. Army Corps of Engineers, Omaha, Nebraska, USA; S.L. Larson, Watersystems Experiment Station, Vicksburg, Mississippi, USA; J.H. Kiker, Environmental Chemical Corporation, Providence, Rhode Island, USA

4:55 PM Remediation of Explosives Contaminated Soils at Joliet Army Ammunition Plant via Windrow Composting [69]

Session 8
Innovative Approaches to Characterization of Sites Contaminated with DNAPL or Volatile Organic Compounds II
Monday, 11 June, 3:15 PM - 5:15 PM, Lake

Session Chairs: George Blaha Clifford Ho
RS DYNAMICS Ltd Sandia National Laboratory

3:15 PM Characterization of the Vadose Zone using Partitioning Interwell Tracer Tests [170]
J.T. Londergan, C.M. Young, J.A.K Silva, Duke Engineering & Services, Austin, Texas, USA; J.P. Moran, S.M. Stoller Corporation, Boulder, Colorado, USA; J.C. Childress, M.R. Amos, BWXT Pantex, LLC, Amarillo, Texas, USA

3:35 PM Source Characterization of a DNAPL Site using Multiple Assessment Techniques [331]
B.W. Nocita, C.D. Henry, J.P. Caballero, T.W. Griffin, HSW Engineering, Inc., Tampa, Florida, USA

3:55 PM Accurate Assessment of Natural Attenuation using Depth Discrete Multi-level Monitoring: Evidence at Three Chlorinated Solvent Sites [316]
M.A. Gulbeaut, B.L. Parker, J.A. Cherry, University of Waterloo, Waterloo, Ontario, Canada

4:15 PM Characterizing the Release and Discharge of a Contaminant Plume using a Numerical Model, Environmental Tracers and Water-to-Vapor Diffusion Samplers [167]
C. Casey, Southern Division Naval Facilities Engineering Command, North Charleston, South Carolina, USA

4:35 PM Microchemical Sensors for In Situ Monitoring and Characterization of Volatile Contaminants [143]
C.K. Ho, R.C. Hughes, M.W. Jenkins, M.T. Itamura, M. Kelley, Sandia National Laboratories, Albuquerque, New Mexico, USA; P. Reynolds, Team Specialty Products, Albuquerque, New Mexico, USA

4:55 PM New Method & Instrumentation for the In Situ Soil Contamination Survey [362]
G. Blaha, L. Kouklík, RS DYNAMICS Ltd, Prague, Czech Republic

 concurrency: 15
Session 9
Step Change Improvements for Department of Energy’s Subsurface Remediation Program
Tuesday, 12 June, 8:00 AM - 10:00 AM Seminole A

Session Chair:  Karen Hooker
U.S. Department of Energy

8:00 AM  Building on Success I: Raising the Standards of Performance [493]
G. Boyd, U.S. Department of Energy, Washington, DC, USA

8:20 AM  Building on Success II: Strengthening the Foundation [496]
M. Goddu, JMJ Consultants, Inc., Austin, Texas, USA

8:40 AM  Building on Success III: Stretching to Reach Our Goals [494]
T. Heenan, U.S. Department of Energy, Aiken, South Carolina, USA

9:00 AM  Building on Success IV: Achieving Results [492]
J.A. Wright, U.S. Department of Energy, Aiken, South Carolina, USA

9:20 AM  Building on Success V: Forging Our Future [495]
K. Hooker, U.S. Department of Energy, Aiken, South Carolina, USA

Installation of a permeable reactive barrier - hopper full of iron.
Session 10

*In Situ* Thermal Treatment of Organic Contaminants I

Tuesday, 12 June, 8:00 AM - 10:00 AM, Seminole B

**Session Chairs:**
- Roger D. Aines
  - Lawrence Livermore National Laboratory
  - Remediation Program
- J. Edward O Neill
  - Smithville Bedrock National Laboratory

8:00 AM *In Situ* Thermal Desorption of Soils, Completed Project Results, and New Application for Treating MGP Waste [414]

- J.M. Bierschenk, R.S. Baker, TerraTherm, Inc., Fitchburg, Massachusetts, USA; M.I. Kuhlman, MK Tech Solutions, Houston, Texas, USA

8:20 AM Performance Evaluation of a Forced Hot Air Remediation System [163]

- R.C. Dorrler, K.A. Kievit, M. Kleczkowski, Arcadis Geraghty & Miller, Mahwah, New Jersey, USA

8:40 AM Safe, Effective Steam Remediation: Constraints on Removal Mechanisms and Optimum Operational Strategy [322]

- R.D. Aines, R.L. Newmark, J.N. Nitao, C.R. Carrigan, Lawrence Livermore National Laboratory, Livermore, California, USA

9:00 AM Steam Stripping/Hydrous Pyrolysis Oxidation for *In Situ* Remediation of a TCE DNAPL Spill [278]

- G. Heron, S. Carroll, H. Sowers, SteamTech Environmental Services Inc., Bakersfield, California, USA

9:20 AM Steam Remediation of Chlorinated Solvent Sources [285]

- N. Brown, D.L. Parkinson, Integrated Water Resources, Inc., Santa Barbara, California, USA; J. Dablow, IT Corporation, Irvine, California, USA

9:40 AM Discussion

Session 11

Modeling I: Permeable Reactive Barriers and Reactive Transport

Tuesday, 12 June, 8:00 AM - 10:00 AM, Osceola

**Session Chairs:**
- Alan J. Rabideau
  - University at Buffalo
  - The State University of New York
- Craig H. Benson
  - University of Wisconsin-Madison

8:00 AM Moffett Field Funnel and Gate TCE Treatment System: Interpretation of Field Performance using Reactive Transport Modeling [59]

- S.B. Yabusaki, K.J. Cantrell, Pacific Northwest National Laboratory, Richland, Washington, USA; B. Sass, Battelle, Columbus, Ohio, USA

8:20 AM An Approach for Estimating Kinetic Mass Transfer Rate Parameters in Modeling Groundwater Transport at Fernald, Ohio, USA [77]


8:40 AM Economic and Performance Based Design of Monitoring Systems for PRBs [128]

- C.R. Elder, GeoSyntec Consultants, Acton, Massachusetts, USA; C.H. Benson, G.R. Eykholt, University of Wisconsin-Madison, Madison, Wisconsin, USA

9:00 AM Probabilistic Design of a Combined Permeable Reactive Barrier and Natural Biodegradation Remedy [159]

- J.E. Vidumsky, R.C. Landis, E.I. du Pont de Nemours & Co., Inc., Wilmington, Delaware, USA

9:20 AM Fuzzy Systems Modeling of *In Situ* Bioremediation of Chlorinated Solvents [193]

- B. Faybishenko, T.C. Hazen, Lawrence Berkeley National Laboratory, Berkeley, California, USA

9:40 AM Application of a Competitive Cation Exchange Model for Simulating Removal of Strontium in a Zeolite Permeable Reactive Barrier [386]

- J.E. Van Benschoten, A.J. Rabideau, K. Bandilla, A. Chang, A. Patel, University at Buffalo, Buffalo, New York, USA
Session 12
Recent Advances in Characterization of Heterogeneous Sites
Tuesday, 12 June, 8:00 AM - 10:00 AM, Lake

Session Chairs:  
Brian Looney  
Savannah River Technology Center  
Bill Lowry  
Science & Engineering Associates, Inc.

8:00 AM Characterization of Heterogeneous Contaminated Sites - Geometry, Geology, and Geography [446]
B. Looney, Savannah River Technology Center, Aiken, South Carolina, USA

8:20 AM Characteristics of Fractured Rock Hydrogeology that Impact on Contaminated Site Remediation [328]
J.E. Gale, E. Seok, Memorial University and Fracflow Consultants Inc., St. John's, Newfoundland, Canada;  
G.G. Bursey, Fracflow Consultants Inc., Dartmouth, Nova Scotia, Canada

8:40 AM Scale Characteristics of the Different Methods of Measuring Soil Permeability [456]
B. Lowry, S. Dalvit Dunn, N. Mason, V. Chipman, J. Santo, K. Kisiel, Science and Engineering Associates, Inc., Santa Fe, New Mexico, USA

9:00 AM Characterizing Vadose Zone Heterogeneities at Scales Controlling Contaminant Transport using Pneulog® [237]
L.D. Stewart, Praxis Environmental Technologies, Inc., Burlingame, California, USA

9:20 AM Solvent Plume Characteristics Elucidated from a DNAPL Experiment at the Borden Site [309]
K.A. Laukonen, B.L. Parker, J.A. Cherry, University of Waterloo, Waterloo, Ontario, Canada

9:40 AM Discussion

Session 13
Permeable Reactive Barrier Best Practice for Design and Emplacement
Tuesday, 12 June, 10:15 AM - 12:15 PM, Seminole A

Session Chairs:  
Jacqueline W. Quinn  
NASA Kennedy Space Center  
John L. Vogan  
EnviroMetal Technologies Inc.

10:15 AM The Use of Ultrasound to Restore the Dehalogenation Activity of Iron in Permeable Reactive Barriers [151]
C.A. Clausen, C.L. Geiger, D.R. Reinhart, A. Sonawane, University of Central Florida, Orlando, Florida, USA;  
N.E. Ruiz, GeoSyntec Consultants, Inc, Huntington Beach, California, USA;  
J.W. Quinn, NASA Kennedy Space Center, Kennedy Space Center, Florida, USA

10:35 AM The Innovative Use of High Pressure Jetting of Thin Diaphragm Walls to Construct Hydraulic Control Barriers [158]
R.C. Landis, DuPont Specialty Chemicals, Wilmington, Delaware, USA

10:55 AM Wall-and-Curtain for Subsurface Treatment of Contaminated Groundwater [212]
D.R. Lee, D. Hartwig, Atomic Energy of Canada Ltd., Chalk River, Ontario, Canada

11:15 AM Performance of a Deep Iron Permeable Reactive Barrier for Groundwater Remediation of VOCs [217]
G. Hocking, S.L. Wells, R.I. Ospina, Golder Sierra LLC, Atlanta, Georgia, USA

11:35 AM Successful Remediation of Solvent-Contaminated Groundwater using a Funnel & Gate Constructed by Slurry Trench Methods [221]
S.R. Day, Geo-Solutions Inc., Littleton, Colorado, USA;  
J. Porter, B. Kellems, D. Hillman, Hart Crowser, Seattle, Washington, USA

11:55 AM Use of Blast Fracturing and In Situ Treatment Agents for Passive Treatment of a Chlorinated Solvent Plume in Bedrock [240]
V.B. Dick, Haley & Aldrich, Inc., Rochester, New York, USA;  
R. Sheneman, Princeton University, Princeton, New Jersey, USA;  
J.L. Vogan, EnviroMetal Technologies Inc., Waterloo, Ontario, Canada;  
D. Peterson, Regenesis Bioremediation Corp., Red Hook, New York, USA

18 concurrent sessions 12 & 13
Session 14
In Situ Thermal Treatment of Organic Contaminants II
Tuesday, 12 June, 10:15 AM - 12:15 PM, Seminole B

Session Chairs: J. Edward O Neill Roger D. Aines
Smithville Bedrock Lawrence Livermore
Remediation Program National Laboratory

10:15 AM  In Situ Thermal Remediation of DNAPL using Six-Phase Heating [101]
G. Beyke, Thermal Remediation Services, Inc., Marietta, Georgia, USA; D. Fleming,
Thermal Remediation Services Inc., Bellevue, Washington, USA

10:35 AM  Pilot-Scale Thermally Enhanced Soil Vapor Extraction and Free Product Recovery [21]
W.E. Collins, Naval Facilities Engineering Command, San Diego, California, USA;
M.A. Coons, The IT Group, San Diego, California, USA

10:55 AM  Steam Pressure Filtration for the Treatment of Limey Soils Contaminated with Aliphatic
Hydrocarbons [27]
M. Bottlinger, H.B. Bradl, A. Krupp, Umwelt-Campus Birkenfeld, Birkenfeld, Germany;
U. Peuker, Technical University of Karlsruhe, Karlsruhe, Germany

11:15 AM  Remediation of a Partially Fractured Aquifer System Containing a TCE Source using Steam
Enhanced Extraction [117]
P. Dusilek, AQUATEST, Prague, Czech Republic; P. Kvařil, AQUATEST, Liberec, Czech Republic;
K.S. Uded, University of California, Berkeley, California, USA

11:35 AM  The Steam Stripping Process: A Remediation Technique for TBT- and PAH-Contaminated
Dredged Sediments and Soils [43]
A.A. Eschenbach, J. Hoehne, Z. Soeding, G. Luther, GKSS Research Center GmbH,
Geesthacht, Federal Republic of Germany

11:55 AM  Discussion

Session 15
Modeling II: Barriers, Caps and Liners
Tuesday, 12 June, 10:15 AM - 12:15 PM, Osceola

Session Chairs: Craig H. Benson Alan J. Rabideau
University of Wisconsin-Madison University at Buffalo
The State University of New York

10:15 AM  Projected Long-Term Infiltration Rates Through a Degraded Multi-Layer Soil/Geosynthetic
Closure Cap [51]
J.R. Luellen, J.M. Brydges, W.T. Frederick, URS Corporation, Orchard Park, New York, USA

10:35 AM  Stochastic Simulations for Risk-Based Performance Assessments of Long-Term Cover Systems [144]
C.K. Ho, S.W. Webb, B.W. Arnold, Sandia National Laboratories, Albuquerque, New Mexico, USA

10:55 AM  Modeling Contaminant Transport Through Clay Membrane Barriers [146]
M.A. Malusis, C.D. Shackelford, Colorado State University, Fort Collins, Colorado, USA

11:15 AM  Intercode Comparisons for Simulating Water Balance of an Engineered Cover [148]
B.R. Scanlon, University of Texas at Austin, Austin, Texas, USA; M. Christman, GeoSyntec Consultants,
Austin, Texas, USA; R.C. Reedy, University of Texas at Austin, Austin, Texas, USA;
B.A. Gross, GeoSyntec Consultants, Austin, Texas, USA

11:35 AM  Barrier-Controlled Monitored Natural Attenuation [157]
G.M. Fitz, M.A. Widowsen, J.C. Little, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA

11:55 AM  Contaminant Transport through Composite Geomembrane-Soil Cut-Off Walls [172]
G.J. Foose, G. Vonderembse, University of Cincinnati, Cincinnati, Ohio, USA

underlined name denotes speaker
[number in brackets] denotes abstract number

concurrent sessions 14 & 15  19
Session 16
Geophysical Techniques for Site Characterization
Tuesday, 12 June, 10:15 AM - 12:15 PM, Lake


10:15 AM  Quantitative Characterization of an IAS Air Plume using Geophysics [219]
D.P. Simon, D.L. Alumbaugh, C.H. Benson, University of Wisconsin-Madison, Madison, Wisconsin, USA

10:35 AM  Electrical Resistivity Tomography Imaging of a Colloidal Silica Grout Injection [137]
D.K. Reichhardt, CH2M Hill Hanford Group, Inc., Richland, Washington, USA; M. Ewanic, MSE Technology Applications, Inc., Butte, Montana, USA; P. Brunette, Terratherm Environmental Services Inc., The Woodlands, Texas, USA

10:55 AM  Detecting Free Phase Product Outside of Polyvinyl Chloride (PVC) Well Casings [387]
T. Kwader, URS Corporation, Tallahassee, Florida, USA; P.G. Benson, Advanced Borehole Services, Tampa, Florida, USA

11:15 AM  Waste Pit Imaging at the Idaho National Engineering and Environmental Laboratory using the Very Early Time Electromagnetic (VETEM) System [306]

11:35 AM  The Use of 3D Seismic Imaging in Making Groundwater Management Decisions at Hazardous Waste Sites [232]
M. Adams, Resolution Resources, Inc., Warrenton, Virginia, USA

11:55 AM  Rapid Characterization and Removal of Hazardous Gas Cylinders [269]
D.E. Raunig, D.F. Gianotto, INEEL, Idaho Falls, Idaho, USA

Session 17
PRB Field Case Studies: Hydraulic and Geochemical Measurements, Contaminant Removal
Tuesday, 12 June, 1:15 PM - 3:15 PM, Seminole A

Session Chairs: Liyuan Liang Oak Ridge National Laboratory Neeraj Gupta Battelle

1:15 PM  Performance Monitoring of Permeable Reactive Barriers: Hydrologic and Geochemical Assessment [268]
G.R. Moline, L. Liang, O.R. West, N.E. Korte, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

R.T. Wilkin, R. Puls, U.S. Environmental Protection Agency, Ada, Oklahoma, USA

1:55 PM  Geochemical Investigation of Three Permeable Reactive Barriers to Assess Impact of Precipitation on Performance and Longevity [431]
B. Sass, A. Gavaskar, W-S. Yoon, N. Gupta, E. Drescher, Battelle Memorial Institute, Columbus, Ohio, USA; C. Reeter, U.S. Navy, Port Hueneme, California, USA

2:15 PM  Removal of TCE and Chromate in a Permeable Reactive Barrier using Zero-Valent Iron [121]
P. Kjeldsen, T. Locht, A.P. Karvonen, Technical University of Denmark, Lyngby, Denmark

2:35 PM  Performance Monitoring of a Permeable Reactive Barrier at the Somersworth, New Hampshire Landfill Superfund Site [164]
T. Sivavec, General Electric Corporate, Niskayuna, New York, USA; T.A. Krug, K. Berry-Spark, GeoSyntec Consultants, Guelph, Ontario, Canada

2:55 PM  In Situ Treatment of Acid Mine Drainage in Groundwater using Permeable Reactive Materials [110]
D.J.A. Smyth, D.W. Blowes, University of Waterloo, Waterloo, Ontario, Canada; S.G. Benner, Stanford University, Stanford, California, USA; A.H.M. Hulshof, University of Waterloo, Waterloo, Ontario, Canada

20 concurrent sessions 16 & 17 underlined name denotes speaker [number in brackets] denotes abstract number
### Session 18
#### Treatment of Organic Contaminants by *In Situ* Chemical Oxidation I
##### Tuesday, 12 June, 1:15 PM - 3:15 PM, Seminole B

**Session Chairs:**
- Robert L. Siegrist
  - Colorado School of Mines
- Laymon L. Gray
  - Florida State University

<table>
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<tr>
<th>Time</th>
<th>Title</th>
<th>Abstract ID</th>
<th>Authors and Institutions</th>
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<tbody>
<tr>
<td>1:35 PM</td>
<td><em>In Situ</em> Chemical Oxidation of a Perchloroethene Source Area using Potassium Permanganate [313]</td>
<td>313</td>
<td>M.J. Salvetti, W.A. Murray, Harding ESE, Wakefield, Massachusetts, USA; E.R. Nwokike, Naval Facilities Engineering Command, Charleston, South Carolina, USA</td>
</tr>
<tr>
<td>1:55 PM</td>
<td><em>In Situ</em> Oxidation of DNAPL using Permanganate: IDC Cape Canaveral Demonstration [265]</td>
<td>265</td>
<td>W.C. Leonard, IT Corporation, Miami Lakes, Florida, USA; E. Mott-Smith, J. Ramirez, IT Corporation, Tampa, Florida, USA; R.W. Lewis, IT Corporation, Norwood, Massachusetts, USA</td>
</tr>
<tr>
<td>2:15 PM</td>
<td>Delivery of Permanganate Solution to a DNAPL Zone using a Direct Push Tool and Density Induced Flow [315]</td>
<td>315</td>
<td>C. Stewart Bourne, B.L. Parker, J.A. Cherry, University of Waterloo, Waterloo, Ontario, Canada</td>
</tr>
<tr>
<td>2:55 PM</td>
<td><em>In Situ</em> Oxidation Treatment of High Explosives in Groundwater [267]</td>
<td>267</td>
<td>W.S. Clayton, Aquifer Solutions, Inc., Evergreen, Colorado, USA; T. Harris, Mason and Hanger, Amarillo, Texas, USA; B. Marvin, IT Corporation, Concord, California, USA; A. Struse, IT Corporation, Denver, Colorado, USA</td>
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### Session 19
#### Sediment Characterization
##### Tuesday, 12 June, 1:15 PM - 3:15 PM, Osceola

**Session Chairs:**
- Michael R. Palermo
  - U.S. Army Engineering
- Ruth W. Owens
  - U.S. Navy Research & Development Center

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<tr>
<td>1:35 PM</td>
<td>The Use of Sediment Trend Analysis (STA*) in Contaminant Management Issues [108]</td>
<td>108</td>
<td>P. McLaren, GeoSea Consulting Ltd., Brentwood Bay, British Columbia, Canada</td>
</tr>
<tr>
<td>1:55 PM</td>
<td>Innovative Strategies for the Investigation and Remediation of Metals-Contaminated Sediment in the St. Lawrence River [435]</td>
<td>435</td>
<td>M. Johns, F. Dillon, Windward Environmental LLC, Seattle, Washington, USA; M. Ciubotariu, M. Claude-Wilson, R. Ciubotariu, Tecslt, Montreal, Quebec, Canada</td>
</tr>
<tr>
<td>2:15 PM</td>
<td>Using Rapid Sediment Characterization Technologies to Expedite the Marine Site Characterization Process [66]</td>
<td>66</td>
<td>M. Pound, Naval Facilities Engineering Command, San Diego, California, USA; J.M. Leather, SPAWAR, San Diego, California, USA; P. White, Battelle, Oakland, California, USA</td>
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<tr>
<td>2:35 PM</td>
<td>Remedial Decisions for Estuarine Sediment at Navy Base Depend on Chronic Amphipod Testing [210]</td>
<td>210</td>
<td>W.M. Starkel, Tetra Tech NUS, Stone Mountain, Georgia, USA; R.E. Mayer, Engineering Field Activity Chesapeake, Washington Navy Yard, DC, USA; A.G. swope, Naval Surface Warfare Center Dahlgren Laboratory, Dahlgren, Virginia, USA</td>
</tr>
<tr>
<td>2:55 PM</td>
<td>A Microbial Screening Method for Heavy Metal Contamination in Stream Sediments [147]</td>
<td>147</td>
<td>R.C. Tuckfield, Savannah River Technology Center, Aiken, South Carolina, USA; J.V. McArthur, Savannah River Ecology Laboratory, Aiken, South Carolina, USA</td>
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*underlined name denotes speaker
[number in brackets] denotes abstract number*

**concurrent sessions 18 & 19**
Session 20
Vadose Zone Issues Influencing Remediation I
Tuesday, 12 June, 1:15 PM - 3:15 PM, Lake

**Session Chairs:**
Lorne G. Everett
The IT Group
Jeanne Yacoub
The IT Group

1:15 PM  The DOE Vadose Zone Science and Technology Roadmap: Vadose Zone Science and Remediation Initiatives [455]
S.J. Kowall, P.M. Wright, Idaho National Engineering and Environmental Lab, Idaho Falls, Idaho, USA

1:35 PM  Geophysical Applications in Vadose Zone Characterization [448]

1:55 PM  Column Experiment Design to Estimate Parameters for Modeling of Vapor Extraction/Bioventing Sequential Soil Treatment [145]
G. Malina, Technical University of Czestochowa, Czestochowa, Poland

2:15 PM  Tightening Up Vadose Zone Gas Phase Characterization and Monitoring [457]
J. Rossabi, B.D. Riha, B. Looney, Westinghouse Savannah River Company, Aiken, South Carolina, USA

2:35 PM  The Effect of Barometric Pumping on Field Determined Respiration Rate for Bioventing Process [343]
J.C. Hu, California Regional Water Quality Control Board, Los Angeles, California, USA; R.R. Dupont, Utah State University, Logan, Utah, USA

2:55 PM  Successful Implementation of the In Situ Gaseous Reduction Approach for Vadose Zone Remediation [421]
E.C. Thornton, T.J. Gilmore, K.B. Olsen, R. Schalla, Pacific Northwest National Laboratory, Richland, Washington, USA

Session 21
PRB, Material Development and RTDF Plenary Discussion
Tuesday, 12 June, 3:30 PM - 5:30 PM, Seminole A

**Session Chair:**
Robert W. Puls
U.S. Environmental Protection Agency

3:30 PM  The In Situ Treatment of DNAPL with Zero-Valent Iron Emulsions [152]
C.L. Geiger, C.A. Clausen, D.R. Reinhart, K. Brooks, University of Central Florida, Orlando, Florida, USA; D. Major, Geosyntec Consultants, Guelph, Ontario, Canada; J.W. Quinn, NASA Kennedy Space Center, Kennedy Space Center, Florida, USA

3:50 PM  Permeable Reactive Barrier for Metals Treatment at the Newport, Delaware Superfund Site [293]
J.A. Wilkens, DuPont Central Research & Development, Wilmington, Delaware, USA; P.B. Butler, W.R. Kahl, URS Corporation, Wilmington, Delaware, USA; N.C. Scribner, DuPont Engineering Technology, Wilmington, Delaware, USA

4:10 PM  An Examination of Zero-Valent Iron Sources used in Permeable Reactive Barriers [420]
R.C. Landis, E.I. du Pont de Nemours & Co., Inc., Wilmington, Delaware, USA; R.W. Gilham, E.J. Reardon, University of Waterloo, Waterloo, Ontario, Canada; R.M. Focht, EnviroMetal Technologies, Inc., Waterloo, Ontario, Canada; J.L. Vogan, EnviroMetal Technologies Inc., Guelph, Ontario, Canada

4:30 PM  RTDF Plenary Session
Panel Members:
Liyuan Liang, Oak Ridge National Laboratory
Jacqueline W. Quinn, NASA Kennedy Space Center
Stephan A. Jefferis, University of Surrey
Robert Gilham, University of Waterloo

underlined name denotes speaker
[number in brackets] denotes abstract number
Session 22
Treatment of Organic Contaminants by In Situ Chemical Oxidation II
Tuesday, 12 June, 3:30 PM - 5:30 PM, Seminole B

Session Chairs: Laymon L. Gray Robert L. Siegrist
Florida State University Colorado School of Mines

3:30 PM Fenton’s Reagent In Situ Chemical Oxidation of TCE Source Area, NTC Orlando, Florida, USA [140]
S. Tsangaris, CH2M Hill Constructors, Tampa, Florida, USA; B.R. Nwokike, NAVFAC, Charleston, South Carolina, USA; D. Bryant, R. Levin, Geo-Cleanse International, Inc., Kenilworth, New Jersey, USA

3:50 PM Fenton-Based Remediation of a Chlorinated Solvent Groundwater Plume using Segmented Injection Wells - a Field Study [242]
E.C. Heijn, Metcalf and Eddy, Inc., Miramar, Florida, USA; P.K. Kakarla, In-Situ Oxidative Technologies, Inc., West Windsor, New Jersey, USA; B.D. Hartsfield, Florida Department of Environmental Protection, Tallahassee, Florida, USA; B. Koenig, Metcalf & Eddy, Inc., Miramar, Florida, USA

4:10 PM In Situ Ozonation to RemEDIATE Recalcitrant Organic Contamination [352]
J. Dablow, IT Corporation, Irvine, California, USA; M. Seaman, IT Corporation, Urbandale, Iowa, USA; B. Marvin, IT Corporation, Concord, California, USA

4:30 PM Ozone Sparging and Recirculation - Comparison of Design Approaches for Two Site Remediations [224]
S. Schroeder, RMT, Inc., Greenville, South Carolina, USA

4:50 PM The Effects of In Situ Chemical Oxidation on Aquifer Hydrogeology and Geochemistry [318]
O.R. West, L. Liang, R.L. Siegrist, S.R. Cline, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

5:10 PM Expectations for the Performance of In Situ Chemical Oxidation: Field Experiments and Modeling Studies [389]
E.D. Hood, GeoSyntec Consultants, Guelph, Ontario, Canada; N.R. Thompson, University of Waterloo, Waterloo, Ontario, Canada

Session 23
Sediment Remediation
Tuesday, 12 June, 3:30 PM - 5:30 PM, Osceola

Session Chairs: Richard H. Jensen Ruth W. Owens
E.I. du Pont de Nemours & Co., Inc. U.S. Navy

3:30 PM Design Features of Confined Disposal Facilities (CDFs) for Contaminated Sediments [383]
M.R. Palermo, D.E. Averett, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, USA

3:50 PM Recent Developments in Bioremediation of PCBS in Dredged Material Confined Disposal Facilities [382]
T.E. Myers, D.E. Averett, US Army Engineer Research & Development Center, Vicksburg, Mississippi, USA

4:10 PM Confined Aquatic Disposal for Dredged Material at Bremerton Naval Complex [182]
M.T. Otten, Foster Wheeler Environmental Corporation, Bothell, Washington, USA

4:30 PM Use of a Clay Based Barrier Technology for In Situ Management of Impacted Sediments [417]
J.M. Jersak, J.H. Hull, Hull & Associates, Inc., Toledo, Ohio, USA

4:50 PM Sediments Remediation [371]

5:10 PM Field Testing Advanced Remedial Dredging and Sediment Transport Technologies at the New Bedford Harbor Superfund Site [141]
J.E. Lally, Foster Wheeler Environmental Corporation, Bothell, Washinton, USA; A.J. Ikalaainen, Foster Wheeler Environmental Corporation, Boston, Massachusetts, USA

underlined name denotes speaker
[number in brackets] denotes abstract number

concurrent sessions 22 & 23  23
Session 24
Vadose Zone Issues Influencing Remediation II
Tuesday, 12 June, 3:30 PM - 5:30 PM, Lake

Session Chairs: Lorne G. Everett Jeanne Yacoub
The IT Group The IT Group

3:30 PM A Summary of Vadose Zone Science and Technology Solutions: Case Studies from the DOE Book [513]
B.B. Looney, Westinghouse Savannah River Company, Aiken, South Carolina, USA; R.W. Falta, Clemson University, Clemson, South Carolina, USA

3:50 PM Deployment of an Alternative Closure Cover and Monitoring System at the Mixed Waste Disposal Unit U-3ax/bl at the Nevada Test Site [175]
T.M. Fitzmaurice, D.G. Levitt, Bechtel Nevada, Las Vegas, Nevada, USA

4:10 PM Performance of the Colloidal Silica Barrier Installed at Brookhaven National Laboratory, a Computer Modeling Study [136]
M.H. Zaluski, K.R. Manchester, M.A. North-Abbott, MSE Technology Applications, Butte, Montana, USA; J.M. Wraith, Montana State University, Bozeman, Montana, USA

4:30 PM Plume Delineation and Monitoring of Natural Attenuation Processes via In Situ Flux Measurement [123]
A. Tartre, Ecoremediation, Inc., Longueuil, Quebec, Canada

4:50 PM Containment of Subsurface Hydrocarbon Contamination at Texaco Refinery, Casper, Wyoming [453]

5:10 PM Discussion

Cement-grouted waste at Weldon Spring Site Remedial.
The International Program of the U.S. Department of Energy’s (DOE) Office of Science and Technology sponsors collaborative research and development activities with institutions throughout the world. The objectives of these activities are to identify, evaluate and deploy environmental remediation technologies that have application to the DOE complex. The International Program maintains agreements of cooperation with several countries and international institutions. One of these programs is the Joint Coordinating Committee for Environmental Systems (JCCES). The JCCES was established between DOE and the Institute for Ecology of Industrial Areas (IETU), Katowice, Poland in 1995. The JCCES targets environmental remediation technologies throughout the Central and Eastern European region. This session will provide an overview of the activities currently being conducted through this program.

Session Chair: Skip Chamberlain  
U.S. Department of Energy

JCCES Program Introduction

S. Chamberlain, U.S. Department of Energy, Germantown, Maryland, USA

Bioremediation Advances: Discovery, Development and Deployment of Biocatalysts [486]

R.L. Brigmon, Westinghouse Savannah River Company, Aiken, South Carolina, USA;
D. Singleton, University of Georgia, Athens, Georgia, USA;
S. Story, D.J. Altman, C.J. Berry, M.A. Heitkamp, Westinghouse Savannah River Company, Aiken, South Carolina, USA

Application of Bioremediation to Petroleum Contaminated Soils [487]

A. Worsztynowicz, D. Rzychon, M. Adamski, S. Iwaszenko, Institute for Ecology of Industrial Areas, Katowice, Poland;
M.A. Heitkamp, Westinghouse Savannah River Company, Aiken, South Carolina, USA

Microbial Aspects of Bioremediation [488]

K. Ulfig, G. Plaza, Institute for Ecology of Industrial Areas, Katowice, Poland;
A.J. Tien, Corporate Industrial Ecology, Holderbank, Switzerland;
A. Worsztynowicz, Institute for Ecology of Industrial Areas, Katowice, Poland;
M.A. Heitkamp, Westinghouse Savannah River Company, Aiken, South Carolina, USA;
T.C. Hazen, Lawrence Berkeley National Laboratory, Berkeley, California, USA

Phytoremediation: State of the Science [489]

S.M. Dushenkov, Florida State University, Tallahassee, Florida, USA

Application of Phytoremediation to Lead-Contaminated Soils [490]

R. Kucharski, A. Sas-Nowosielska, Institute for Ecology of Industrial Areas, Katowice, Poland;
E. Malkowksi, University of Silesia, Katowice, Poland;
M. Pogrzeba, Institute for Ecology of Industrial Areas, Katowice, Poland;
S.M. Dushenkov, J.M. Kuperberg, Florida State University, Tallahassee, Florida, USA

Optimization of Phytoremediation Process by Monitoring Plant Fluorescence [491]

P.I. Richter, Technical University Budapest, Budapest, Hungary
Session 26
Regulatory Acceptance of Technologies: Case Studies
Wednesday, 13 June, 8:00 AM - 10:00 AM, Seminole B

Session Chair: Annette Gatchett
U.S. Environmental Protection Agency

8:00 AM Use of Low-Flow Sampling Technique for Compliance Groundwater Monitoring at Resource Conservation and Recovery Act (RCRA) Facilities in New Mexico [53]
V. Maranville, E. Frank, New Mexico Environment Department, Santa Fe, New Mexico, USA

8:20 AM Water Balance Data from the Alternative Landfill Cover Demonstration [359]
S.F. Dwyer, Sandia National Laboratories, Albuquerque, New Mexico, USA; G. Newman, GRAM Inc., Albuquerque, New Mexico, USA; B. Reavis, Sandia National Laboratories, Albuquerque, New Mexico, USA

8:40 AM Regulatory Acceptance of Organic Stabilization [354]
P.R. Lear, IT Corporation, Knoxville, Tennessee, USA

9:00 AM UIC Class V Well Variances for Remediation of Contaminated Sites and Their Case Studies, Florida Department of Environmental Protection [214]
G.F. Heuler, Florida Department of Environmental Protection, Tallahassee, Florida, USA

9:20 AM Successful Strategies for Integration of In Situ Oxidation with Existing Technologies to Support Site Closure [282]
R.W. Lewis, D.E. Egan, IT Corporation, Norwood, Massachusetts, USA

9:40 AM In Situ Application of Potassium Permanganate Solution for VOCs-Impacted Groundwater Cleanup — The Regulatory Perspective [344]
J.G. Hu, R.S. Chou, California Regional Water Quality Control Board, Los Angeles, California, USA

Session 27
Long-Term Stewardship
Wednesday, 13 June, 8:00 AM - 10:40 AM, Osceola

Session Chair: Scott R. McMullin John D. Koutsandreas
U.S. Department of Energy Florida State University

8:00 AM Performance Evaluation and Long-Term Environmental Monitoring Optimization: Methods for Long-Term Stewardship [470]
B. Moore, U.S Department of Energy, Washington, DC, USA; J.D. Ditmars, Argonne National Laboratory, Argonne, Illinois, USA; B. Minsker, University of Illinois Urbana - Champaign, Urbana, Illinois, USA; J.T. Bachmaier, U.S. Department of Energy, Washington, DC, USA

8:20 AM The Fernald Long-Term Stewardship Pilot [84]
S.R. Brechbill, U.S. Department of Energy, Miamisburg, Ohio, USA; J. Bradburne, Fluor Daniel Fernald, Cincinnati, Ohio, USA

8:40 AM Long-Term Stewardship - Do We Need A New Paradigm? [370]
J.H. Clarke, F.L. Parker, W.P. Hamilton, D.S. Kosson, F. Sanchez, Vanderbilt University, Nashville, Tennessee, USA

9:00 AM Deployment Issues for Sensors for Long-Term Monitoring Applications [419]
D.L. Hale, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, USA; T.R. Smal, Westinghouse Savannah River Company, Aiken, South Carolina, USA

9:20 AM Assuring the Performance of Subsurface Monitoring Systems for Long-Term Stewardship: Challenges [423]

9:40 AM Demonstration of Geostatistical Methods for Long-Term Groundwater Monitoring Optimization [461]
K. Yager, U.S. Environmental Protection Agency, Edison, New Jersey, USA; T. Lillys, P. Sullivan, Hydrogeologic, Inc., Herndon, Virginia, USA

continued on the next page

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[number in brackets] denotes abstract number
Session 27 (continued)
Long-Term Stewardship
Wednesday, 13 June, 8:00 AM - 10:40 AM, Osceola

10:00 AM Decision Support Software for Designing Monitoring Plans [462]
J.J. Aziz, C.J. Newell, Groundwater Services, Inc., Houston, Texas, USA;
H.S. Rifai, M. Ling, University of Houston, Houston, Texas, USA;
J. Gonzales, Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas, USA

J.B. Gladden, Westinghouse Savannah River Company, Aiken, South Carolina, USA;
A.M. Filippi, J.R. Jensen, University of South Carolina, Columbia, South Carolina, USA;
D.J. Kelch, MTL Systems, Inc., Dayton, Ohio, USA;
M.G. Serrato, Westinghouse Savannah River Company, Aiken, South Carolina, USA;
M.M. Pendergast, SMP Enterprises, Martinez, Georgia, USA

Session 28
Multi-Agency Remediation
Wednesday, 13 June, 8:00 AM - 10:20 AM, Lake

Session Chairs: Thomas Holdsworth
U.S. Environmental Protection Agency

8:00 AM Finding Containment, Remediation and Site Characterization Solutions in Fractured Rock: The Smithville Strategy [373]
J.E. O Neill, Smithville Bedrock Remediation Program, Smithville, Ontario, Canada

8:20 AM A Multidisciplinary Approach to Innovative Technology Development and Deployment: The INEEL TAN Project [87]
K. Owens, University of Idaho, Idaho Falls, Idaho, USA;
L.R. Mink, Idaho Water Resources Research Institute, Moscow, Idaho, USA

8:40 AM Groundwater Central Demonstration - Ground-Water Remediation Technologies Analysis Center (GWRTAC) [272]
S. Chamberlain, U.S. Department of Energy, Germantown, Maryland, USA;
D.S. Kaback, Concurrent Technologies Corporation, Denver, Colorado, USA;
D. Roote, Concurrent Technologies Corporation, Pittsburgh, Pennsylvania, USA;
F.G. Pohland, University of Pittsburgh, Pittsburgh, Pennsylvania, USA

9:00 AM Private Sector, University, DOE, and DoD Partnerships for Deployment and Commercialization of the Well Injection Depth Extraction (WIDETM) Technology Case Study [426]
J.D. Quaranta, Informatics Corporation, Richland, Washington, USA;
R.G. Spears, U.S. Department of Energy, Morgantown, West Virginia, USA

9:20 AM The Innovative Treatment and Remediation Demonstration (ITRD) Program: Lessons Learned in Overcoming Barriers to the Adoption of Innovative Technology [183]
M.D. Siegel, G.S. Brown, W.C. Cheng, M.J. Kelley, Y. McClellan, J.M. Phelan, Sandia National Laboratories, Albuquerque, New Mexico, USA

9:40 AM Advanced Integrated Information Management System: A Flexible, Customized Decision Support Tool [63]
R. Machanoff, AIIMTech, Oak Ridge, Tennessee, USA

10:00 AM Interagency DNAPL Consortium: A Successful Commitment to Accomplish Three Complex Demonstrations of Innovative Technologies for DNAPL Remediation [467]
T. Holdsworth, U.S. Environmental Protection Agency, Cincinnati, Ohio, USA;
J.W. Quinn, NASA Kennedy Space Center, Kennedy Space Center, Florida, USA;
S. Chamberlain, U.S. Department of Energy, Germantown, Maryland, USA

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concurrent sessions 27 & 28  27
Evening Session I
International Case Studies in Remediation
Monday, 11 June, 6:00 PM - 8:00 PM, Lake

Just as problems associated with environmental contamination are shared without respect for national borders, solutions should also be shared among individuals, institutions and governments. A number of organizations support the international interchange of information regarding environmental remediation. The sponsoring organizations of this conference are among that group. This special evening session will present a collection of international case studies of environmental remediation technology identification, evaluation and exchange.

Session Chair: J. Michael Kuperberg
Florida State University

6:00 PM Vegetative Cover for Phosphogypsum Dumps: A Romanian Field Study [466]
I.G. Petrisor, Institute of Biology of Romanian Academy, Bucharest, Romania;
K. Komnitsas, National Technical University of Athens, Athens, Greece;
I. Lazar, A. Voicu, S. Dobrota, Institute of Biology of Romanian Academy, Bucharest, Romania;
J.M. Kuperberg, Florida State University, Tallahassee, Florida, USA

6:20 PM Overview of the Regional Environmental Center for Central Asia [512]
B. Yessyekin, Regional Environmental Center for Central Asia, Almaty, Kazakhstan

6:40 PM Spatial Data Analysis and Modeling of Radioactively-Contaminated Territories: Lessons Learned from Chernobyl [88]
M.F. Kanevski, L.A. Bolshov, V.V. Demyanov, E.A. Savelieva, V.A. Timonin, S. Chernov, Russian Academy of Sciences, Moscow, Russia

7:00 PM Full Scale Clean-Up of PCE and Turpentine under Buildings by Steam Stripping [510]
T. Heron, NIRAS A/S, Aarhus C, Denmark; H. Hansen, The County of Northern Jutland;
B.H. Heron, NIRAS A/S, Aarhus C, Denmark; G. Heron, SteamTech Environmental Services Inc., Bakersfield, California, USA

7:20 PM NATO/CCMS Pilot Study on Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean-up of Contaminated Land and Groundwater [509]
S.C. James, U.S. Environmental Protection Agency, Cincinnati, Ohio, USA;
J.E. Moerlins, Florida State University, Tallahassee, Florida, USA

7:40 PM Characterization of Hydrogeologic Systems with Machine Learning Algorithms and Geostatistical Models [99]
M.F. Kanevski, L.A. Bolshov, E.A. Savelieva, A.N. Pozdnukhov, V.A. Timonin, Russian Academy of Sciences, Moscow, Russia

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The need to cost-effectively prevent or ameliorate adverse environmental effects of persistent contaminants has brought increased attention to innovative cleanup approaches. Environmental bioremediation is an emerging research area actively supported by the U.S. EPA through the competitive Science to Achieve Results (STAR) grants program. In this session, selected research projects focusing on the bioremediation mechanisms of recalcitrant contaminants will be discussed by the investigators.

Session Chair: Mitch M. Lasat
U.S. Environmental Protection Agency

6:00 PM EPA Star Grants for Environmental Biotechnology Research [504]
M.M. Lasat, U.S. Environmental Protection Agency, Washington, DC, USA

6:20 PM Effects of Anaerobic Sorbent Degradation on the Sorption of Toluene and o-Xylene on Municipal Solid Waste Components [501]
B. Wu, A. Barlaz, D. Knappe, North Carolina State University, Raleigh, North Carolina, USA; M.A. Nanny, University of Oklahoma, Norman, Oklahoma, USA

6:40 PM Biostabilization of Multicomponent Dense Non-Aqueous Phase Liquids (DNAPLs) [500]
A. Ramaswami, University of Colorado, Denver, Colorado, USA; T.H. Illangasekare, A. Bielefeldt, University of Colorado, Boulder, Colorado, USA

7:00 PM Enhanced Biodegradation of Petroleum: Contaminants in Rhizosphere Soil [502]
K. Banks, Purdue University, West Lafayette, Indiana, USA

7:40 PM Relations of Heavy Metal Sequestration and Production of Metal Ion Ligands in Plants under Different Environmental Conditions [503]
T.W. Fan, University of California, Davis, California, USA; A.N. Lane, National Institute for Medical Research, Mill Hill, London; R.M. Higashi, University of California, Davis, California, USA

Underlined name denotes speaker
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Poster Session I
Poster Session Reception
Monday, 11 June, 5:30 P.M. - 7:30 P.M., Exhibition Hall

Topic: Barriers and Permeable Reactive Walls

Sub-Topic: Barriers, Caps and Liners: Materials, Testing and Development

Barriers Beyond Permeability [29]
G.R. Tallard, Liquid Earth Support, Inc., Pelham, New York, USA

Emplacement Techniques: Impervious & Pervious Wall Construction [107]
D.A. Wesolek, F.C. Schmednecht, Slurry Systems, Inc., Gary, Indiana, USA

Migration and Retardation of Chemical Toxic Radioactive Waste in Engineered Barriers [119]
V. Jedinakova-Krizova, Institute of Chemical Technology, Prague, Czech Republic; D. Sirotkova, TGM Water Research Institute, Prague, Czech Republic

Grout Selection and Characterization in Support of the Colloidal Silica Barrier Deployment at Brookhaven National Laboratory [135]

Application of Protecting Layers to Existing Non-Insulated Fly-Ash Landfills for Reduction of Environmental Impact - Experimental Stage [196]
J.M. Laczny, P. Cofalka, Institute for Ecology of Industrial Areas, Katowice, Poland; M. Huzarski, Projbud sp. z.o.o., Szczecin, Poland

MatCon Modified Asphalt Cover Containment System Demonstration [206]

Hydraulic Pulse Interference Tests for Integrity Testing of Containment and Reactive Barrier Systems [218]
G. Hocking, Golder Associates LLC, Atlanta, Georgia, USA

The F.E. Warren AFB Spill Site 7 Iron-Filings Treatment Wall is Working [229]
F.C. Heneman, M.R. May, B.G. Powers, URS, Denver, Colorado, USA

Paper Clay Utilization in Engineering Applications [241]
C.E. Ochola, Lehigh University, Bethlehem, Pennsylvania, USA

Environmental Contamination Recovery System Utilizing Soil Freezing and Jetting [323]
A. Ousaka, The University of Tokushima, Tokushima, Japan; K. Horii, The University of Shirayurijoshi, Tokyo, Japan; K. Kusano, The University of Tokushima, Tokushima, Japan; M. Shibazaki, H. Yoshida, H. Souma, Chemical Grouting Company Ltd., Tokyo, Japan

Hydraulic Conductivity of Cement-Bentonite-Slag Slurry Wall Barriers [349]
S. Opdyke, J.C. Evans, Bucknell University, Lewisburg, Pennsylvania, USA

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Monday for discussion with conference participants.
Poster Session I (continued)
Poster Session Reception
Monday, 11 June, 5:30 P.M. - 7:30 P.M., Exhibition Hall

Topic: Barriers and Permeable Reactive Walls (continued)

Sub-Topic Barriers, Caps and Liners: Case Studies and Demonstration Projects

Approaching Closure at a Fuel Oil Recovery Site Along a Pier using a Vertical Impermeable Barrier and Interceptor Trench [3]
R.F. Strahle, The IT Group, Trenton, New Jersey, USA; R.W. Magee, Naval Facilities Engineering Command, Norfolk, Virginia, USA; K.M. Lista, The IT Group, Somerset, New Jersey, USA

Design and Control of Slurry Wall Backfill Mixes for Groundwater Containment [41]
K.B. Andromalos, M.J. Fisher, Geo-Con, Inc., Monroeville, Pennsylvania, USA

Integrated Technologies for In Situ Source Management at an Operating Wood Treatment Site [154]

Interim Measures to Contain Creosote DNAPL at a Wood-Treating Facility in Grenada, MS [165]

Demonstration of Groundwater Containment Through the Use of a Barrier Wall, Surface Cover Systems and Natural Attenuation [180]
D.S. Bausmith, Key Environmental, Inc., Lebanon, New Jersey, USA; M. Brouman, Beazer East, Inc., Pittsburgh, Pennsylvania, USA; M. Ting, J.S. Zubrow, Key Environmental, Inc., Carnegie Pennsylvania, USA

Construction of a Soil-Bentonite Cutoff Wall for Containment of Wood Treatment Products [226]
L.M. Owaidat, Geo-Con, Inc., Sacramento, California, USA; S.G. Sumner, TRC, Irvine, California, USA; T.J. Pajutee, URS, Portland, Oregon, USA

Quality Control and Performance of a Cutoff Wall for Containment of DNAPL Plume [230]
J. McKnight, L.M. Owaidat, Geo-Con, Inc., Sacramento, California, USA

NAPL Containment at the Former Northern Indiana Public Service Company Manufactured Gas Plant in Fort Wayne, Indiana [289]
E.P. Zimmerman, M. Haney, Harding ESE, Inc., Nashua, New Hampshire, USA; D. Helmers, S. Wuellner-Rice, Northern Indiana Public Service Company, Merrillville, Indiana, USA

Innovative Strategies for DNAPL Containment and Degradation - Nashua Site, New Hampshire [338]
M. Brouman, Beazer East, Inc., Irvine, California, USA; S.G. Sumner, M. Leonard, TRC, Irvine, California, USA; M. Wheeler, Jr., Sevenson Environmental Services, Inc., Niagara Falls, New York, USA

Barrier Wall Installation on the Vermilion River [376]
D.A. Edwards, Geo-Con, Inc., Westhampton, New Jersey, USA

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Monday for discussion with conference participants.

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Topic: Barriers and Permeable Reactive Walls (continued)

Sub-Topic PRB Best Practice for Design and Emplacement

New Large Scale PRB Network RUBIN Launched In Germany [44]
V. Birke, University of Applied Sciences, Gehrden, Germany; H. Burmeier, Fachhochschule North-East Lower Saxony, Suderburg, Germany; D. Rosenau, RUBIN, Gehrden, Germany

In Situ Fluidization for Solids Addition to Permeable Reactive Barriers [115]
R.K. Niven, Australian Defence Force Academy, Canberra, ACT Australia

Permeable Reactive Barrier (PRB) Installation using the Biopolymer Slurry Trench Method [254]
V. Jayaram, M.D. Marks, Geo-Con, Inc., Tampa, Florida, USA; R.M. Schindler, Geo-Con, Inc., Monroeville, Pennsylvania, USA; R.J. Kohnke, Geo-Con, Inc., Tampa, Florida, USA

Bio-Polymer Construction and Testing of a Zero Valent Iron PRB at the Somersworth Landfill Superfund Site [259]
T.A. Krug, K. Berry-Spark, GeoSyntec, Guelph, Ontario, Canada; M. Monteleone, C. Bird, GeoSyntec, Atlanta, Georgia, USA; C.R. Elder, GeoSyntec Consultants, Boston, Massachusetts, USA; R.M. Focht, EnviroMetal Technologies, Inc., Waterloo, Ontario, Canada

Construction of a Deep Permeable Reactive Barrier in a Slurry-Supported Trench [310]
Z.H. Tuta, C.T. Miller, R.M. Yeates, IT Corporation, Englewood, Colorado, USA; M. Finney, IT Corporation, Overland Park, Kansas, USA; W.T. Chan, IT Group, Monroeville, Pennsylvania, USA

Blast Fracturing and In Situ Treatment Agents for Passive Treatment of Chlorinated Solvent Plumes in Bedrock [333]

Installation of Permeable Reactive Barriers Using Pneumatic Injection [483]
D.L. Schnell, Pneumatic Fracturing Inc., Alpha, New Jersey, USA

Topic: Barriers and Permeable Reactive Walls (continued)

Sub-Topic PRB Field Case Studies-Hydraulic and Geochemical Measurements, Contaminant Removal

Dual Reactive Barrier Walls for the Remediation of CHC Contamination, Watervliet Arsenal, New York: Design and Installation of an Innovative Technology [156]
C. Gaule, Malcolm-Pirnie, Inc., Latham, New York, USA; K. Goldstein, Malcom-Pirnie, White Plains, New York, USA; C.A. Heckelman, U.S. Army Corps of Engineers, Baltimore, Maryland, USA

Applicability of Zero-Valent Iron With Lignite Additives as Geochemical In Situ Barrier for Acid Mine Water [208]
C. Klinger, Deutsche Montan Technologie GmbH, Essen, Germany; U. Jenk, J. Schreyer, Wismut GmbH, Chemnitz, Germany

Passive Above Ground Iron Filings Treatment of Contaminated Groundwater [415]
W.D. Daily, R.G. Blake, Lawrence Livermore National Laboratory, Livermore, California, USA

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Topic: Barriers and Permeable Reactive Walls (continued)

Sub-Topic: PRB, Material Development

Formation on In Situ Apatite Barriers using Water Soluble Reagents for Sequestering Uranium and Strontium [104]
R.C. Moore, P. Zhang, F. Salas, D. Lucero, Sandia National Laboratories, Albuquerque, New Mexico, USA; G.R. Choppin, Florida State University, Tallahassee, Florida, USA

A Comparison of Synthetic and Animal Bone Derived Apatites for Sorption of Uranium and Strontium in Soil and Groundwater [105]
R.C. Moore, F. Salas, D. Lucero, Sandia National Laboratories, Albuquerque, New Mexico, USA; C. Sanchez, University of Arizona, Yuma, Arizona, USA; G.R. Choppin, Florida State University, Tallahassee, Florida, USA; A. Tofe, Xmax Corporation, Golden, Colorado, USA

The Removal of Arsenic from Groundwater using Permeable Reactive Barriers (PRBs) [111]
D.J.A. Smyth, D.W. Blowes, University of Waterloo, Waterloo, Ontario, Canada; C.W.T. McRae, Golder Associates, Mississauga, Ontario, Canada; C.J. Ptacek, L. Spink, University of Waterloo, Waterloo, Ontario, Canada

Permeable Reactive Barriers at Great Depth - Material Testing and Application at a Chromate Contaminated Site [122]
R. Hermanns Stengele, S. Koehler, Institute of Geotechnical Engineering, Zurich, Switzerland

Enhanced Dehalogenation of Halogenated Methanes by Bimetallic Cu/Al [169]
H. Lien, W. Zhang, Lehigh University, Bethlehem, Pennsylvania, USA

Use of Novel Reactive Barrier Materials for Treatment of Strontium, Uranium, Nitrate and Perchlorate in Groundwater [177]
T.P. Taylor, B.A. Strietelmeier, S.D. Ware, M.L. Espinosa, N.N. Sauer, J.L. Conca, Los Alamos National Laboratory, Los Alamos, New Mexico, USA

The Use of Column Experiments to Predict Performance and Long-Term Stability of Iron Treatment Walls [228]
M. Ebert, D. Schfer, R. Kber, University of Kiel, Kiel, Germany

Long-Term Effect of Biotic Reductive Dechlorination on Permeable Treatment Walls [327]
H.A. Steir, A. Randall, D.R. Reinhart, C. Clausen, C.L. Geiger, University of Central Florida, Orlando, Florida, USA

Modification of a Commercial Activated Carbon for Metal Adsorption by Several Approaches [408]
S. Wu, J.P. Chen, National University of Singapore, Singapore, Singapore

Topic: Biological Remediation Technologies

Sub-Topic: Bioremediation of Chlorinated Solvents

Bioremediation of TCE Source Area at the Mobile Launch Platform Rehabilitation Sites/Vehicle Assembly Building Area [76]
M.R. Castellanos, GeoSyntec Consultants, Boca Raton, Florida, USA; M. McMaster, GeoSyntec Consultants, Guelph, Ontario, Canada; J. Adkisson, NASA, Kennedy Space Center, Florida, USA; T. Peel, GeoSyntec Consultants, Boca Raton, Florida, USA
Topic: Biological Remediation Technologies (continued)

Sub-Topic Phytoremediation

Impact of Natural Attenuation and Phytoremediation on MTBE and Fuel [54]
K. Brown, L. Tyner, D. Grainer, T. Perina, IT Corporation, Knoxville, Tennessee, USA; M. Leavitt, Newfields, Inc., Knoxville, Tennessee, USA; M. McElligott, Vandenberg Air Force Base, Lompoc, California, USA

Phytoremediation of Nitrate-Contaminated Groundwater by Desert Phreatophytes [161]
E.P. Glenn, C. McKeon, D. Moore, University of Arizona, Tucson, Arizona, USA; W.J. Waugh, U.S. Department of Energy, Grand Junction, Colorado, USA

Adsorption-Enhanced Phytoremediation [225]
S.V. Mikhalovsky, University of Brighton, Brighton, East Sussex, UK; D.I. Shvetz, N.M. Openko, V.V. Strelko, Institute for Sorption and Problems of Endoecology, Kiev, Ukraine; S. Waite, University of Brighton, Brighton, East Sussex, UK

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Monday for discussion with conference participants.
A Combined Biological/Phytological Design for Remediation of Chlorinated Solvents in a Low Permeability Aquifer [287]

D.E. Rieske, G.W. Snyder, Pro2Serve Technical Solutions, Piketon, Ohio, USA; D.J. Wilkes, Bechtel Jacobs Company LLC, Piketon, Ohio, USA

Enhanced Bioremediation of Chlorinated Solvents in Groundwater: Using Mulch Derived from Waste Organic Material at Cape Canaveral Air Force Station (CCAFS), Florida [295]

R.P. Bogert, BEM Systems, Inc., Orlando, Florida, USA; M.A. Kershner, 45CES/CEVR, Patrick Air Force Base, Florida, USA

Coupling Natural Attenuation and Phytoremediation to Cleanup a Shallow Chlorinated Solvent Plume at the Former Naval Training Center in Orlando, Florida [395]

V. Nzengung, University of Georgia, Athens, Georgia, USA; S. Ramaley, Acardis Geraghty and Miller, Baltimore, Maryland, USA

Phytosorption Method of Decontamination of Soils Polluted with Heavy Metals and Radionuclides [409]

V.V. Strelko, D.I. Shvetz, S. Mikhalovsky, N. Openko, E.A. Diyuk, National Academy of Sciences of Ukraine, Kiev, Ukraine

Heavy Metal Removal from Municipal Sewage Sludges by Phytoextraction [475]

M. Pogrzeba, R. Kucharski, A. Sas-Nowosielksa, Institute for Ecology of Industrial Areas, Katowice, Poland; E. Malkowski, University of Silesia, Katowice, Poland, K. Krynski, Institute for Ecology of Industrial Areas, Katowice, Poland; J. M. Kuperberg, Florida State University, Tallahassee, Florida, USA

Strip Test as a Method for Optimizing Land Characterization for Phytoremediation of Heavy Metals [507]

A. Sas-Nowosielksa, R. Kucharski, M. Korcz, Institute for Ecology of Industrial Areas, Katowice, Poland; S.M. Dushenkov, J.M. Kuperberg, Florida State University, Tallahassee, Florida, USA; E. Malkowski, University of Silesia, Katowice, Poland

**Topic:** Biological Remediation Technologies (continued)

**Sub-Topic:** Bioremediation of Petroleum and Other Organics

Use of a Unique Biobarrier to Remediate Nitrate and Perchlorate in Groundwater [80]

B.A. Strietelmeier, M.L. Espinosa, J.D. Adams, P. Leonard, M. Hodge, Los Alamos National Laboratory, Los Alamos, New Mexico, USA

Biotreatability Studies Lead to Landfarming Innovations [162]


Production - Scale Bioreactor for Petroleum Contaminated Soils [197]

A. Worsztynowicz, D. Rzychon, M. Adamski, S. Iwaszenko, Institute for Ecology of Industrial Areas, Katowice, Poland; D.J. Altman, Westinghouse Savannah River Company, Aiken, South Carolina, USA; J.M. Kuperberg, Florida State University, Tallahassee, Florida, USA

Biological Treatment of a Tritiated HPLC Mixed Waste to Meet RCRA Requirements [273]

L. Chang, E. Rychel, W.T. Stringfellow, C. Than, P. Williams, Lawrence Berkeley National Laboratory, Berkeley, California, USA

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Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Monday for discussion with conference participants.

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*number in brackets* denotes abstract number
**In Situ Remediation at a Brownfield Site in Pennsylvania using Reinjectable Points [302]**

L. Ochs, Regenesis Bioremediation Products, Cinnaminson, New Jersey, USA; B.E. Duffy, Inland Pollution Services, Inc., Elizabeth, New Jersey, USA

**Biological Permeable Barrier - An Innovative Approach to Clean Contaminated Groundwater [307]**

F.R. Shirazi, Stratum Engineering, Overland Park, Kansas, USA

**Enhanced Bioattenuation of a Gasoline UST Release in Puerto Rico [329]**

B.E. Duffy, Inland Pollution Services, Inc., Elizabeth, New Jersey, USA; J. Negron, J.H. Guy, Inland Pollution Services PR, Inc., Carolina, Puerto Rico

**Enhanced Anaerobic Benzene/Hydrocarbon Biodegradation via Sulfate Amendment for Aquifer Remediation at a Refinery [348]**

G.A. Ulrich, M.A. Hasegawa, J. Brammer, T. Joiner, Surbec-ART Environmental, LLC, Norman, Oklahoma, USA

**Bioremediation of Soils Contaminated with Oily Sludge: A Field Experiment in Romania [465]**

I.G. Petrisor, S. Dobrota, I. Lazar, A. Voicu, M. Stefanescu, Institute of Biology of Romanian Academy, Bucharest, Romania; J.M. Kuperberg, Florida State University, Tallahassee, Florida, USA

**Natural and Accelerated Bioremediation Research Program Field Research Center in Oak Ridge, Tennessee [498]**

D.B. Watson, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

**Topic:** Biological Remediation Technologies (continued)

**Sub-Topic:** Bioremediation of Heavy Metals

**In Situ Immobilization of Redox Sensitive Contaminants [61]**

H. Guha, D. Roelant, R. Srivastava, Florida International University, Miami, Florida, USA

**Innovative, In Situ Use of Sulfate Reducing Bacteria to Remove Heavy Metals in Acid Mine Drainage [65]**

M.C. Canty, R. Hiebert, M.A. Harrington-Baker, MSE Technology Applications, Butte, Montana, USA

**Heavy Metal ionmobilisation with use of Aspergillus Species [70]**

D. Sri, St. Istv n University, Budapest, Hungary; L. Vermes, University of Horticulture and Food Industry, Budapest, Hungary

**Field Performance of Engineered SRB Reactors for Removing Heavy Metals [283]**


**The Use of Microbial Parameters to Estimate the Influence of EDTA Application during Phytoextraction of Lead-Contaminated Soil [350]**

R. Galimska-Stypa, University of Silesia, Katowice, Poland; A. Sas-Nowosielska, R. Kucharski, Institute for Ecology of Industrial Areas, Katowice, Poland

**Microbial Processes Used for Heavy Metal Remediation [351]**

R. Galimska-Stypa, University of Silesia, Katowice, Poland

**Cr(VI) Reduction in Continuous Flow Soil Columns [360]**

M. Alam, D.R. Yonge, B.M. Peyton, J.N. Petersen, Washington State University, Pullman, Washington, USA; W.A. Apel, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, USA

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Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Monday for discussion with conference participants.
Poster Session I (continued)
Poster Session Reception
Monday, 11 June, 5:30 P.M. - 7:30 P.M., Exhibition Hall

The Retention of Fe and Mn in Wetlands in Former Brown-Coal Mining Area [361]
T. Hezina, University of South Bohemia, Ceske Budejovice, Czech Republic; J. Pokorny, Academy of Sciences of the Czech Republic, Trebon, Czech Republic; I. Kallistova, University of South Bohemia, Ceske Budejovice, Czech Republic

Effect of Heavy Metal Ions on the Wastewater Treatment Using Membrane Bio-Reactor (MBR) [406]
W. Zhao, J.P. Chen, W.P. Ting, National University of Singapore, Singapore, Singapore
Presenter: S. Wu, National University of Singapore, Singapore, Singapore

Topic: Modeling

Modeling Cesium Fate in the Rhizosphere [10]
L.S. Siegel, Northeastern University, Enfield, New Hampshire, USA; A.N. Alshawabkeh, Northeastern University, Boston, Massachusetts, USA; M. Hamilton, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, USA

Modeling Evaluation of Flooding of the Old Deep Uranium Mine by Water from Tailings Pond [91]
J. Novak, J. Maryska, J. Muzak, Technical University of Liberec, Liberec, Czech Republic

Comparing Approaches to Locating Boreholes in Spatially Heterogeneous Aquifers [150]
S.A. McKenna, Sandia National Laboratories, Albuquerque, New Mexico, USA

Theoretical and Experimental Study of Using Horizontal Wells to Recover DNAPL [216]
H. Zhan, J. Chung, Texas A&M University, College Station, Texas, USA

Cost-Reliability Relationships for Reactive Barriers and Funnel-and-Gate-Systems in Heterogeneous Aquifers [220]
M.W. Finkel, C. Burger, M. Morio, P. Bayer, G. Teutsch, University of Tuebingen, Tuebingen, Germany

Probabilistic Design of Permeable Reactive Barriers [223]
R.I. Ospina, G. Hocking, Golder Sierra LLC, Atlanta, Georgia, USA. Presenter: M.A. Thurman, Golder Sierra LLC, Atlanta, Georgia, USA

Simulating Plume Capture by a Permeable Reactive Barrier Wall [282]

Y. Wang, Sandia National Laboratories, Carlsbad, New Mexico, USA; H. Xu, University of New Mexico, Albuquerque, New Mexico, USA

Multi-Agency Modeling Platform Supporting Long-Term Site Issues [334]
G. Wheelan, Pacific Northwest National Laboratory, Richland, Washington, USA; G.F. Laniak, U.S. Environmental Protection Agency, Athens, Georgia, USA; M.A. Pelton, Pacific Northwest National Laboratory, Richland, Washington, USA;
P.M. Beam, U.S. Department of Energy, Germantown, Maryland, USA

The Design and Construction of an Evapotranspiration Landfill Cover For A Semi-arid Site [392]
P.E. McGuire, Earth Tech, Sheboygan, Wisconsin, USA; J.A. England, Earth Tech, Englewood, Colorado, USA

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Monday for discussion with conference participants.

underlined name denotes speaker
[number in brackets] denotes abstract number
Topic: Thermal and Chemical Remediation Technologies

Sub-Topic: Treatment of Contaminants by Extraction or Stabilization

Application and Development of the Technologies for Contaminated Sites Remediation in the Czech Republic [14]
M. Kuras, Prague Institute of Chemical Technology, Praha, Czech Republic

Groundwater Circulation Wells Using Innovative Treatment Systems [28]
A.C. Elmore, URS Corporation, Overland Park, Kansas, USA; T. Graff, U.S. Army Corps of Engineers, Kansas City, Kansas, USA

Fe-containing Zeolites as Active and Selective Catalysts for Nitrogen-Oxides Reduction [30]
O.A. Anunziata, L.B. Pierella, Universidad Tecnologica Nacional, Cordoba, Argentina; E.J. Lede, UNLP and IFILP, La Plata, Argentina; F.G. Requejo, UNLP and IFILP and Lawrence Berkeley National Laboratory, La Plata, Argentina and Berkeley, California, USA

Chemical Stabilization of Heavy Metals [40]

Electrokinetic Remediation of Mercury-Contaminated Soils [62]
K.R. Reddy, C. Chaparro, University of Illinois at Chicago, Chicago, Illinois, USA

Field Test of Limestone as a Treatment Medium for Groundwater at the Savannah River Site [103]
M.E. Denham, F.C. Sappington, A.A. Ekechukwu, G.C. Blount, Westinghouse Savannah River Company, Aiken, South Carolina, USA

In Situ Plasma Vitrification of Buried Wastes [132]
L.J. Circeo, R.C. Martin, Jr., Georgia Tech Research Institute, Atlanta, Georgia, USA

Stabilization of DNAPL at a Former Creosote Wood Treating Site [171]
D. Cervenak, Key Environmental Inc., Carnegie, Pennsylvania, USA; P. Sawchuck, Key Environmental Inc., Portland, Maine, USA; M. Brouman, R. Fisher, Beazer East, Inc., Pittsburgh, Pennsylvania, USA; K. Mullins, SK Services (East), Kearny, New Jersey, USA; S. Radel, Renewable Resources Company, Milford, Massachusetts, USA

Remediation of DNAPLs and Heavy Metals at a Boston Brownfields Site using Cement-Based Solidification/Stabilization [266]
C.M. Wilk, Portland Cement Association, Skokie, Illinois, USA; M. Germano, Coler & Colantonio Inc., Norwell, Massachusetts, USA

Stabilization of Explosives and Propellants in Soil [353]
P. Lear, IT Corporation, Knoxville, Tennessee, USA

In Situ Stabilization of Uranium Contaminated Groundwater in Low Permeability Clay Using Phosphate Amendments with Prefabricated Vertical Drains [379]
J.E. Hughes, Earthline Technologies, Ashtabula, Ohio, USA

New Remediation Techniques for Polluted Water and Contaminated Sediments by Application of Minerals [381]
H. Minato, University of Tokyo, Tokyo, Japan; T. Morimoto, Astec Co., Tokyo, Japan

Enhanced Delivery of In Situ Chemical Treatment Using the On-Contact Process [390]
R.E. Adams, Environmental Business Solutions International, Centreville, Virginia, USA; W. Mahaffey, Pelorus Labs, Evergreen, Colorado, USA; W.W. Slack, FRx, Cincinnati, Ohio, USA; R. Werner, ECI, Norristown, Pennsylvania, USA; M. Vigneri, Environmental Business Solutions International, Wayne, New Jersey, USA

Concentration and Immobilization of Spent Radioactive Lubricating-Cooling Liquids [460]
V.N. Borisov, N.A. Ovchinnikov, M.N. Ovchinnikova, N.I. Savin, Russian Federal Nuclear Center—All-Russian Research Institute of Technical Physics, Snezhinsk, Chelyabinsk Region, Russia

Mobile Injection Treatment Unit [464]
C. Romberger, CBA Environmental Services, Inc., Hegins, Pennsylvania, USA. Presenter: B.L. Bruso

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Tuesday for discussion with conference participants.
Topic:  Thermal and Chemical Remediation Technologies (continued)

Sub-Topic  In Situ Thermal Treatment of Organic Contaminants

D.E. Fulton, IT Corporation, Trenton, New Jersey, USA; J.D. Conway, Naval Facilities Engineering Command, Norfolk, Virginia, USA

Operational Complications Associated with Application of Steam Extraction Technology to Recover Diesel Fuel [336]
M.D. Nelson, Leggette, Brashears and Graham, Inc., Minneapolis, Minnesota, USA

Case Study of Remediation of Pesticide Impacted Soils in Florida using On-Site, Ex Situ Thermal Desorption [367]
J.R. Butner, Parsons Engineering Science, Tampa, Florida, USA; J. Bodamer, FMC Corporation, Philadelphia, Pennsylvania, USA; S. Warren, Parsons Engineering Science, Syracuse, New York, USA; T. Murphy, Parsons Engineering Science, Tampa, Florida, USA

A Laboratory Test to Evaluate Potential for Steam Enhanced Removal of Coal-Tar in a Sand Matrix [400]
I.P. Murarka, Ish Inc., Sunnyvale, California, USA; K.S. Udell, University of California, Berkeley, California, USA

Field Demonstration of Steam Enhanced Extraction at Alameda Point, California, USA [511]
K.S. Udell, University of California, Berkeley, California; G. Heron, Steamtech Environmental Services, Bakersfield, California, USA; T. Heron, NIRAS A/S, Aarhus C, Denmark

Topic:  Thermal and Chemical Remediation Technologies (continued)

Sub-Topic  Treatment of Organic Contaminants by In Situ Chemical Oxidation

Pilot-Scale Remediation of Dissolved TCE and Vinyl Chloride Plumes using Different Approaches to In Situ Chemical Oxidation [20]
M. Bonsavage, W.E. Collins, Naval Facilities Engineering Command, San Diego, California, USA; R. Wong, M.A. Coons, The IT Group, San Diego, California, USA

Electrochemical Remediation Technologies for Soil, Sediment and Ground Water [22]
F. Doering, N. Doering, P2 Soil Remediation, Inc., Stuttgart, Germany; J. Iovenitti, D. Hill, W.A. McIlvride, Weiss Associates, Emeryville, California, USA

DNAPL Remediation Project Utilizing Oxy-CatSM [24]
K.J. Cooper, Oxy-Cat Asset Recovery Group, Inc., Cocoa, Florida, USA

Applications of Ionizing Radiation for Degradation of Organic Pollutants in Waters and Wastes [200]
M.A. Trojanowicz, P. Drzewicz, P. Panta, W. Gliśzewski, Institute of Nuclear Chemistry and Technology, Warsaw, Poland; G. Nałęcz-Jawecki, J. Sadowski, Warsaw University of Medicine, Warsaw, Poland

Bench-Scale Testing of Remedial Technologies for NAPLs Containing PCBs and Chlorinated Benzenes [211]
B.R. Maurer, Cummings/Riter Consultants, Inc., Monroeville, Pennsylvania, USA

Catalytic Oxidation of Tritiated Mixed Waste with High-specific Activity For RCRA Delisting Petition [276]
L. Chang, C. Than, H. Morimoto, P.G. Williams, Lawrence Berkeley National Laboratory, Berkeley, California, USA

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Tuesday for discussion with conference participants.
Use of In Situ Chemical Oxidation (Fentons Chemistry) to Remediate Tetrachloroethene (PCE) in Groundwater [292]
G.D. Schaefer, Harding ESE, Inc., Tallahassee, Florida, USA

Mass Reduction versus Mass Movement of Chlorinated Aliphatic Hydrocarbons during In Situ Chemical Oxidation Pilot Test [303]
J. Shiple, R. Wong, IT Corporation, San Diego, California, USA; M. Bonsavage, W.E. Collins, Naval Facilities Engineering Command, San Diego, California, USA

Advanced Oxidation in Casting Emissions Reduction Program: Underwater Plasma, a New Remediation Technology for MTBE and BTEX [326]
M.R. White, Concurrent Technologies Corporation, Oakland, California, USA; A.A. Gremos, Keramida Environmental, Inc., Indianapolis, Indiana, USA

Remediation of Volatile Organic Contamination from a Radioactive Environment Using Thermal and Catalytic Treatment Technologies [345]
R.D. McMurtrey, M.D. Jorgensen, L.A. Harvego, INEEL Environmental Restoration, Idaho Falls, Idaho, USA

Innovative Treatment of DNAPL using Co-Oxidation [378]
K.M. Warner, R. Cowdery, R. Sillan, Levine Fricke Recon, Tallahassee, Florida, USA

CIIC, Chemical Reduction Technology [471]
T.S. Wagner, Clean Technologies International Corp., Austin, Texas, USA

Chemical Oxidation of Tetrachloroethene (PCE) Contamination in a Fractured Saprolitic Bedrock Aquifer using Fenton's Reagent and Sodium Permanganate [472]
P.G. Wener, Versar, Inc., Springfield, Virginia, USA

Topic: Characterization/Monitoring/Verification

Sub-Topic: Innovative Techniques for Site Characterization

Distribution of Metals in Cultivated Soils from Hungary [13]
T. Horvath, University of Veszprem, Veszprem, Hungary

Analysis of Verification Data from the NTISV Demonstrations at Los Alamos National Laboratory Using the Data Correlation Program FUSION.M [138]
D.K. Reichhardt, CH2M Hill Hanford Group, Inc., Richland, Washington, USA; M. Ewanic, MSE Technology Applications, Inc., Butte, Montana, USA

Using Web Browsers to Operate a Data Management System for the Excavation and Remediation of the Sandia National Laboratory Chemical Waste Landfill [181]
M.N. Creech, D. Kwiecinski, R. Emery, URS, Albuquerque, New Mexico, USA; S. Young, Sandia National Laboratories, Albuquerque, New Mexico, USA

Capturing Hydrogeologic Uncertainty in Transport Predictions at the Hanford Site, Washington [185]

Radiation-Hygienic Situation along the Ukrainian Territory Due to the Chernobyl Accident [257]
I.I. Karachev, V.I. Datsenko, Ukrainian Scientific Centre of Hygiene, Kiev, Ukraine

Measurement of the Aerosol Size Distribution and Its Implications for Dose Calculations [363]

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Tuesday for discussion with conference participants.
Characterization of a Ca-Alginate Based Ion Exchange Resin and its Applications in Lead, Copper and Zinc Removal [404]
J.P. Chen, L. Wang, S. Wu, National University of Singapore, Singapore, Singapore

The Physicochemical Analysis of Objects of an Environment for Detection of Aerosol Fragments of an Explosive Origin [432]
N.N. Laptev, R.I. Voznyuk, S.M. Ulyanov, A.V. Smirnov, V.N. Borisov, Russian Federal Nuclear Center - All-Russian Research Institute of Technical Physics, Snezhinsk, Chelyabinsk Region, Russia

Mercury Content in Soils Around a Chlor-Alkali Production Facility, Tarnow, Poland [508]
U. Zielonka, R. Kucharski, A. Sas-Nowosielska Institute for Ecology of Industrial Areas, Katowice, Poland

Topic: Characterization/Monitoring/Verification (continued)

Sub-Topic Innovative Monitoring Sensors and Systems

Differential Thermal Fiber Optic Sensors: A New Approach to Distributed Soil Moisture Monitoring for Landfill Covers and Barriers [71]
D.J. Borns, J.L. Peace, J.D. Weiss, Sandia National Laboratories, Albuquerque, New Mexico, USA

Radiofrequency Sensor Network for Monitoring Containment Integrity [168]
N. Gopalsami, J. Woodford, Argonne National Laboratory, Argonne, Illinois, USA

Real-Time Vadose Zone Monitoring Capability For Performance Assessment of the Corrective Action Management Unit Containment Cell at Sandia National Laboratories, New Mexico [281]
M.J. Irwin, Sandia National Laboratories, Albuquerque, New Mexico, USA; L.A. Brouillard, Duke Engineering and Services, Albuquerque, New Mexico, USA; J.E. Gould, U.S. Department of Energy, Albuquerque, New Mexico, USA

Cost Efficient Long-Term Monitoring (LTM) of Chlorinated VOC Plumes through the Utilization of Passive Diffusion Samplers [297]

Granular iron PRB for groundwater remediation. EnviroMetal Technologies Inc.
Site Characterization Technology For Long-Term Monitoring System Application [380]
J.H. Ballard, J. Cullinane, Army Corps of Engineers, Vicksburg, Mississippi, USA

Networked Implantable Sensors and Web-Based Data Acquisition for Long-Term Environmental Monitoring [474]

Topic: Characterization/Monitoring/Verification (continued)

Sub-Topic: Innovative Approaches to Characterization of Sites Contaminated with DNAPL or Organic Compounds

Fuel Identification in Reactor Fuel Storage Basin Decommissioning [48]
D.S. Smith, Bechtel Hanford Inc., Richland, Washington, USA

Contaminated Groundwater Interception and Remediation within the Mid-Plume Constriction Area at NASA White Sands Test Facility [58]
M.W. Stepro, G.C. Giles, J.W. Pearson, Lynx, Ltd., Las Cruces, New Mexico, USA

Performance Comparison Between Direct-Push and Conventional Drilled Monitoring Wells [102]
M.L. Kram, U.S. Navy, Port Hueneme, California, USA; D. Lorenzana, Intergraph, Port Hueneme, California, USA;
J. Michaelsen, University of California, Santa Barbara, California, USA;
E. Lory, Naval Facilities Engineering Services Center, Port Hueneme, California, USA

The Use of the Membrane Interface Probe (MIP) for expedited DNAPL Characterization [149]
A. Nadolishny, Nedlytek, Inc., Brandon, Florida, USA; P.L. Fleischmann, ZEBRA Environmental Corporation, Lynbrook, New York, USA

Sampling and Remedial System Design Optimization Through Passive Soil Gas Screening [186]
K. Monks, Tetra Tech EM Inc., Albuquerque, New Mexico, USA; M.D. Godwin, Washington Group International, Inc., San Francisco, California, USA

Sample Design Optimization and Identification of Contaminant Plumes and Subsurface Structures Through Use of Multi-tool Surface Geophysics [187]
K. Monks, Tetra Tech EM Inc., Albuquerque, New Mexico, USA; M.D. Godwin, Washington Group International, Inc., San Francisco, California, USA

A Comparison of Field Techniques for Confirming Dense Non-Aqueous Phase Liquids (DNAPLs) [203]
T.W. Griffin, K.W. Watson, HSW Engineering, Inc., Tampa, Florida, USA

New Ways in Detecting LNAPL Plumes in Granular Sediments using Geophysical and Atmogeochemical Methods [204]
S. Mares, J. Knez, J. Dohnal, Z. Jane, L. Zima, Charles University, Prague, Czech Republic;
G. Blaha, RS DYNAMICS Ltd., Prague, Czech Republic

Automating the Monitoring Process [234]
S.R. Burge, D. Hoffman, Burge Environmental Inc., Tempe, Arizona, USA

Successful Applications of Field-Scale Two-Region Modeling to Evaluate SVE Rebound Tests [236]
L.D. Stewart, Praxis Environmental Technologies, Inc., Burlingame, California, USA

Expedited Site Assessment at a Large Naval Fuel Terminal [271]
R.W. Magee, Naval Facilities Engineering Command, Naval Base Norfolk, Virginia, USA;
G.D. Steffen, P. Lang, Navy Public Works Center, Norfolk, Virginia, USA

Auger Drilling into a DNAPL Invaded Clayey Aquitard Cross-Contaminates an Overlying Sand Aquifer [312]
T.H. Baine, B.L. Parker, J.A. Cherry, University of Waterloo, Waterloo, Ontario, Canada

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Tuesday for discussion with conference participants.
Demonstration/Validation of Long-Term Monitoring Wells Installed by Direct Push Technologies [342]
R. Young, L.L. Ackert, Air Force Research Laboratory, Tyndall Air Force Base, Florida, USA;
S. Farrington, M. Gildea, ARA, Inc., South Royalton, Vermont, USA;
L. Parker, Cold Regions Research Engineering Laboratory, Hanover, New Hampshire, USA;
K. Greene, Naval Facilities Engineering Service Center, Pt. Hueneme, California, USA

Challenges in Monitoring the Short-Term and Long-Term Performance of DNAPL Remediation Technologies [425]
A. Gavaskar, S. Naber, W.S. Yoon, Battelle, Columbus, Ohio, USA; J.W. Quinn, NASA Kennedy Space Center, Kennedy Space Center, Florida, USA; T. Holdsworth, U.S. Environmental Protection Agency, Cincinnati, Ohio, USA; C. Reeter, U.S. Navy, Port Hueneme, California, USA

A New Hysteresis Coefficient Based on a Differential Approach for Characterizing the Adsorptive-Desorptive Behavior of Contaminants in Soils [430]
H.M. Poggi-Varaldo, CINVESTAV, Mexico D.F., Mexico; N. Rinderknecht-Seijas, ESIQIE del IPN, Mexico D.F., Mexico;
S. Caffarel-Mendez, TESE, Ecatepec, Edo. de Mexico, Mexico

Topic: Sediment Characterization

The Use of X-Ray Fluorescence Spectrometry to Support Long-Term Monitoring of Heavy Metals Migration at a Wetlands Site [94]
B.P. Ayers, Space and Naval Warfare Systems Center, San Diego, California, USA; G. Dalisay, San Diego State Foundation, San Diego, California, USA; V.J. Kirtay, Space and Naval Warfare Systems Center, San Diego, California, USA

Assessment of Sediment Quality in Baltic Sea Coastal Waters [399]
A. Mueller, Federal Institute of Hydrology, Berlin, Germany

Topic: Sediment Remediation

Field Testing Advanced Remedial Dredging and Sediment Transport Technologies at the New Bedford Harbor Superfund Site [141]
J.E. Lally, Foster Wheeler Environmental Corporation, Bothell, Washinton, USA; A.J. Ikalainen, Foster Wheeler Environmental Corporation, Boston, Massachusetts, USA

A Risk-Based Methodology for Disposal of Arsenic Containing Sediments [201]
W.R. Sloger, Navy Facilities Engineering Command, North Charleston, South Carolina, USA

Optimization of Remedial Design for Remediation of SRS s Radioactive Seepage Basins by In Situ Stabilization/Solidification [364]
A. Ganguly, Bechtel Savannah River Inc., Aiken, South Carolina, USA

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Tuesday for discussion with conference participants.
The Contamination of Sediments into the Selected Reservoirs in Northern Bohemia [372]
T. Spanila, Institute of Rock Structure and Mechanics, Praha, Czech Republic; M. Stastny, V. Srein, Institute of Rock Structure and Mechanics AS CR, Praha, Czech Republic; J. Bendl, Ministry of Environment, Praha, Czech Republic; S. Chomic, T. Kolosova, Academy of Sciences of Belarus, Belarus

Phytoremediation of Soil and Sludge Impacted by Petroleum Hydrocarbons and Metals - A Case Study [436]
S. Ueland, Langan Engineering & Environmental Services, Inc, Doylestown, Pennsylvania, USA

Topic: Regulatory Acceptance of Technologies

Environmental Technology Cost-Savings Analysis Project (ETCAP) [64]
S. DeMuth, Los Alamos National Laboratory, Los Alamos, New Mexico, USA

The Florida Drycleaning Solvent Cleanup Program [98]

Regulatory Acceptance of Monolayer Vegetative Cover for the Mixed Waste Disposal Unit U-3ax/bl at the Nevada Test Site [131]
J.L. Smith, T.M. Fitzmaurice, Bechtel Nevada (Environmental Restoration), Las Vegas, Nevada, USA

Do You Think You Manage Your Source? [194]
V. Dries, OVAM (Public Waste Agency of the Flemish Region), Mechelen, Belgium

Deployment of In Situ Bioremediation and Monitored Natural Attenuation as the Final Remedy for Restoration of Chlorinated Solvent Contaminated Groundwater [209]
L.N. Peterson, J.S. Rothermel, K.S. Sorenson, Jr., North Wind Environmental, Inc., Idaho Falls, Idaho, USA

R. Black, Bechtel BWXT LLC, Idaho Falls, Idaho, USA

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Vibrated Beam Slurry Wall installation using IMPERMIX for containment of pig farm leachate, by Slurry Systems, Inc. Project located in Onslow County, North Carolina.
Poster Session II (continued)
Poster Session Reception
Tuesday, 12 June, 5:30 P.M. - 7:30 P.M., Exhibition Hall


J. Reisenauer, Bechtel BWXT, Idaho Falls, Idaho, USA

Method DYVELOP - the Instrument for not only Industrial Environmental Management [449]

Z. Skala, J.F. Urbanek, Technical University of Brno, Brno, Czech Republic

Theory of Processes - New Language of Human Sustainable Development [452]

J.F. Urbanek, Z. Skala, Technical University of Brno, Brno, Czech Republic

Topic:  Long-Term Stewardship

Long-Term Water Balance Monitoring of Engineered Covers for Waste Containment [73]

R.C. Reedy, B.R. Scanlon, The University of Texas at Austin, Austin, Texas, USA

A Cost-Effective Approach to Multi-Parameter Hydrologic Monitoring to Characterize Groundwater Flow Conditions [188]

K. Monks, Tetra Tech EM Inc., Albuquerque, New Mexico, USA; M.D. Godwin, Washington Group International, Inc., San Francisco, California, USA

Fernald Post Closure Stewardship Technology Project [213]

M.J. Prochaska, L. Stebbins, Fluor Daniel Fernald, Cincinnati, Ohio, USA

Optimization of Groundwater LTM Programs [238]

W.L. Jeffers, C. Schultz, ADI Technology Corporation, Alexandria, Virginia, USA

Uranium Mill Tailings Covers: Evaluating Long-Term Performance [244]

W.J. Waugh, U.S. Department of Energy, Grand Junction, Colorado, USA

LandTrek [347]

J. Lee, U.S. Department of Energy, Oakland, California, USA

Technical Methodology for Evaluating Risk and Cost Information for Long-Term Resource Management of Contaminated Sites [355]

J.W. Buck, R.Y. Taira, L.M. Bagaasen, W.B. Andrews, Pacific Northwest National Laboratory, Richland, Washington, USA

Topic:  Multi-Agency Remediation Strategies

Interagency DNAPL Consortium Project Update [46]

S. Antonioli, MSE Technology Applications, Butte, Montana, USA

U.S. Army Decommissioning and Mixed Waste Remediation Experiences [139]

M.S. Styvaert, U.S. Army, Rock Island, Illinois, USA

New Approaches to Solve Remediation Challenges using Technological Applications at the Sandia National Laboratories Chemical Waste Landfill [304]

S. Young, D. Schofield, Sandia National Laboratories, Albuquerque, New Mexico, USA; R. Methvin, Gram, Inc., Albuquerque, New Mexico, USA; D. Kwiecinski, S.W. Maxey, URS Corporation, Albuquerque, New Mexico, USA

Posters will be on display during the entire day. Authors will be available from 5:30 PM to 7:30 PM on Tuesday for discussion with conference participants.

underlined name denotes speaker
[number in brackets] denotes abstract number
[2]  
Heat Enhanced Recovery of Navy Special Fuel Oil  
D.E. Fulton  
IT Corporation  
Trenton, New Jersey, USA  
J.D. Conway  
Naval Facilities Engineering Command  
Norfolk, Virginia, USA

This presentation is a case history of an innovative approach to recover highly viscous Navy Special Fuel Oil (NSFO) from the subsurface using a closed-looped indirect steam process in conjunction with a series of recovery trenches and water treatment. The presentation will highlight the application of “indirect” steam heating at the Fleet and Industrial Supply Center, Defense Fuel Supply Point, located in Yorktown, Virginia. This facility served as a bulk storage and fueling operation between 1918 and 1980. Historical losses over the years resulted in an estimated 3 million gallons of NSFO released into the subsurface, covering approximately 13 acres. Construction techniques such as horizontal directional drilling and “one-pass” trenching are highlighted as well as treatment technologies using precipitation, dissolved air floatation, organic clay, filtration, and activated carbon. Recovery rates, system performance data, and cost information for the Yorktown project will also be presented that illustrate the benefits of this innovative thermal approach.

[3]  
Approaching Closure at a Fuel Oil Recovery Site Along a Pier using a Vertical Impermeable Barrier and Interceptor Trench  
R.E. Strahle  
The IT Group  
Trenton, New Jersey, USA  
R.W. Magee  
Naval Facilities Engineering Command  
Norfolk, Virginia, USA  
K.M. Lista  
The IT Group  
Somerset, New Jersey, USA

This presentation is a case study on the success of a petroleum recovery project at a Navy facility in Norfolk, Virginia where over 16,680 gallons of free product were recovered, and approval was obtained by the VADEQ to cease active product recovery operations. History had showed that product (with properties similar to a No. 2 fuel oil) from several sources had migrated along several piers and into a nearby sensitive body of water. The project strategy was to intercept the product plume with a vertical impermeable barrier to stop the product from migrating into the nearby harbor and to remove the source by capturing the product with an interceptor trench. This combination provided a unique application of innovative and tested technologies that shortened the duration of the cleanup and provided a responsive and effective solution for stopping the oil from migrating into the harbor. Underground steam vaults were used to reduce the trenched and piping costs prevalent in a pier area, common to all Navy bases, that is full of utility unknowns. As system operation entered the startup phase, a microbiological control agent was employed to prevent biological growth and fouling of process equipment.

[7]  
Asphalt Barriers for Waste Containment  
J.J. Bowders, J.E. Loehr, D. Neupane  
University of Missouri-Columbia  
Columbia, Missouri, USA  
A.M. Bouazza  
Monash University  
Melbourne, Victoria, Australia

An alternative barrier system has been designed that incorporates 100 to 150 mm of asphalt concrete overlain by a 2 to 3 mm thick fluid applied asphalt/geotextile (FAA/GT). Hydraulic conductivity tests were performed separately on laboratory prepared FAA/GT and asphalt concrete specimens. The FAA/GT specimens exhibited hydraulic conductivities less than 1x10^{-11} cm/s. Conductivity tests on asphalt concrete specimens revealed that specimens having 7% or more asphalt cement and unit weight of 22 kN/m^3 or greater have conductivity less than 1x10^{-9} cm/s. A full-scale test pad (60 m x 18 m) was constructed and tested. FAA/GT and asphalt concrete samples were retrieved from the test pad. Laboratory conductivity measurements on field samples demonstrated conductivities comparable to that of the lab prepared specimens. In situ hydraulic conductivity measurements were performed on the test pad using sealed-double ring infiltrometers. The average conductivity was 1x10^{-10} cm/s. Compatibility tests with construction and demolition debris leachate on the field-constructed specimens did not show any appreciable change in the barrier property of the asphalt specimens. Tests are underway to monitor the deformation characteristics of the asphalt liner and the resulting hydraulic conductivity.
Abstracts 10, 13

[10] Modeling Cesium Fate in the Rhizosphere
L.S. Siegel
Northeastern University
Enfield, New Hampshire, USA
A.N. Alshawabkeh
Northeastern University
Boston, Massachusetts, USA
M. Hamilton
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho, USA

Radiocesium (Cs) is one of the most common contaminants found at Department of Energy (DOE) sites. Cs is either bound to soil solids or dissolved in pore water. When plants are incorporated, phytoextracted Cs must also be considered. To engineer innovative remediation technologies, it is necessary to understand the solubilization of Cs from the bound phase in the rhizosphere, the zone where soil and plant roots interface. Researchers have investigated many mechanisms controlling the fate and transport of inorganic compounds in the rhizosphere, including geochemical, biological, and physical factors, but only as discrete subjects. Interactions between these components have not been incorporated into a comprehensive model. A conceptual comprehensive model is being developed that integrates the effects of these processes on Cs solubilization in the rhizosphere. The model categorizes the processes into six sub-models: geochemistry, physical factors, root density, microorganisms, nutrients, and root exudates. A seventh sub-model (Cs fate) describes Cs movement between bound, soluble, and phytoextracted phases. Functional relationships and parametric values within and between the sub-models are being developed based on literature and on-going laboratory experiments. This extended abstract describes the general foundation for the comprehensive model and focuses on the basic formulation for the Cs fate sub-model.

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In our experiments we selected three representative soils in Hungary. The samples were separated into eight particle size fractions. Mineralogical and chemical compositions were studied using X-ray analytical methods (XRD and XRFS). Speciation of elements was determined by the AAS method. In all samples the main components and the trace elements were examined as a function of grain size distribution and mineralogical composition. Examination of trace element distribution of grain-size-fractionated soil samples showed how the measured elements connect to the mineralogical phases. In the case of all examined soil types, trace elements are enriched in the smallest grain size fraction. They are adsorbed onto clay minerals surfaces or built in the interlayer space. Silica was found in the largest amount among the major elements. It binds to the sand fraction (to the quartz) similar to the sodium. Distribution of the later element depends on the feldspar distribution. Al, K and Fe are enriched in the finest fraction thus their amount correlates to the most major and minor elements. In the case of dolomite-derived soils, Ca and Mg were found in significant amounts belonging to the finest fraction. As far as S concerned it appears mainly in the form of organic complexes and in very small quantity in the case of all measured samples. Ba shows some biophile character. The distribution of Cu could be influenced by dissolution-reprecipitation processes in soil water. Zr appears as the main constituent of zircon. According to the AAS measurements the trace elements were connected to organic complexes, amorphous hydroxides and clay minerals.
The Czech Republic is one of the countries with extremely high soil contamination especially due to the vast industrial and military activities. Therefore, programs for soil remediation have the utmost priority in the Czech environmental state policy. Successfully applied remediation technologies include:

- venting and bioventing for the removal of light petroleum products from the former military areas (airfields),
- desorption technologies such as thermal desorption for removal of organic compounds (including PCBs) and so-called solidification-evaporation process (applied successfully, for example, for treatment of neutralization sludge containing volatile chlorinated compounds),
- bioremediation technologies applied, in particular, for hydrocarbon contamination but also successfully field tested for PCB contamination,
- solidification of soil contaminated by petroleum products by homogenization of waste with active calcium oxide followed by adsorption of hydrocarbon components.

The research and development in this field is focused especially on: the removal of metals and other compounds by electrokinetic decontamination, mathematic modeling to describe equilibrium and kinetic effects associated with the passage of air through porous materials contaminated by volatile compounds, phytoremediation – investigation of the ability of selected plant cultures to accumulate toxic metals from contaminated media.

The State Coalition for Remediation of Drycleaners (SCRD), established in 1998, is designed to promote collaboration among states with a common interest; cleaning up soils and groundwater at drycleaner sites. It is comprised of representatives of state governments with operating drycleaner remediation programs. These state programs cover about a third of the drycleaner sites in the United States. SCRD offers its member states an opportunity to learn from their colleagues, techniques for improving the effectiveness of their individual cleanup efforts. The group was formed with the help of the U.S. EPA Technology Innovation Office and the National Ground Water Association. SCRD objectives are to: provide a forum for the exchange of information and the discussion of both technical and implementation issues related to state programs, share information and lessons learned with states without drycleaner-specific programs, serve as a resource for remediation issues, and encourage the use of innovative technologies in remediation. Members of the SCRD are states that have formal drycleaner remediation programs: Alabama, Florida, Illinois, Kansas, Minnesota, Missouri, North Carolina, Oregon, South Carolina, Tennessee, and Wisconsin. Associate members, currently Louisiana and New Mexico, are states considering a formal cleanup program. In addition, participation in SCRD as “Represented States” is open to states without drycleaner-specific programs but active in the remediation of sites under other authorities. New York currently participates as a “Represented State”. SCRD members, associate members, and represented states meet twice yearly. Other interested parties, including industry representatives and individual drycleaners, may attend as visitors. The day-to-day work of the Coalition is carried out by subgroups during monthly conference calls overseen by an elected chairperson. SCRD accomplishments include: improved communications among states with drycleaner-specific programs through semi-annual meetings, including discussions of the status of state program implementation and funding and other related programmatic issues, and training on investigative and remedial technologies; the development of a World Wide Web site that includes links to individual state, industry, and health-related sites, information on the elements of state programs, summaries of SCRD meetings and conference calls, and a private area where members can pose questions and discuss drycleaner operations and/or cleanup topics; and, provided training to members through the presentation and discussion of case studies of drycleaner site cleanups and formal technical training provided by NGWA on relevant technologies. Members conducted a survey of 28 states concerning the technologies they either used or planned to use to assess and remediate sites. Also the 11 member states provided information concerning the administrative aspects of implementing a drycleaner remediation program.

Pilot-scale remediation of dissolved volatile organic compounds (VOCs) using Fenton-based in situ chemical oxidation was conducted at two sites at Naval Air Station North Island. A traditional approach was used at Installation Restoration (IR) Site 5 Unit 2, requiring acidification of the aquifer to generate hydroxyl radicals. A modified approach, using an iron-chelate catalyst under neutral conditions, was used at Operable Unit (OU) 20. In September 2000, IT successfully completed a pilot-scale remediation at IR Site 5 using the traditional approach to in situ Fenton-based chemical oxidation, requiring acidification.
Analytical results indicate that vinyl chloride and cis-1,2-DCE were reduced by 62 percent and 46 percent, respectively, within the pilot area. Full-scale application of the technology is scheduled to begin in March 2001. In December 2000, IT successfully completed a pilot-scale remediation at the OU20 site using a modified in situ Fenton’s chemistry, which occurred under neutral conditions. Non-acidification reduces concerns about potential mobilization of metals and potential highly exothermic reactions. Preliminary data indicate mass reductions of up to 98 percent 6 feet distant from injection wells, and up to 31 percent at 28 feet distant from injection wells. Full-scale application of the technology is being evaluated for potential implementation in 2001.

[21]

Pilot-Scale Thermally Enhanced Soil Vapor Extraction and Free Product Recovery

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Approximately 32,000,000 gallons of liquid waste were disposed at the former Chemical Waste Disposal Area at Naval Air Station, North Island, California. In 1997 a soil vapor extraction (SVE) system was installed, and approximately 80,000 pounds of volatile organic compounds (VOCs), primarily trichloroethene (TCE), were removed. In 1998 additional investigations identified free product underlying the site, consisting primarily of jet fuel and commingled TCE. In August 1999 4 steam injection wells, 10 combination SVE/product recovery wells were added to the system to enhance product and TCE removal on a pilot scale. The pilot area was approximately one-tenth the area of the original, non-enhanced SVE area. The pilot-scale system operated for 9 months, during which over 28,600 pounds fuel hydrocarbons and VOCs were removed from the subsurface. This is compared to approximately 25,000 pounds removed by the original (non-enhanced) SVE system during the first 9 months of its operation, but from over 10 times the area. The steam enhancement and free product removal increased the removal efficiency of the SVE system by over 1000 percent. The efficiency was increased by over 500 percent when comparing the vapor data only.

[22]

Electrochemical Remediation Technologies for Soil, Sediment and Ground Water

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ElectroChemical Remediation Technologies (ECRTs) are phenomena related to colloid electrochemistry and belong to the class of Direct Current Technologies (DCTs) where DC electricity is passed between two electrodes. The primary distinctions between ECRTs and traditional electrokinetics are the (1) operative mechanisms, (2) energy input, (3) nature of the direct current, and (4) resulting outcome. Employing low-energy, proprietary AC/DC current, ECRTs generate reduction - oxidation (redox) reactions at the pore scale, mineralizing organic contaminants and complexing and removing metals. ECRTs are patented in the United States and Europe and include the ElectroChemical GeoOxidation (ECGO) process to destroy organics in soil and sediments, and the Induced Complexation (IC) process to mobilize and remove metals in soil, sediments and ground water. ECRTs are successful both in situ and ex situ. Among the contaminants remediated to below regulatory standards are VOCs, CVOCs, SVOCs, PAHs, PCBs, phenols, fuels, other hydrocarbons, explosives, mercury, cadmium and lead. In many of the more than 50 successful projects, multiple contaminants have been removed with a single system, including combinations of metals and organics. ECRT projects are documented, ISO 9001-certified and insurable. ECRTs work rapidly, on the order of months, at costs well below excavation and disposal. Site data are presented.

[24]

DNAPL Remediation Project Utilizing Oxy-CatSM

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Asset Recovery Group, Inc. (ARG) is a registered environmental engineering and geological firm specializing in the use of a patented (U.S. Patent # 5,967,230) in situ chemical oxidation process that utilizes Fentons chemistry called Oxy-CatSM. ARG was contracted to perform the Oxy-CatSM remediation technology on a site located on the Jacksonville Naval Air Station. An area of ground water and soil had become impacted as a result of aircraft maintenance activities. An underground storage tank used to hold spent solvents and wash water had discharged, impacting an area of soils and groundwater. Soils were removed during tank removal activities. Seven Oxy-CatSM injection points were installed in the area of impacted ground water. Constituents of concern included ground water contamination in excess of 4,440 ppb TCE and other degradation by products. Two vent points were provided to prevent gas generated during the reaction from migrating away from the treatment zone. A soil vacuum extraction (SVE) blower was connected to the vent points to provide a sink, and recovered gas was treated with activated carbon. The Oxy-CatSM process was successful in reducing constituents of concern by greater than 98% with one injection event.
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Radioactive mixed waste buried in multi-acre size un-lined pits and trenches is a huge problem. A field test of a new type of barrier material along with a unique in situ construction method is described. The new barrier material is installed as a viscous liquid but does not harden like a conventional grout but instead cures to a plastic state similar to modeling clay. Even in its liquid state it provides physical and hydraulic bias which acts to isolate contaminants inside the barrier as well as preventing contamination of the grout itself. The soft grout is able to tolerate earth movements and can self-heal drilling penetrations. Reactive elements in the grout increase performance. The EarthSaw field test formed a 24 inch thick bottom and perimeter wall barrier around a simulated waste site using the soft grout. Plans for a larger 200 foot square basin are described. Even larger barrier construction under large multi-acre sites is also discussed. This method divides the bottom barrier into sections using directionally drilled holes and operating the abrasive cutting cable through these holes. An HDPE and clay cap structure completes a vault around the waste and allows enhanced closed system techniques for monitoring of vault integrity.

[27] Steam Pressure Filtration for the Treatment of Limey Soils Contaminated with Aliphatic Hydrocarbons
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Laboratory-scale experiments have been carried out to investigate the possibility of remediating soils contaminated with aliphatic hydrocarbons with the help of Steam Pressure Filtration. Two artificial calcareous model soils of different grain size distribution (Füller Gral and Omyacarb 40 Al) have been contaminated with dodecane, isooctane and isopropanol and then subjected to Steam Pressure Filtration. The laboratory tests showed that even contaminants with high boiling point like dodecane, can be expelled from the model soil with the help of steam. The contaminant concentration can be reduced to 0.4% (isopropanol), 0.1% (isooctane) and 1.5% (dodecane) of initial concentration after 300 s subjected to pressurized water vapor. This steam flows through the porous media of some centimeter thickness. The containment is reduced in the soil samples due to drying effects, dragging forces and changes in the wetting. Additionally, scale-up tests for continuous and discontinuous filter systems (vacuum and pressure filters) have been made. The use of Steam Pressure Filtration offers different advantages: first, soil treated with this method remains biologically active, second, there are no toxic by-products which have to be treated and third, the water necessary for the process can be reused for dispensing the soil matrix.

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Groundwater circulation wells (GCWs) constitute an innovative technology which combines traditional pump-and-treat techniques with quasi in situ treatment. The technology is attractive at the former Nebraska Ordnance Plant site where the public perception of on-going pump-and-treat remedial action is mixed. An expanded remedial action consisting of additional pump-and-treat wells to hydraulically contain the contaminant plumes combined with GCW to more rapidly remove greater masses of upgradient contamination is being considered. Two GCW systems are being pilot tested at two groundwater contamination hot spots on site. Both systems use standard submersible pumps to circulate groundwater from the aquifer to an in-ground treatment system at the wellhead. The pilot system at the location where the explosive compound RDX is found at relative high levels uses ultra-violet (UV) photolysis for treatment, and the second pilot system uses an “off-the-shelf” shallow tray air stripper to remove trichloroethene (TCE). The groundwater is recharged subsequent to treatment. Widely available groundwater flow models were used during the design of the pilot systems, and field analysis kits were used to measure contaminant concentrations during the pilot study. The effective treatment area for each system is characterized by evaluating the change in concentrations measured in nearby monitoring wells.

[29] Barriers Beyond Permeability
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Vertical barriers impeding horizontal ground water transport have been installed by various techniques for decades. In the case of permanent enclosures, the chemical contaminant stock is the containment’s objective. To consider hydraulic conductivity as the sole confining criterion could be misguided when analyzing long term performance. Molecular diffusion resulting from chemical molecules moving through an aqueous phase from a highly concentrated level to a lesser concentrated level under a so called chemical gradient can be, over the long term, a cause of major contaminant transport. In other words, the barrier may be a chemical sieve. This is especially true when the boundary conditions are unaffected as is the case of a barrier supposed to
Fe-Containing Zeolites as Active and Selective Catalysts for Nitrogen-Oxides Reduction

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NO has now been revealed to be generating pollutants on a much broader scale due to its reaction with the wider range of alcohols. In this work we described the catalytic activity of FeZeolites, their preparation, characterization by TPD, FTIR and XAFS used to decompose NO₂ to N₂ by SCR system with very high activity and low selectivity to non-desired N₂O compound. Fe-containing zeolites obtained by novel sol-gel process with Fe³⁺ and/or Fe²⁺ as counter ion incorporated by reproducible post-synthesis methods are obtained. Fe³⁺ on the framework as counter ions also exist as a Lewis site. We differentiated it from the well-known Lewis sites from Aluminium of the zeolithic framework. Thus, LUMO of above cited metal leading to a coordinatively activity with Bronsted acid sites would be successfully applicable to SCR reaction of NO₂. The catalysts emerging as the preferred choices due to their selectivity, availability, and relatively low cost.

Chemical Stabilization of Heavy Metals

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Heavy metals contamination can be found at battery acid recycling sites, electroplating facilities, military installations, firing ranges, brownfields redevelopment sites, and associated with mining activities. The chemical stabilization process uses non-hazardous chemical binders that permanently stabilize heavy metals. The treated soils contain stable metal-reagent compounds that eliminate the leaching of metals. One of the advantages of using chemical stabilization is the ease of application. The reagent(s) can be applied in situ or ex situ. At some sites the reagent can be tilled into the soil in its dry form. At other sites liquid reagents can be sprayed onto the contaminated materials. This adaptability makes reagent application economic and ideal for use at a wide range of sites. In addition to the application advantages, the cost of using chemical stabilization to treat heavy metals contamination is attractive. Typically costs range from $5 to $20 per treated ton. Metals can be treated to meet EPA Resource Conservation Recovery Act (RCRA) or Universal Treatment Standard (UTS) requirements. Often times, stabilized materials can be left on site rather than transported to a hazardous landfill. The transportation and disposal cost savings can be hundreds of dollars per ton.

Design and Control of Slurry Wall Backfill Mixes for Groundwater Containment

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For the last several decades, the use slurry cutoff walls for the containment of contaminated groundwater have proven a cost-effective remediation technology. The proper design of the final backfill for these cutoff walls is dependent on a variety of requirements that include: permeability, strength, density, compatibility with contaminants, soil/groundwater conditions, and of course cost. After proper selection and design of an appropriate backfill mix, quality assurance/quality control (QA/QC) of this material is essential to produce repeatable results consistent to that achieved during initial laboratory bench-scale testing. Here in the United States, a majority of the slurry wall backfill mixes in the past have consisted of either soil-bentonite or cement-bentonite backfill. Recently, the development of soil-cement-bentonite backfill mixes has taken place, particularly for the strengthening of levees. In addition, during the past few years, there has been significant increase in the use of extremely low permeability self-hardening slurries. Based on over twenty years of actual field experience, this paper summarizes: design considerations for slurry wall backfill mixes based on site conditions and performance requirements; typical design mixes utilizing various combinations of soil, bentonite, attapulgite bentonite, cement, slag cement and a variety of admixtures; advantages/disadvantages of various backfill mixes and proper
QA/QC procedures to be utilized in the field.

**[43]** The Steam Stripping Process: A Remediation Technique for TBT- and PAH-Contaminated Dredged Sediments and Soils

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The contamination of dredged sediments by PAH, residues of mineral oils and organotin-compounds (TBT-tributyltin) is a topic of high importance because contaminated sludges occur all over the world as a result of dredging activities, for example at harbors, shipyards or docks. Up to now no technologies are available to treat and decontaminate TBT-containing dredged sludges. In a case study, extremely high TBT-concentrations were detected at a shipyard site in the north of Germany (Baltic Sea area). TBT-concentrations of about 18,000 – 22,000 µg/kg dry matter were detected at that site. In a research and development study we have investigated the decontamination of PAH- and TBT-contaminated soils and sediments. A newly developed steam stripping process has become an efficient way for the treatment of contaminated fine-grained particles. In general cleaning performances of more than 95% for mineral oil, PAH and also TBT have been realized.

**[44]** New Large Scale PRB Network RUBIN Launched in Germany

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In addition to the already running German R&D network for PRBs “SAFIRA”, another novel initiative focussing on actually technical PRB implementations was set up last year. The German Ministry for Education and Research (BMBF) launched “RUBIN”, the large-scale joint R&D and implementation program for the “Use of Treatment Walls for Site Remediation” in Germany. Several general targets were defined that have to be achieved over the next years. RUBIN is an interdisciplinary R&D network focussing on fully technical implementations of PRBs in Germany. RUBIN is scheduled to deliver extensive information on and solutions for general and particular problems regarding design, construction, operation and environmental effects of PRBs as well as legal aspects and regulatory acceptance. Data will be obtained from many different applications for assessing benefits, drawbacks and applicability of PRBs to groundwater remediation problems. Furthermore, with the help of RUBIN, experts will get opportunity of testing thoroughly already running German PRB installations, especially pertaining to long-term performance. Rentability is going to be scrutinized and compared with the Pump-and-Treat technology and quality standards will be set up. RUBIN’s time schedule and financial scope is about 3 years and appr. 4 Mio EUR at least, resp. The lecture to be held will cover a general presentation of RUBIN, its targets, missions and actions and will report on the 11 RUBIN projects.

**[46]** Interagency DNAPL Consortium Project Update

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The U.S. Department of Energy, Office of Science and Technology (DOE-OST); U.S. Air Force Research Laboratory, Air Base and Environmental Technology Division (AFRL/MLQ); U.S. Environmental Protection Agency, National Risk Management Research Laboratory (EPA-NRMRL); National Aeronautics and Space Administration, Kennedy Space Center (NASA-KSC); and the U.S. Air Force 45th Space Wing (45th Space Wing) have combined resources to form the Interagency Dense Non Aqueous Phase Liquids (DNAPL) Consortium. From 1998 through 2001 the Interagency DNAPL Consortium will conduct demonstrations of DNAPL remediation and monitoring technologies. The objective of the demonstrations is to evaluate and compare the cost and performance of in situ DNAPL remediation processes through concurrent testing under realistic, field-scale conditions and in similar geologic environments. The demonstrations are being conducted at Launch Complex 34 (LC34), Cape Canaveral Air Station (CCAS), Florida. The results to date for the project will be presented. Currently, two technology demonstrations are complete and the third (and final) demonstration is in progress. It is anticipated that the cost and performance results will be complete for the permanganate oxidation and 6-Phase Heating demonstrations. It is also possible that the preliminary results from the steam injection demonstration will also be presented.

**[48]** Fuel Identification in Reactor Fuel Storage Basin Decommissioning

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The 105-F or F Reactor was one of the nine reactors constructed by the U.S. Government at the Hanford site in Washington State to support plutonium production initiated in 1942. Construction of the 105-F Reactor began December 1943; operations began in February 1945, and the reactor was shut down in June 1965. Deactivation of the F Reactor Fuel Storage Basin (FSB) occurred in 1970. After the FSB was partially drained, backfill was placed into the basin. Sediment, sludge and miscellaneous items such as fuel buckets, spacers, and other tools were left behind. It is also suspected that there may be as many as 5 fuel pieces
removing at the bottom of the basin. Removal of fuel elements will be accomplished by using a small remote-controlled excavator to expose and remove the fuel elements. Characterization of the sediment will be provided by an Advanced Characterization System (ACS) consisting of an In Situ Object Counting System (ISOCS™) and GammaCam™ unit working together to identify and characterize the isotopic constituents of the material. The system is able to distinguish fuel pieces from other activated items. Use of the remote excavator and ACS will greatly reduce worker exposure during lower fill removal and fuel dispositioning.

[51]
Projected Long-Term Infiltration Rates through a Degraded Multi-Layer Soil/Geosynthetic Closure Cap
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The Hydrologic Evaluation of Landfill Performance (HELP) Model (Version 3.07) was used with a set of published leakage equations to predict the long-term hydraulic performance of a (degraded) multi-layer soil/geosynthetic closure cap, as part of an evaluation of a conceptual closure alternative for a radioactively-contaminated facility. Because the HELP Model does not account for effects of aging on the integrity of a geomembrane, a component of the proposed cap, a review of environmental and geomechanical degradation processes that could detrimentally affect the hydraulic characteristics of the geomembrane was performed, and possible effects of these processes on the geomembrane’s (and other cap components’) hydraulic properties were estimated. Estimated long-term percolation (leakage) rates through two different types of defects, predicted to occur in the geomembrane as a consequence of these degradation processes, were developed. Additional HELP Model simulations were then conducted, using adjusted geomembrane installation quality input parameters to duplicate the calculated leakage rates through the composite barrier unit of the cap. Results of the modeling simulations and leakage calculations indicate, for the cap investigated in this case study, that the HELP Model underpredicted long-term percolation rates through the cover barrier components, compared to rates projected using the leakage equations.

[53]
Use of Low-Flow Sampling Technique for Compliance Groundwater Monitoring at Resource Conservation and Recovery Act (RCRA) Facilities in New Mexico
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Currently, many sites use a “traditional” method of purging and sampling. Meaning a specific (pre-calculated) number of well volumes are removed (generally 3-5 well volumes) from the monitoring well prior to sample collection, indicator parameters are stabilized, followed by collection of the sample. There are many disadvantages of specific volume removal, including increased sample turbidity, possible mobilization of colloids, large volumes of purge water may be generated, predetermined number of well volumes is arbitrary and not site/well specific and agitation can alter groundwater chemistry. Due to rising disposal costs, facilities are looking for ways to reduce the volume of water produced during purging, and are exploring new techniques. As a result, low-flow purging and sampling techniques for compliance groundwater monitoring at Resource Conservation and Recovery Act (RCRA) permitted facilities in New Mexico have become important issues for both the facilities and the regulatory agency. The low-flow purging and sampling technique attempts to reduce the amount of purge water generated, lower disposal costs, and reduce sample turbidity eliminating the need for filtration. The New Mexico Environment Department guidance attempts to promote clarity and consistency and examples of appropriate uses of the low-flow technique for RCRA facilities in New Mexico.

[54]
Impact of Natural Attenuation and Phytoremediation on MTBE and Fuel
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Groundwater contamination including MTBE and BTEX resulted from leaking fuel storage tanks at the Base Exchange Service Station at Vandenberg AFB, California. The perched groundwater system is hydraulically recharged by a car wash operation and landscaping irrigation system. The plume was defined within 9 to 28 feet below the surface. Although soil excavation was completed during UST removal for the majority of impacted soil, a small volume (estimated 7,800 cubic yards) remained in place, resulting in a continual source of impact to the groundwater. Groundwater balance and flow was found to be highly impacted by existing mature eucalyptus trees surrounding the station. To confirm this impact, a field investigation was completed. Groundwater, rhizosphere soil gas, leaf, xylem and tree core samples were collected. In addition, transpired gas sampling and analysis was completed to determine the potential for contaminant uptake as an indirect consequence of root system water uptake. The impact of natural attenuation was modeled using kriging and linear trend comparisons. The impact of the trees was estimated using the mathematical model PlantX. Linear trends fitted to the data indicated decreases of 12 and 6 pounds per year of BTEX and MTBE respectively. Plant uptake was estimated between 18 and 20 pounds per year from the groundwater and vadose zone. The data also suggested that phytoremediation had affected the aerial extent of contamination with trees outside the plume boundary containing compounds of concern. Data were used to revise the site fate and transport model for MTBE, reducing the
time to achieve cleanup goals from 79 to 13 years.

[55]
Oxygen Release Compound Stimulation of Biodegradation Following Landfill Excavation
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Employing the flexibility of the TERC contract to achieve compliance with the Moody AFB RCRA Corrective Action Permit, IT concurrently completed vertical and horizontal delineation of a benzene plume emanating from the Burma Road Landfill (LF01), while implementing an interim measure to address off-Base plume migration. All activities were completed in full partnership with CDM and USACE. Contracted under a fixed price contract, CDM originally defined plume boundaries and the aerobic biological activity in the area, designed the interim measure, and will be completing the final site RFI Investigation Report. Interim measure objectives included the following: 1) removal of buried materials and 1,062 cubic yards of soil within the landfill that were identified as potential sources of benzene contamination, 2) acceleration of existing biodegradation processes that are currently remediating the groundwater plume by the addition of Oxygen Release Compound (ORC), and 3) improvement of the existing drainage pattern over LF01 to ensure positive drainage away from the site to minimize infiltration and erosion. ORC was added to the impacted media using two methods; addition through mixture with excavation backfill materials and slurry injection to groundwater downgradient of the plume source area. Approximately 312 pounds of ORC were introduced to excavations in the source area and 615 pounds were introduced to impacted groundwater through 41 DPTs injecting at approximately 30 to 40 ft bgs from June to August 2000. Initial comparison to baseline conditions illustrated a 3 to 4 ppm dissolved oxygen concentration increase within 8 weeks of injection within select monitoring wells. Initial effectiveness monitoring indicated isolated decreases in benzene concentration within the plume. For example, benzene concentrations in monitoring wells BR10 and BR11 decreased from a June 2000 concentration of 130 ppb to 1.5 and 100 ppb, respectively, in November 2000. A second injection of ORC and placement of a piezometer through which the backfilled ORC mixture can be hydrated in the former source area are planned in the near future. This interim measure will be monitored through August 2001 and may stand as the final corrective action for this site.

[56]
Immobilization of Radionuclides in Soil Minerals After Thermal Treatment
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Heating of common minerals (quartz, feldspar, or limestone) or a soil (Hanford Reservation) up to 1000°C, after spiking with radioisotopes (58Sr, 57Co, 134Cs, or U), markedly decreased their leachability after cooling using a sequential extraction sequence designed to assess each contaminant’s environmental mobility. For example, 85Sr was converted from 98% leachable in the ambient Hanford soil to less than10% leachable, even in the final acid extracts, by heating to 1000°C. The overall effect is consistent with rapid high-temperature solid diffusion from initial contaminated surfaces into the interior of uncontaminated minerals; subsequent diffusion out of these mineral particles at ambient temperature, as measured by their sequential extraction behavior, would be such a slow diffusion process that the radionuclides may be considered sequestered from further potential environmental movement. The effect was found to follow an Arrhenius-type relationship with treatment temperature and to be independent of previous thermal treatment of the minerals. Although these results are consistent with a temperature-dependent diffusion process, a general and promising technique for environmental treatment of contaminated soil by high-temperature heating can be extrapolated directly from the empirical leaching information without dependence on any mechanistic explanation. The immobilization technique may be applicable to any non-volatile radionuclide or inorganic contaminant in soil or geologic material and has the potential to achieve high degrees of immobilization for most contaminants.

[58]
Contaminated Groundwater Interception and Remediation within the Mid-Plume Constriction Area at NASA White Sands Test Facility
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NASA White Sands Test Facility is currently developing and implementing corrective measures to address a four mile long contaminant plume (halogenated solvents and N-nitrosodimethylamine). Hydrogeologic controls within a mid-section (fractured volcanic bedrock) of the plume, the mid-plume constriction area (MPCA), confine contaminated flow to a relatively narrow zone. If remediation extraction wells could be effectively placed in this area, the plume-front could be isolated from the source. Groundwater modeling simulations within the MPCA were utilized to provide the initial target flowrate required for plume interception. A 1988 site-wide seismic survey indicated some potential structural conduits within the MPCA, but lacked sufficient resolution to identify specific drill targets. A 1997 hydrostratigraphic investigation of individual volcanic units within the MPCA revealed only limited potential aquifer yields, insufficient for remediation purposes. A seismic reflection survey conducted in 1998 focused on structural targets within the MPCA. Well MPE-1, spotted from the 1998 seismic survey, encountered a narrow conductive fault zone that produces nearly five times the sustained volume at elevated contaminant concentrations relative to surrounding monitoring wells. Based on the success
of well MPE-1, additional seismic exploration has been used to locate other structures in the MPCA that could potentially yield high volumes of contaminated water to wells.

[59]
Moffett Field Funnel and Gate TCE Treatment System: Interpretation of Field Performance using Reactive Transport Modeling
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A multicomponent reactive transport simulator was used to understand the behavior of chemical components, including TCE and cis-1,2-DCE, in groundwater transported through the pilot-scale funnel and gate chemical treatment system at Moffett Field, California. Field observations indicated that zero-valent iron emplaced in the gate to effect the destruction of chlorinated hydrocarbons also resulted in increases in pH and hydrocarbons, as well as decreases in Eh, alkalinity, dissolved O2 and CO2, and major ions (i.e., Ca, Mg, Cl, sulfate, nitrate). Of concern are chemical transformations that may reduce the effectiveness or longevity of the iron cell and/or create secondary contaminants. A coupled model of transport and reaction processes was developed to account for mobile and immobile components undergoing equilibrium and kinetic reactions including TCE degradation, parallel iron dissolution reactions, precipitation of secondary minerals, and complexation reactions. The model reproduced solution chemistry observed in the iron cell using reaction parameters from the literature and laboratory studies. Mineral precipitation in the iron zone, which is critical to correctly predicting the aqueous concentrations, was predicted to account for up to 3 percent additional mineral volume annually. Interplay between rates of transport and rates of reaction in the field was key to understanding system behavior.

[61]
In Situ Immobilization of Redox Sensitive Contaminants
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Contamination of groundwater and soil by redox-sensitive contaminants has gained importance in recent studies (Saier et al. 2000, Guha et al. 2001). Many redox sensitive contaminants like chromium (Cr), cobaltEDTA (CoEDTA), and uranium (U) transport in the subsurface is dependent on the pH of the pore water and soil chemistry. The transport of Cr in the subsurface at many of the U.S. Department of Energy facilities is influenced by hydrological, geochemical, and microbiological processes. No studies to date have focused on coupled hydrological, geochemical, and microbiological processes affecting Cr transport, either in laboratory column or in field-scale experiment. The successful use of microorganisms for in situ stabilization of contaminants requires an understanding of coupled flow, transport, and reaction processes that control their growth and distribution in porous media. In order to better understand these hydrobiogeochemical systems attempts have been made to simulate subsurface conditions in laboratory column experiments. Laboratory column experiments were conducted for microbiological reduction of Cr(VI) with a facultative bacteria Shewanella alga Simidu (BrY-MT), and included both columns packed with pyrolusite coated-sand, and uncoated-sand. In concurrence with these experiments, a mathematical model has been developed to quantitatively identify coupled processes that control chromium transport and geochemical-microbial reactions. Calculations of this model were also compared to data collected from the column experiments. The results of this work supplement the severely limited database on the transport of Cr, and provide a means for quantifying the coupled hydrological, geochemical, and microbiological processes that contribute to the phenomenon. The outcome of this research will be directly applicable at various DOE sites, where in situ stabilization of redox sensitive contaminants is of priority concern.
Electrokinetic Remediation of Mercury-Contaminated Soils  
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Numerous contaminated sites exist that have been polluted with mercury as a result of accidental spills and improper disposal practice. The mercury-contaminated soils can have adverse effects on the ecology and human health. The purpose of this study is to investigate the potential for electrokinetic remediation of mercury-contaminated soils. A series of batch tests were conducted to investigate the relative desorption potential of mercury from kaolin and glacial till soils using three extractant agents, namely, KI, Na-EDTA and NaCl (all of them with a concentration of 0.1 M). These tests were conducted under different pH conditions (within a pH range between 2 and 12). Also batch tests using deionized water were performed for comparison purposes. The results of the batch tests revealed that the extractant agent KI was the most effective agent for removing mercury from both soils. Na-EDTA also, but in lesser extent, exhibited mercury removal. Electrokinetic tests were conducted to evaluate the effect of the extractant agents Na-EDTA and KI on overall remedial efficiency. For comparison purposes, electrokinetic baseline tests using deionized water were also carried out. All of these electrokinetic tests were conducted under the same conditions of voltage gradient (1 V/cm) and extractant ion concentration (0.1 M). The results of these electrokinetic tests revealed that KI was efficient in removing mercury from soils, while Na-EDTA did not show any significant removal of mercury. Overall, 95% removal was achieved from kaolin; however, only 77% removal was achieved from glacial till which is mainly attributed to the existence of insoluble mercury complexes in this soil. The results of this laboratory study are being utilized in the on-going study to evaluate the removal efficiency in actual field contaminated soils as well as to perform a field pilot-scale test.

Advanced Integrated Information Management System: A Flexible, Customized Decision Support Tool  
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The AIMTech-developed Advanced Integrated Information Management System (AIIMS) is a computer-based management tool that combines the power of relational databases and geographic information systems to provide a user-friendly interface for organizing, storing, retrieving, and displaying data from a manager’s desktop. AIIMS tracks the complete range of infrastructure, operations, and environmental activities and provides easy-to-use, customized applications to meet customer-specific compliance and reporting requirements. The system facilitates knowledge-based decisions through a ready-reference library of pertinent site information. AIIMS serves as a tool kit for rolling up functionalities (reporting tools, multiple dissimilar databases) and organizes and integrates complex information that resides in multiple locations and in various formats (computer-aided design drawings, financial spreadsheets, site maps, models, photographs, schedules, word processing documents). AIIMS accesses information through either a map or data hierarchy interface and tracks environmental and facility projects at one or multiple installations simultaneously. AIIMS utilizes a plug-in architecture that allows it to provide functionality for a diverse set of requirements. AIIMS incorporates intelligent agent technology that merges information from desktop, network, enterprise, and internet sources. AIIMS can be deployed as an application or via the web. The AIIMS toolkit provides methods to wirelessly enable for a host of new applications on handheld and cellular devices. AIIMS has been successfully adapted and deployed for the U.S. Department of Defense Joint Program Office for Infrastructure Assurance; U.S. Army Kwajalein Atoll, Republic of the Marshall Islands; Fort Campbell, Kentucky; Robins Air Force Base, Georgia; Loring Air Force Base, Maine; and U.S. Air National Guard Bases.

Environmental Technology Cost-Savings Analysis Project (ETCAP)  
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The Los Alamos National Laboratory Environmental Technology Cost-Savings Analysis Project (ETCAP) has been in existence for over ten years with the primary goal of analyzing the remediation economics of national environmental problems. The projects studied have been primarily focused on, but not limited to, nuclear waste legacy problems. These problems are analyzed using a variety of methodologies such as economic analyses, technology performance evaluations, modeling and simulation, and complex-wide workshops. ETCAP has sponsored studies resulting in over 100 publications. This poster will highlight ETCAP’s accomplishments during the past decade and summarize the result of several recent case studies. In particular, the results of ETCAP’s recent effort to summarize potential remediation cost savings due to the use of innovative technologies across the Department of Energy (DOE) complex will be presented. Additionally, more specific case studies for the Decontamination and Volume Reduction System for efficient processing of oversized metallic transuranic waste at Los Alamos National Laboratory, and for the remediation of high-level waste in underground storage tanks at the DOE Hanford site by way of enhanced sludge washing, will also be presented.
Abstracts 65, 66, 69

[65] Innovative, In Situ Use of Sulfate Reducing Bacteria to Remove Heavy Metals in Acid Mine Drainage
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Unregulated heavy-metal mining in the West during the early to mid-1900s resulted in the generation of acid mine drainage (AMD) at many locations. AMD is characterized by low pH and high concentrations of heavy metals. Results are presented that were gathered during on-going field-scale testing of an innovative technology, the use of sulfate-reducing bacteria (SRB), designed to treat and control acid mine drainage (AMD). The project was performed under the Mine Waste Technology Program (MWTP) which is funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by the EPA and the U.S. Department of Energy (DOE). SRB produce hydrogen sulfide and bicarbonate when supplied with sources of carbon and sulfate. Hydrogen sulfide reacts with metal ions in AMD, precipitating them as metal sulfides; the bicarbonate serves to help neutralize the drainage. After thorough pilot-scale testing, the field demonstration is being performed at an abandoned, hard rock mine where a flooded underground mine is being used as an in situ biological reactor. Data collected during the first seven years of operation will be presented. Although seasonal variation is observed, significant pH increase and high removal efficiencies are seen for Al, Cd, Cu, and Zn (70% to near 100%).

[66] Using Rapid Sediment Characterization Technologies to Expedite the Marine Site Characterization Process
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Rapid sediment characterization (RSC) technologies are field-transportable analytical tools that provide real-time or near real-time data and reduce the time and cost of marine sediment characterization. RSC technologies (including x-ray fluorescence (XRF) for metals, ultraviolet fluorescence (UVF) for PAHs, immunoassay for PCBs and QwikSed bioassay for biological effects have been refined and implemented by the Navy to delineate areas of concern, fill information gaps and assure that expensive, certified laboratory analyses are targeted in areas where they will have the greatest possible value. Field analytics (often labeled screening tools) do not totally replace standard laboratory analyses, but more efficiently guide placement of the limited number of expensive laboratory samples that are generally available. The ability to integrate, interpret and present screening results in an effective manner is critical to successfully using these tools to assist with the site characterization process. RSC analyses allow better delineation of contaminant distribution by providing higher data density in a time- and cost-effective manner, without relying solely on costly laboratory analyses. Results from several Navy sites will be presented to demonstrate the range of utility of these techniques. For example, RSC tools were used at Hunters Point Shipyard to map contaminant distribution and support development of a stratified random sampling design for a more detailed study.

[69] Remediation of Explosives Contaminated Soils at Joliet Army Ammunition Plant via Windrow Composting
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During active periods, contamination of soils and sediments has occurred at Army ammunition plants and Army depots during production and handling of explosives such as 2,4,6-trinitrotoluene (TNT), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) and methyl-n-2,4,6-tetranitroaniline (tetryl). The Joliet Army Ammunition Plant (JOAAP) is a former munitions production facility located on approximately 36 square miles (23,542 acres). The most cost effective and efficient methods of explosives contaminated soils remediation at JOAAP was determined to be a bioremediation process called windrow composting. It involves mixing the contaminated soils with organic matter (amendments) to promote degradation of the explosives. The amendments selected for use are corn processing waste, wood chips, and stable bedding. The compost blending ratio is 70:30 amendments:soil. The amendment portion of the compost is approximately 18% corn processing waste, 52% stable bedding, and 30% wood chips to obtain a the required carbon:nitrogen (C:N) ratio and moisture level. At JOAAP, the process is accelerated by starting the microbial activity prior to mixing with contaminated soil. A 20-acre state-of-the-art facility capable of treating 40,000 tons of soil a year was constructed onsite at JOAAP to accomplish this. During its initial 4 months of operation, 14,000 tons of explosives contaminated soil have been successfully bioremediated. As the treatment process is refined, it is anticipated that over 50,000 tons can be treated in a year. In this paper, the success of windrow composting at JOAAP, the impact of improvisations on the treatment time and the lessons learnt will be presented.
Laboratory experiments were carried out in order to determine the effect of organic acids synthesized by Aspergillus species on the mobility of heavy metal ions in contaminated soils. The experiments were performed as part of a project to establish the usefulness of that Aspergillus species for ex situ remediation of highly polluted soils. Soil samples originated from A and B-horizons of a cambisol (Gyöngyösoroszi, Hungary) and from A horizon of a chernozem soil (Dombóvár, Hungary). Fermented solutions contained Aspergillus foetidus or Aspergillus niger species were added to the soils in a column experiment in 6 parts and the different fractions were examined separately. In the leachate Zn, Pb, Cd, Cr, Ni and Cu ion concentrations were determined by Varian SpectrAA10 atomic adsorption spectrometer. For presenting substance balance the soils were analyzed before and after the column study. The variability in the agent conditions resulted in high levels of deviation in the experimental results therefore a statistical procedures were used to estimate the specific effect of fermented solution. We supposed that the sulfide ores would be dissolved by the fermented solution, which contains reducing components. In Gyöngyösoroszi soil the HNO₃ soluble amount of Ni, Pb and Cd and in the Dombóvár soil the HNO₃ soluble amount of Cr were increased after the treatment with fermented solution. The Ni ion indicates any hardly solute iron sulfide existence in the soil and the Pb and Cd refer to galena or zinc blende content of soils. The Aspergillus niger solution dissolved higher amount of Zn and Cu ions from the soils despite the higher pH of this fermented solution. In acid soils this is true also for the Cd accompanying the Zn. Specific effects of Aspergillus niger was found for Zn, Cd and Ni ions and less for Cu ions. Aspergillus foetidus is specific for Zn.

To support the Mixed Waste Landfill, at Sandia National Laboratories, Albuquerque, NM, we designed a soil moisture system based on a commercial differential-thermal optical fiber system used in oil wells. The DOE ASTD program facilitated the incorporation of this distributed moisture sensor system. The optical fiber system consists of an optical fiber line and an encasing stainless steel tube, which together are emplaced along layers in the landfill. The basis of this system is that a change in soil water content causes a change in the thermal conductivity of the soil. When constant power is dissipated from a line heat source (in this design the electrically conducting stainless steel tubing), the temperature increase near the fiber and tubing will depend on the thermal conductivity of the surrounding soil. This method is similar to electrical thermistor-based method (Campbell 299 Soil Water Potential Probe). The optical fiber system was calibrated to the expected ranges of soil moistures in a field test adjacent to the Mixed Waste Landfill at Sandia National Laboratories.

Site investigations at a manufacturing facility in Virginia, USA delineated the presence of trichloroethylene; 1,1,1-trichloroethane; chlorinated breakdown products; acetone; and isopropanol in soil and groundwater in a fractured rock aquifer. In situ cometabolic bioremediation through the injection of air, gaseous-phase nutrients (nitrogen and phosphorous), and carbon source (methane) was undertaken to stimulate existing microbial populations to promote and accelerate the degradation of target volatile organic compounds (VOCs). Monitoring data indicate that the enhanced bioremediation system has been successful in stimulating microbial growth based on increases in phospholipid fatty acid (PLFA) biomass and methanotroph (MPN) measurements of several orders of magnitude within four months of system start-up. The initial total VOC concentrations ranged from 50,000 ug/L to >1,000,000 ug/L. Groundwater monitoring shows significant (90 to 99.96%) total VOC reductions in the pilot test area and in down-gradient monitoring locations since the initiation of the injection campaign. This indicates that the bioremediation process is very effective in treating VOCs in the source area, which leads to reduced VOC concentrations in down gradient locations. VOC reductions of 99.99% have been observed in monitoring wells 75 ft down-gradient from the area affected by the injection system. As a result of the treatment system operation, groundwater in several monitoring locations meets drinking water standards. Based on the pilot test observations, the system has been expanded to full-scale application to increase the delivery of the necessary amendments to complete the site restoration. The expansion has resulted in further removal of VOCs in locations within the source area where previous results had shown limited improvement.
Abstracts 73, 75, 76

[73]
Long-Term Water Balance Monitoring of Engineered Covers for Waste Containment
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The growing realization that remediation of many contaminated sites is technically infeasible has resulted in a shift in emphasis to containment as an alternative to remediation. Monitoring is required to demonstrate the effectiveness of engineered cover systems in minimizing infiltration into underlying waste. The purpose of this study is to evaluate a variety of monitoring technologies. Monitoring systems are installed in a resistive (GCL/asphalt) barrier at 1.3 m depth and a conductive (capillary) barrier at 2.0 m depth constructed near El Paso in 1997. The site is heavily instrumented with both automated and manual monitoring systems designed to quantify the soil water balance and to monitor soil water potential energy. All of the water balance components are being monitored. Results indicate that electromagnetic induction (EM), once calibrated with neutron probe and temperature data, can reliably monitor water storage changes. The non-invasive nature of EM measurements could preclude the development of preferential pathways resulting from instrument installation. Neutron probe measurements of water storage are more reliable at this site than TDR because of signal attenuation resulting from high conductivity soils. Heat dissipation sensors have proved more reliable than thermocouple psychrometers for measuring soil water pressure. Results of this study provide valuable information on appropriate technologies for monitoring performance of engineered covers.

[75]
Side-Slope Considerations For Above-Grade Earthen Covers
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Above-grade earthen covers are often used at newly constructed waste sites and for waste left in place at toxic-waste landfills, both to minimize worker health risks and reduce excavation costs. Side slopes are critical to the overall performance of such covers and traditionally have been used to stabilize cover extremities. Because protective slopes may occupy half the footprint of covers at small waste sites (< 5 ha), they can potentially influence the overall water balance. Yet, there is no consistent design standard to optimize hydrologic performance. A multi-year test, comparing two side slope designs, was recently initiated at the Department of Energy’s Hanford Site where a field-scale prototype cover was placed over a radioactive waste trench. Results show that side slopes play an important role in a cover’s water balance. Essentially all measured drainage from the cover was due to net infiltration into the coarse-gravel and rock side slopes. As much as 30 percent of annual precipitation intercepted by the side slopes has been captured and diverted through passive and active lateral drains. Advevtive loss from wind action on the rock surfaces reduces, but does not eliminate, drainage from the rock slopes. These data suggest that in arid or semiarid climates, consideration of slope design and the impacts of lateral diversion on adjacent waste sites must be a top priority. The ideal side slope design should minimize water accumulation and intrusion along the extremities. Design considerations might include water harvesting by terraced vegetated strips on side slopes.

[76]
Bioremediation of TCE Source Area at the Mobile Launch Platform Rehabilitation Sites/Vehicle Assembly Building Area
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Microcosm tests are being performed to evaluate the potential to biodegrade trichloroethene (TCE) in groundwater at KSC, Florida. Microcosm treatments were constructed to: (i) evaluate if indigenous microorganisms at the site could be stimulated with electron donors to completely dechlorinate TCE; and (ii) assess the potential for bioaugmentation with KB-1, a dehalorespiring microbial culture, that improves the rate and extent of dechlorination. The microcosm treatments amended with electron donors indicated that reducing conditions were present at day 36. Although natural microbial populations had developed, TCE was only slowly degrading to cis-1,2-dichloroethene after 126 days. These results tend to indicate that the natural population of dehalorespiring bacteria is low and that the electron donors did not sufficiently stimulate growth. At day 36, KB-1 was added to microcosm treatment amended with electron donors. Complete TCE dechlorination via cis-1,2-dichloroethene and vinyl chloride (VC) to ethane was observed in the bioaugmented treatment. Results indicated that the time required to degrade TCE and cis-1,2-dichloroethene by one half (half-lives) was 7 days and 40 days, respectively. Although most of the TCE mass has been reduced to ethane, some VC is still present. The results, after 163 days of incubation, indicate that bioaugmentation with KB-1 can greatly improve the rate and extent of TCE dechlorination. The results of the next sampling event will provide the data necessary to evaluate the potential for total dechlorination.
We present an alternative approach for improving the estimation of mass transfer rates among the phases used in groundwater models. The objectives of this study are to understand in detail the sorption processes occurring at Fernald, Ohio, and to refine Fernald’s groundwater model. The distribution coefficients with and without considering chemisorption will be determined by laboratory experiments using sediment samples. Once the distribution coefficients are determined, the rates of adsorption, desorption and chemisorption will be calculated by the proposed approach that includes analytical methods and the laboratory experiments. The injection/extraction of groundwater can cause the mass transfer processes among the phases to be in a nonequilibrium state. The importance of nonequilibrium sorption processes involving adsorption, desorption, chemisorption, dissolution and precipitation among the phases has been recognized (Harmon et al., 1992; Brogan and Gailey 1995; Lee et al., 1998). The rate for each process that needs to be determined can greatly affect the model calculations of the underground distribution of a contaminated plume. The accurate determination of rates, particularly for the chemisorption, in which the sorbed contaminant is in the chemically bonded state, is essential for modeling groundwater transport studies. At present, there are no specific formulations that can be used for determining the rate for each process. The values of the adsorption and desorption rates were studied and reported from laboratory studies (for example, Harmon et al., 1992) and from field studies (for example, Goltz and Roberts, 1986). The present study will emphasize the determination of the chemisorption rate that has been shown to have a profound impact on the calculations of underground uranium plumes at the Fernald Environmental Management Project (FEMP), Fernald, Ohio (Lee et al., 1998). In addition, we will also determine the adsorption and desorption rates.

Factors such as the build-up of surface precipitates, bio-fouling, and changes in subsurface transport govern long-term performance of in situ Permeable Reactive Barriers for treating contaminated groundwater. Authigenic precipitates can impact remedial performance by decreasing iron reactivity and permeability, resulting in decreased reaction efficiency and the potential rerouting of subsurface flow paths. Reactive barriers containing zero-valent iron alter ambient groundwater chemistry by increasing pH and decreasing the oxidation-reduction potential. Depending on the composition and oxidation state of ambient groundwater, these conditions can favor the precipitation of mixed iron oxyhydroxides, Ca-Fe carbonates, magnetite, or mixed valence Fe(II)/Fe(III) ternary compounds (such as green rusts). In sulfate-rich groundwaters, reducing conditions promote microbial sulfate reduction and the precipitation of iron monosulfides and the subsequent transformation to pyrite. The results of long-term monitoring studies (groundwater chemistry and soil/iron characterization) are presented from PRBs at the U. S. Coast Guard Base (Elizabeth City, NC) and the Denver Federal Center (Lakewood, CO), each with contrasting groundwater compositions. At both sites, barrier installations have been in place for over 4 years. We present a comparison of groundwater equilibrium modeling with the results of mineralogical characterization using microscopy, XRD, stable sulfur isotope ratios, and extraction studies. This is an abstract of a proposed presentation and does not necessarily reflect EPA policy.

Research was conducted to evaluate a multiple-layer system of volcanic rock, limestone, Apatite®II mineral and a “biobarrier” to impede migration of radionuclides, metals and colloids through shallow alluvial groundwater, while simultaneously destroying contaminants such as nitrate and perchlorate. The “bio” portion of this Multi-Barrier system uses highly porous, slowly degradable, carbon-based material (pecan shells) that serves as an energy source and supports the growth of indigenous microbial populations capable of destroying biodegradable compounds. The studies, using elevated nitrate concentrations in groundwater, have demonstrated reduction from levels of 6.5-9.7 mM nitrate (400-600 mg/L) to below discharge limits (0.16 mM nitrate). Perchlorate levels of 4.3 µM (350 µg/L) were also greatly reduced. Elevated levels of nitrate in drinking water are a public health concern, particularly for infants and adults susceptible to gastric cancer. Primary sources of contamination include feedlots, agriculture (fertilization), septic systems, mining and nuclear operations. A major source of perchlorate contamination in water is ammonium perchlorate from manufacture/use of rocket propellants. Perchlorate, recently identified as an EPA contaminant of concern, may affect thyroid function and cause tumor formation. A biobarrier used to support the growth of microbial populations (i.e. a biofilm) is a viable and inexpensive tool for cleaning contaminated groundwater.
[83] Demostration of Rapid In Situ Detection of VOCs by Membrane Introduction Mass Spectrometry
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The Tri-Service Site Characterization and Analysis Penetrometer System (SCAPS) was developed to reduce the time and cost required for site characterization. Direct-push sensors were developed to detect specific classes of contaminants such as petroleum hydrocarbons, explosive compounds, radionuclides, metals, and volatile organic compounds (VOCs). This presentation describes the demonstration of a direct-push sensor that can quantify VOC contamination in the subsurface in real-time. This system consists of a modified Membrane Interface Probe (MIP) developed by Geoprobe Systems, Inc. coupled to a direct sampling ion-trap mass spectrometer (ITMS). The ITMS-MIP system was proven capable of rapidly collecting and analyzing samples from the subsurface, regardless of matrix. Five performance demonstrations with validation of results have been completed to date. Two of the five demonstrations resulted in a strong linear correlation ($r^2 = 0.9$) with validation samples analyzed using EPA Method 8260. While the other three demonstrations revealed that the calibration method used introduced a bias compared to EPA Methods.

[84] The Fernald Long-Term Stewardship Pilot
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This presentation would discuss the long-term stewardship activities that are presently underway at this Department of Energy closure site. The Fernald Environmental Management Project (FEMP) is a DOE site closure project located 20 miles north of Cincinnati, OH. The FERNALD plant was part of the country’s nuclear weapons program producing the finest uranium metal in the world for over 40 years. In the mid to late 1980’s the plant shut down as the cold war came to an end leaving major cleanup challenges at the site. The mission of the Fernald project is to return the site to an ecologically restored area under federal control in the 2006-2010 time frame. The current plans call for demolition of all buildings and facilities at the site, remediation of contaminated groundwater, solidification and shipment offsite of high level radioactive waste currently stored at the site, and burial of certain low level waste in on site disposal cells. We are today at FEMP integrating the long-term stewardship needs into the ongoing remediation activities. The process includes involvement of the DOE staff, the site contractor (Fluor Fernald), the regulators and the stakeholders. The goal of stewardship is to ensure that the level of human and environmental health and safety, achieved by the selected remedies is maintained. The trust of the pilot program is to identify site needs and to find or develop and deploy technologies that will meet those needs. Major components of the FEMP stewardship plan identified to date include: 1) monitoring and maintenance of the on site disposal facility (cell); 2) monitoring and maintenance of the rest of the site; and 3) record keeping. A team comprised of site personnel, universities, the DOE Subcon Focus Area, and national experts in disposal facility design are defining the critical indicators of disposal facility integrity, and the technologies to monitor those indicators. It is expected that several technologies will be deployed and tested in parallel prior to site closure, with a final decision made on the technologies to be used for long-term stewardship prior to final closure of the site.
The Chernobyl accident and modeling applied to monitoring of radionuclide transport on the problem of flooding of the deep uranium mine by water from a tailings pond. The planned flooding of the Hamr I mine will significantly affect the hydrogeological situation in all the area. Intensive underground water flow changes will occur in the first two years of flooding process. That is why the unsteady unsaturated flow and reactive-transport model was used. The problem of flooding the mine goes together with liquidation of the chemical treatment plant tailings pond. The flooding by alkalized tailings pond free water will avoid future acidification of mine water as a result of decomposition of oxidized pyrite minerals.

RFI to CMS: An Approach to Regulatory Acceptance of Site Remediation Technologies
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Over the last two years, Lockheed Martin made a smooth transition from RCRA Facility Investigation (RFI) at a NASA site to its Corrective Measures Study (CMS) phase, within the RCRA Corrective Action Process. The CMS phase began with the selection of three technologies determined to be appropriate for engineering soil characteristics, groundwater redox potential, soil geochemistry, and soil biochemistry. These technologies also address US EPA’s “no migration of contaminated groundwater” environmental indicator (EI) program. Each pilot test provided information that advanced the CMS. The first pilot test involved a field demonstration of shallow-depth soil hydrofracturing within low permeability soils. The second test involved a laboratory evaluation of food sources for enhancing indigenous bacteria responsible for reductive dechlorination of TCE. The third test involved a unique design of a cylindrical zero valent iron reactive barrier wall around a below-sea-level storm drain manhole in a TCE-contaminated area of concern. Following up on the...
laboratory evaluation, an additional test demonstrated that in situ chemical oxidation does not adversely affect the reductive dechlorinating bacteria. The next iteration of technology pilot tests involves additional advancement of the three technologies.

**Abstract 93**

**Enhanced Biological Reductive Dechlorination at a Dry Cleaning Facility**

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A significant level of enhanced biological reductive dechlorination was demonstrated at a commercial dry cleaning facility in Orlando, Florida. Under the auspices of the Florida Department of Environmental Protection, and in accordance with the Dry Cleaning Solvent Cleanup Program, the upper and lower portion of the surficial aquifer at the site was treated with an experimental source of time-release hydrogen (HRC®, Regenesis Bioremediation Products, Inc.). The hydrogen, which is produced by fermentation from HRC derived organic acids, serves as an electron donor that mediates the reduction of chlorinated hydrocarbons. The upper portion of the surficial aquifer at the site generally consists of sand and silty sand to a depth of approximately 29 feet below land surface (bls). It is underlain by approximately 3 feet of sandy clay and clay which separates it from the lower portion of the surficial aquifer. The average linear groundwater velocity in the upper portion of the surficial aquifer was calculated as 16 feet/year. The site was extensively characterized with state-of-the-art direct push diagnostic protocols. An area of approximately 14,600 square feet was found to be within the 1 mg/L isopleth for perchloroethylene (PCE); in some wells contamination levels approached 9 mg/L. As part of a pilot test conducted in 1999, approximately 6,810 pounds of HRC were injected into the area as described via 144 direct-push points spaced 10 feet on center. The total PCE contaminant mass was reduced by 96 percent after 152 days. This was calculated for a larger area that was bounded by wells which included both 1) a series of proximal up gradient wells and 2) a down gradient well series that could have been impacted by the advection and diffusion of the applied hydrogen releasing compound in the 152 days. This designated area, approximately 240' X 180', began with a mass of 19,183 g PCE and rose to 24,378 g by Day 43, presumably through physical desorption related to the injection activity. Subsequent to that point in time, mass was reduced to 17,925 g by Day 77, 12,869 g by Day 110 and then to 822 g by Day 152. Additionally, the daughter products trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride all declined. Due to the success of the pilot test, in November 2000, a secondary injection of HRC was conducted at the site. This included 128 injection points containing 2,550 lbs of HRC into the lower surficial aquifer, and an additional 50 injection points containing 7,500 lbs of HRC into the upper surficial aquifer. The points for the lower surficial aquifer were installed to a depth of 55 feet with continuous injection of HRC from 55 to 30 feet.

**Abstract 94**

**The Use of X-Ray Fluorescence Spectrometry to Support Long-Term Monitoring of Heavy Metals Migration at a Wetlands Site**

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Rapid sediment characterization (RSC) tools (e.g. X-ray Fluorescence for metals, UV Fluorescence for PAHs, Immunoassay for PCBs) are being used at sediment sites to facilitate the Ecological Risk Assessment process. Two different applications of X-ray Fluorescence Spectrometry (XRF) were used in support of a five-year periodic review assessment at the Litigation Area at Naval Weapons Station Seal Beach Detachment Concord, California. The objective of the field investigation was to support a baseline Ecological Risk Assessment and to provide additional data to support the evaluation of migration of heavy metals in the wetlands. During the first phase of the field investigation, field portable XRF was used on site to provide rapid measurements of the relative concentrations of Zn and Cu at the most contaminated portions of the site. These data were used to select samples for the amphipod bulk sediment bioassays. The second phase of the project involved the vertical delineation of metals concentrations on the marsh surface and in the ditches and sloughs. For this phase, a benchtop XRF analyzer was used in the laboratory to quantitatively evaluate concentrations in sections of the surface sediment core samples. The versatility of this analytical technique provided the ability to address different data requirements in a cost- and time-effective manner.
In 1994, the Florida Legislature created the Drycleaning Solvent Cleanup Program (DSCP) to provide funding to identify and rehabilitate sites and drinking water supplies contaminated by drycleaning solvents – the first such program in the nation. The DSCP was open for voluntary joint application by drycleaning and wholesale supply facility owners, operators, and real property owners from March 1996 through December 1998. Over 1400 sites have been made eligible for the DSCP. To date, assessments have been completed at over 180 sites. Data has been collected from 150 drycleaning sites representing approximately 10% of the eligible facilities. The data provide a “snap shot” of drycleaning solvent contamination in Florida, including operational, regulatory, and hydrogeological data as well as information on contaminant source areas and contaminant occurrence, distribution, and degradation. This information has particular relevance to those involved in drycleaning site assessment activities and to states considering the development of drycleaning solvent cleanup programs.

The project site includes an approximately one acre area containing dissolved chlorinated solvents in a sandy glacial outwash underlain by clay. An air sparging system was installed approximately 2 years ago at the upgradient side of the project site, in the former source area. Significant reductions were observed during the early phase of the air sparging system operation, likely due primarily to mass transfer. Recent monitoring suggests that a plateau has been achieved and that further reductions in concentrations of chlorinated solvents will require a modified approach, particularly downgradient of the air sparge system. Consequently, testing has occurred involving the direct injection of hydrogen. The concept was to evaluate the possibility of creating a reductive environment more favorable to degradation of chlorinated solvents and also to achieve direct dechlorination through the increased availability of hydrogen. The process involved injection of hydrogen into a well screened at the base of the glacial sand and monitoring a nearby well. Redox, pH, dissolved oxygen and other field parameters were measured and groundwater samples were collected before, during and after the injection period. Initial results suggest that the result of hydrogen injection was a reduction in redox and pH. In addition, concentrations of PCE trended downward while TCE trended upwards. The total concentration of chlorinated solvents also trended downward.

In 1994, the Florida Legislature created the Drycleaning Solvent Cleanup Program (DSCP) to provide funding to identify and rehabilitate sites and drinking water supplies contaminated by drycleaning solvents – the first such program in the nation. Over 1400 sites have been made eligible for the DSCP. To date, assessments have been completed at over 180 sites. The first remedial systems were installed at sites beginning in 1999; remedial systems have been installed at 20 sites. This includes some large pilot tests utilizing innovative technologies including: co-solvent flushing, chemical oxidation using potassium permanganate and hydrogen peroxide, enhanced biodegradation using Hydrogen Release Compounds (HRC™) and recirculating wells. Remedial proposals currently being evaluated are Oxygen Release Compounds (ORC®), ozone sparging, six-phase electrical heating, enhanced biodegradation using sodium lactate and molasses, enhanced bioremediation – Foster’s Process™, and co-solvent enhanced oxidation. Currently, 50% of the drycleaning sites where assessment work has been completed are scheduled for remedial action; 33% of the sites are in natural attenuation with monitoring and 15% of the sites require no further action. Site Rehabilitation Completion Orders have been issued for 25 sites.

The detailed description of hydrogeologic structures is of great importance for groundwater flow modeling. The main parameters used in the flow equations (permeability, conductivity and others) are strongly dependent on the type of hydrogeologic units in the formation (stone, limestone, sand, fine sand, clay, silt, etc). One of the first problems of hydrogeologic structure modeling is to detect zones of presence and/or absence for the whole set of hydrogeologic units in the region under study. This task is a classification problem and is considered in the present report by
using machine learning algorithms (artificial neural networks of different architectures and Support Vector Machines) and geostatistical models including stochastic simulations. Hanford site hydrogeological data are used as a real case study.

[101]
In Situ Thermal Remediation of DNAPL using Six-Phase Heating
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A demonstration of the Six-Phase Heating (SPH) technology was conducted at Launch Complex 34 in Cape Canaveral, Florida in the Fall/Winter of 1999/2000. The purpose of the demonstration was to test the effectiveness of the technology at remediating Trichloroethene (TCE) as a dense non-aqueous phase liquid (DNAPL). This paper will briefly discuss the theory behind the technology and details about the Cape Canaveral demonstration including test design and procedures, system design and operations, remediation results, and lessons learned. Engineering and logistical improvements to the technology, resulting from this demonstration as well as other commercial applications, will also be discussed. Since 1997, SPH has been deployed in the commercial marketplace for full-scale cleanups of contaminants including DNAPLs, LNAPLs, and other chlorinated solvents and hydrocarbons. Presently, two commercial sites in Illinois have received regulatory closures following remediation with SPH. Thermal Remediation Services, Inc. (TRS) was launched in September 2000 to commercialize the SPH technology. TRS has been retained by the U.S. Department of Defense and Department of Energy to provide SPH for the remediation of Tetrachloroethene (TCE) and TCE DNAPL, respectively. SPH is presently being considered for remediation at dozens of commercial sites nationwide.

[102]
Performance Comparison Between Direct-Push and Conventional Drilled Monitoring Wells
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A comprehensive evaluation of several monitoring well designs was conducted to determine the potential effectiveness of direct-push wells for long-term ground water monitoring in alluvial sediments. Four clusters of five distinct well types were set into one test cell, while four clusters of three distinct well types were set into another test cell approximately 375 ft (114.3 m) downgradient within the same methyl tertiary butyl ether (MTBE) plume. Wells within each cluster were screened within the same short 2 to 5 ft (0.6 to 1.5 m) depth interval. Cluster footprints extend approximately 3 ft (1 m) in diameter. Screen depth ranges were selected based on piezocene data, constant head permeability tests, and water chemistry profiles generated prior to installations. It was assumed that preferential MTBE migration pathways correspond to zones of highest permeability within the semi-perched aquifer. Therefore, well screens were set into the most permeable zones in the upper and lower portions of the aquifer. MTBE concentrations and natural attenuation monitoring parameters from several rounds of ground water sampling will be presented. To date, no significant statistical differences were observed between the direct-push and drilled wells.

[103]
Field Test of Limestone as a Treatment Medium for Groundwater at the Savannah River Site
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Groundwater downgradient from the F- and H-Area Seepage Basins at the Savannah River Site is contaminated with acids, metals, radionuclides, and tritium originally released as part of low-level waste streams from the Separations Areas processing facilities. To stem the flux of tritium discharged from the basin area, a series of wells was installed to extract the groundwater and re-inject it upgradient of the seepage basins. Tritium is captured in an extraction/re-injection cycle that allows it to decay. To meet regulatory criteria for re-injection, metals and radionuclides must be treated and removed. One method under consideration for this removal is in situ contact with limestone. Equilibration of the groundwater with limestone raises the pH to approximately 8. At this pH, metals and radionuclides can be removed by direct precipitation, co-precipitation, and enhanced adsorption. A pilot test was performed to provide data required to assess the applicability of limestone in groundwater treatment. This demonstration unit consisted of several columns of limestone with different total column lengths and thus different residence times. Groundwater from the basins was passed through each of the columns and analyzed for metals, radionuclides, ions, pH, and alkalinity. Results of this field test will be discussed.
formation of apatitic compounds known to irreversibly sorb actinides, strontium and heavy metals. In this work, we report on the results from batch experiments to produce apatitic materials in soil. Additionally, the results from batch sorption experiments using treated soil to sorb uranium and strontium are reported. The results indicate an apatitic barrier is formed in soil using the new in situ method within approximately 2-3 weeks after injection of reagents. Results from sorption experiments indicate that uranium and strontium are immobilized by the apatitic material. The new method is very inexpensive, does not expose workers to dangerous radiation and construction hazards, and can be used to sequester radioactive materials and heavy metals where conventional methods cannot be applied.

A comparison of synthetic and animal bone derived apatites are reported. Animal bone apatites were produced from cow and fish bones using either heat treatment or hydrogen peroxide to remove the organic compounds of the bones. Heat treatment was performed at 500, 700 and 900°C. Kinetic and equilibrium experiments were performed using a batch procedure. The results indicate heat treatment is much more effective that the use of hydrogen peroxide for removing organic material from bone that decrease sorption capacity. Kinetic and equilibrium experiments indicate bone treated by heating at 500°C produces a highly effective material for sequestering uranium and strontium and is only a fraction of the cost of synthetic materials.

Emplacement Techniques: Impervious & Pervious Wall Construction

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For years, the strategy was to contain waste and in many applications, is still the recommended method. Recently, it has become acceptable to create filters below ground for the in situ treatment of waste. Consequently, in lieu of the waste being contained, it is desirable that the waste flow through a pervious treatment zone. How are these impervious and pervious walls being constructed? Vibrated Beam Method? Waterloo® Barrier System? Mandrel Emplacement Technique? For each of these construction methods, the following will be addressed: a detail of the construction technique, its required equipment, its material needs, the construction aspects, the effective life, and its associated highlights, including one case study. One effective means of constructing an impervious barrier is the vibrated beam method. Over one hundred slurry walls have been installed using this method in the United States for both the private and public sector, including the Army Corps of Engineers. The need for the vibrated beam method continues to escalate due to its reduced health and safety considerations, high level of quality control, lack of excavation, narrow working area, and ability to achieve depths greater than 100’. Another effective means of creating an impervious barrier, where structural support from the barrier is needed, is the Waterloo® Barrier System. Finally, one effective construction technique for a pervious wall is the patented mandrel emplacement technique, which results in a pervious wall composed of iron sand or any other flowable media without width or depth limitations.

The Use of Sediment Trend Analysis (STA°) in Contaminant Management Issues

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Sediment Trend Analysis is a technique that enables patterns of net sediment transport to be determined by relative changes in grain-size distributions of all naturally occurring sediments. In
addition, STA can determine the dynamic behavior of bottom sediments with respect to erosion, accretion or dynamic equilibrium. The latter provides a very effective correlation with contaminant behavior contained in the sediments. Invented by GeoSea Consulting, STA has been used in harbor management concerns in over 80 projects worldwide. The data requirements are sediment grab samples collected at a regular spacing that is typically 500 m. The samples are analyzed for their complete grain-size distribution using a laser technique. Transport pathways are then determined by searching for sample sequences whose distributions change according to the “rules of transport”. STA has been particularly useful in a large variety of environmental management issues, particularly in tracing the pathways of contaminated sediments, locating CAD sites, and determining rational environmental monitoring strategies. This talk will describe several projects encompassing Vancouver and Seattle Harbors, and the Anacostia River, where STA is used to assess remediation alternatives, together with a brief theory of STA.

Sediments are the ultimate sinks for most contaminants introduced into watersheds. Sediments support inherently complex ecosystems and differ from soils in their dynamic nature, contaminant mobility, and potential for multiple pathways to the food chain. Additionally, sediment remediation has potentially large cost ramifications due to expensive removal and disposal or treatment options. Because of this, there are numerous technical considerations, in addition to regulatory and procedural issues, involved in assessing and managing sediments and potential remediation. Therefore, NAVFAC initiated a guide to provide sediment-specific concepts and methods that reflect the Navy’s desire for timely, focused, cost-effective use of resources while complying with regulations and protecting the environment and human health. This guide, being developed by SSC San Diego, presents a sound, risk-based approach to streamlining sediment assessment and remediation. It centers on developing the critical questions and hypotheses needed to form a good Conceptual Site Model (CSM), obtaining high quality data, and ultimately achieving focused risk characterization for informed management decisions.

Installation of a permeable reactive barrier in at an AFB in South Carolina - trenches.

In Situ Treatment of Acid Mine Drainage in Groundwater Using Permeable Reactive Materials

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Acid-mine drainage (AMD) can introduce elevated concentrations of sulfate, ferrous iron and other dissolved metals to groundwater and receiving surface water. Permeable reactive barriers (PRBs) offer an approach for the passive interception and in situ treatment of AMD-impacted groundwater. Three field-scale applications and supporting laboratory columns in the past six years have shown that several thousands of mg/L sulfate, more than 1,000 mg/L iron, and several tens of mg/L of other metals can be removed from plume or tailings groundwater. The reactive materials, which incorporate various forms of organic carbon, promote microbiologically mediated sulfate reduction, the generation of hydrogen sulfide, and the subsequent precipitation of sparingly soluble iron and other metal sulfide minerals. The applications include two permeable wall PRBs for the treatment of a plume at full scale from a mine-tailings impoundment (Sudbury, Ontario) and at demonstration-scale at a former metal processing facility (Vancouver, British Columbia). These PRBs have removed iron and other metals from groundwater. Similar materials were also used to create reactive layers within control cells directly in a tailings impoundment (Timmins, Ontario) with the objective of removing iron and sulfate from the pore water before it migrates from the tailings impoundment.

Implementation Guide for Assessing and Managing Contaminated Sediment at Navy Facilities

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Sediments at many Navy facilities have some level of impact from anthropogenic compounds due to past industrial activities, hazardous waste disposal practices, ship activity, and point and non-point source (NPS) inputs. Naval Facilities Engineering Command (NAVFAC) is responsible for assessing and managing sediment sites impacted by past or present Navy operations, under the Environmental Restoration (ER, N) Program. Although regulatory guidance provides procedural direction, technical issues pertinent to sediments have not been addressed in practical terms.
PRBs are engineered systems that provide passive interception and \textit{in situ} treatment of contaminated groundwater. Within the past decade, PRBs have been applied for the control and remediation of a range of organic and inorganic contaminants in groundwater. In recent laboratory batch and dynamic column tests, a selection of reactive materials that effectively attenuate dissolved arsenic in groundwater to low levels (<0.01 mg/L) have been identified. Basic oxygen furnace (BOF) slag promotes the oxidation of As(III) to As(V), which is subsequently sorbed to the BOF surface. Activated alumina also removes arsenic by the sorption of both As(III) and As(V). Zero-valent iron (ZVI) reduces As(V) to As(III), which is subsequently removed from solution by co-precipitation. In groundwater containing sulfate, ZVI and mixtures containing organic carbon can promote sulfate reduction and the subsequent precipitation of sparingly soluble arsenic and other metal sulfides. The laboratory tests have been conducted using neutral and low pH groundwater, with arsenic concentrations of as much as 4 mg/L. Groundwater chemistry, contaminant flux, the required duration for treatment, and costs for materials and installation will influence the selection of specific media for field-scale PRBs.

\textbf{[115]}

\textit{In Situ} Fluidization for Solids Addition to Permeable Reactive Barriers

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This study concerns \textit{in situ} fluidization (ISF), a new remediation method, in which an air/water jet is lowered from the ground surface into a contaminated, sandy soil, to produce a sharply defined \textit{in situ} fluidized zone\(^1\). NAPL removal takes place by the buoyant release of NAPL droplets and composite NAPL–soil particles, while metals can also be removed by the washing of fine particles from the soil\(^2\). The aim of the present study is to report recent work on the application of ISF for the \textit{in situ} emplacement of various particulate solids, including zero-valent iron (ZVI), lime and zeolites, for low-cost construction of permeable treatment barriers. Experiments were conducted on 150 \(\mu\)m sand in columns and tanks, into which added solids of various diameters were added during fluidization, at several mass loadings. It was found that with careful grading and hydraulic controls, ISF could be used for the \textit{in situ} emplacement of different particulate solids. By washing fines from the soil, ISF also increased the permeability of the treated zone. A magnetic technique for the \textit{in situ} recovery of spent ZVI during fluidization, with potential application to barrier maintenance, is also examined.

\textbf{[116]}

Time-Release Electron Donor Technology: Results of Forty-Two Field Applications

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Fermentable organic materials can donate electrons that facilitate the anaerobic microbiological destruction of contaminants, such as chlorinated hydrocarbons. A time-release electron donor can eliminate or reduce major design, capital and operational costs, and support low-impact remediation designs. Glycerol poly lactate ester (HRC\textsuperscript{®}) is a food grade polymer that can perform this function when applied to an aquifer by injection or auguring and is indicated for containment and treatment of dissolved phase plumes and moderate levels of residual sorbed contaminant. HRC has now been used on ninety chlorinated hydrocarbon sites and forty-two are in a position to be evaluated. Nine sites displayed exceptional results, defined as demonstrating very rapid and complete dechlorination. At twenty-two sites results are very positive, displaying accelerated degradation rates with varying degrees of daughter product formation depending on the age of the data set. Finally, nine sites are showing moderately accelerated rates of dechlorination with varying degrees of daughter product formation depending on the age of the data set, and two of the sites were unresponsive to a single treatment. An updated summary of all site results and specific details of representative sites from each of the named categories will be presented.

\textbf{[117]}

Remediation of a Partially Fractured Aquifer System Containing a TCE Source using Steam Enhanced Extraction

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The steam enhanced extraction (SEE) technology was successfully used to remove TCE source (DNAPL) from layered and partially fractured aquifer system at a heavily exploited industrial area near Prague, Czech Republic. Geologically, the site is formed by alternating sandstone (containing groundwater) and siltstone or claystone (representing aquitard and/or aquiclude) layers. The steam and air were first continuously co-injected into two wells
whereupon vapors were extracted from series of extraction wells surrounding the injection wells. After the aquifer system was heated to the maximum temperature (equal to the local boiling point of water), the cyclical manner of air-steam injection takes place. The objective of cyclic operation is to remove TCE from less permeable block, separated by more permeable zones or fractures. Two weeks were needed to heat the contaminated zone to maximum temperature. Four months after the end of heating operations, the temperatures still remained elevated. During a 1 month SEE operation about 2.5 t of pure organic phase (TCE) was extracted from the aquifer. At the same time TCE concentrations in groundwater of the heated zone decreased about 200 times. Details on the project performance will be assembled and presented at the conference.

[119]  
Migration and Retardation of Chemical Toxic Radioactive Waste in Engineered Barriers  
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The mechanisms of transport and retardation processes, chemistry and migration behavior of chemical toxic low and intermediate level radioactive waste in engineered barriers have been summarized. A “critical group of toxic non-radioactive substances” in various radioactive wastes is proposed for thorough investigation of their retardation properties in near-field regions. The use of different combinations of barriers and modelling releases from waste forms and disposal facilities and transfer between environmental media – transfer to surface soil and transfer to surface water and groundwater for individual cases have been discussed. Comparisons were made for radwaste disposal in three types of repositories – repository of radioactive wastes from nuclear plant production (near-surface disposal) and institutional radioactive wastes and wastes contained natural radionuclides (geologic disposal). A systematic analysis of radioactive wastes disposal (near-surface disposal and geologic disposal) in underground repositories has provided the basis for a comparison between the radiotoxicity and chemotoxicity as part of EIA (environmental impact assessment) procedure.

[121]  
Removal of TCE and Chromate in a Permeable Reactive Barrier using Zero-Valent Iron  
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Chlorinated solvents and hexavalent chromium (as chromate) are some of the more serious threats to groundwater resources. At electroplating facilities both pollutants are often observed at the same time. Chlorinated solvents are chemically degraded and chromate is reduced to a less mobile and toxic compound in contact with zero-valent iron surfaces. The use of zero-valent iron in reactive barriers is a relatively new remediation technology, which is used in several places especially in the USA. In Kolding, Denmark a permeable reactive barrier simultaneously treating chromate and TCE has been constructed. The initial laboratory column experiments examining the capacities of chromate removal for different zero-valent iron sources and the simultaneous long-term removal of TCE are presented. Other governing factors were looked at such as flow velocity, chromate concentration, groundwater composition (hardness and pH), and mixing the iron with sand. The laboratory experiments showed that there is a limited capacity for chromate reduction, and that presence of the chromate precipitates also decreases the degradation rate of TCE. These are important facts in dimensioning the reactive barrier. The performance of the full-scale permeable reactive barrier is also presented, looking at the overall hydraulics of the barrier and the efficiency for treating both chromate and TCE.

[122]  
Permeable Reactive Barriers at Great Depth: Material Testing and Application at a Chromate Contaminated Site  
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Permeable Reactive Barriers (PRBs) have proven to be an efficient long-term method to clean up contaminant plumes in groundwater. The deeper they reach to cover the entire extent of a contaminant plume the more normal ground pressure increases within the barrier material. Under these conditions, soil mechanical and hydro geological aspects become more and more considerable, such as hydraulic long-term stability, small deformations, minimal consolidation and swelling effects, high grain strength and erosion stability. Currently, an investigation is being undertaken at a chromate contaminated site to install a PRB with granulated iron oxide as reactive filling material. The aquiclude to reach is at a depth of about 40 m. To verify its suitability and to determine the barrier design, batch and column tests are carried out observing the adsorption behavior of the candidate barrier material on one hand. On the other hand, soil mechanical tests include combined oedometer and hydraulic conductivity tests, swelling tests and abrasion tests. Beside laboratory research tasks, engineering work is done as well, such as planning the arrangement and design of the barrier system as well as modeling the hydrogeological conditions.
During the mid-1990s, research has been conducted in Canada over a two-year period to develop an innovative sampling technique for petroleum contaminated sites. This new method quantifies the rate at which vapors or gases are “produced” during a particular period of time under specific conditions of ventilation. Traditional soil-gas surveys evaluate concentrations of specific vapors that are in chemical equilibrium with dissolved, sorbed or free products in the media. The new proposed sampling technique involves purging the soil with a non-contaminated gas in the vicinity of a sample probe for few minutes. The soil-gas purge affects the gas-liquid-soil equilibrium causing sorbed and dissolved vapors to transfer to the gas phase. During a period when the static equilibrium is unbalanced, the rate at which vapor contaminants are transferred to the soil gas phase is estimated. After this stabilization period, the purge is reduced or stopped altogether. Rebounds after the purging period indicate if petroleum products are present beside the sampling point. This method constitutes a major improvement for plume delineation at low cost. It delivers results on site within 10 minutes and investigated wastes are almost eliminated. More recently, this new sampling approach has been further developed for the saturated zone. Rebounds are used to estimate in situ flux rates of oxygen and biogenic gases. The primary advantages to evaluate biodegradation processes with this method include: [i] better estimates of reactant availability and daughter compounds production rate across a plume, [ii] less interference from temporal and spatial differences in hydrologic and geochemical conditions, [iii] data that are produced on a real-time basis, and [iv] reducing overall monitoring cost of the natural attenuation option. Field data will be presented.

**Abstracts 123, 126, 128**

**[123]**

**Plume Delineation and Monitoring of Natural Attenuation Processes via In Situ Flux Measurement**

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**[126]**

**Novel Method to Enhance Chlorinated Solvent Biodegradation by the Use of Barriers**

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Physical containment has several advantages for managing chlorinated solvent plumes, but is not considered at many sites because of the perception that it does not remove or destroy contaminant mass. Because of this perception, other remediation approaches that do remove mass are often favored, even if they remove it slowly (such as natural attenuation) or are expensive (long-term pumping). Our biodegradation research indicates that barrier systems will result in increased contaminant destruction at many chlorinated solvent sites. Chlorinated solvent biodegradation occurs when electron donors (carbon substrates that form dissolved hydrogen) are utilized by naturally occurring dechlorinating bacteria in the subsurface to consume electron acceptors (the chlorinated solvents). This process occurs naturally at many sites (when source materials contain both solvents and electron donors), and can be enhanced by supplementing the electron donor supply. However, our research shows that the efficiency of naturally occurring and enhanced biodegradation is compromised by the transport of competing electron acceptors (i.e., dissolved oxygen, nitrate, and sulfate) to solvent biodegradation zones via the flow of clean upgradient groundwater through the source. By constructing a low-cost, low-permeability containment barrier upgradient of a chlorinated solvent source zone, three benefits will be realized: 1) competing electron acceptors will be diverted away from the source zone, thereby increasing the rate of naturally occurring bioremediation; 2) the plume will shorten dramatically, greatly reducing long-term monitoring costs; and 3) the plume will be controlled without pumping. Calculations based on a 14-site database show that such a barrier system will be inexpensive, reliable, and have the potential to increase the rate of naturally-occurring chlorinated solvent biodegradation by an order of magnitude at a typical chlorinated solvent site undergoing natural attenuation.

**[128]**

**Economic and Performance Based Design of Monitoring Systems for PRBs**

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This paper evaluates monitoring well configurations for horizontal (HPRB), and funnel and gate permeable reactive barriers (FGPRBs) on their ability to detect the median (C_{50}), 75th percentile (C_{75}), and 90th percentile (C_{90}) of effluent concentration. The framework for the study is a series of heterogeneous aquifers created using a second-order stochastic model and input into MODFLOW. A HPRB or FGPRB is simulated within the each heterogeneous aquifer by replacing appropriate finite difference cells of the model with hydraulic conductivities representative of the barrier. MODFLOW and an adapted particle tracking code are used to predict steady-state flow and advective mass transport through the aquifer and PRB. The probabilities of twenty-five monitoring systems for the HPRB and twenty-four monitoring systems for the FGPRB at detecting C_{50}, C_{75}, and C_{90} are evaluated in each aquifer. Results are combined to determine lateral and vertical well spacings having the greatest probability of detecting C_{50}, C_{75}, and C_{90} for each type of PRB. The most economical lateral and vertical well spacing are about 5 m and 3 m, respectively for the HPRB, and approximately 2 m and 4 m, respectively for the FGPRB. Probabilities of detecting C_{50}, C_{75}, and C_{90} for these spacings are provided.
Abstracts 130, 131, 132

[130] Permanganate In situ Chemical Oxidation of TCE in a Fractured Bedrock Aquifer

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A treatability study of in situ chemical oxidation (ISCO) using permanganate was conducted in a bedrock aquifer at Site N7, NASA Dryden Flight Research Center, Edwards Air Force Base. The objectives were to achieve contaminant destruction, determine the injection radius of influence, optimize injection methods for bedrock, monitor persistence of permanganate, and evaluate groundwater quality effects. The study area was approximately 100 ft by 50 ft and 100 ft deep. 7,450 gallons of 1.8% potassium permanganate solution were serially injected into 8 screened wells and 2 boreholes over 5 days. Groundwater samples collected periodically for 60 days following treatment were analyzed for permanganate, metals, and volatile organic compound concentrations. Trichloroethylene and cis-1,2-dichloroethylene remained below detection (from a pre-injection cumulative concentration of 7,210 ug/L). Acetone (presumably an oxidation product) was detected at up to 3,000 ug/L following injection and has attenuated to ≤460 ug/L. Elevated metal concentrations following treatment have decreased to ≤80% of their post-injection maxima, with the exception of chromium and nickel. Permanganate degradation rates yield an average half-life of 19 days, and permanganate should degrade below visible concentrations (<0.5 mg/L) in approximately 283 days. Permanganate ISCO appears effective and viable for treatment of chlorinated hydrocarbons at Edwards Air Force Base.

[131] Regulatory Acceptance of Monolayer Vegetative Cover for the Mixed Waste Disposal Unit U-3ax/bl at the Nevada Test Site

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Acceptance of new technologies by the regulator starts with a strong position as to why this new technology/approach will benefit the project. This must also provide the data necessary for the regulator to verify that the new technology/approach will provide equivalent protection to the environment. The Nevada Test Site has numerous low-level waste landfills that require closure by 2011. In 1997, a study was conducted on closure covers and subsidence. The study concluded that a monolayer vegetative cover accommodates subsidence better than a traditional multilayered cover. In 1999, planning for the closure of U-3ax/bl mixed waste disposal unit was started. It was decided that a monolayer vegetative cover design would be proposed to the Nevada Division of Environmental Protection (NDEP). No Resource Conservation and Recovery Act landfill in the state of Nevada had been closed using a monolayer vegetative cover. Approval of the monolayer vegetative cover design by the NDEP was achieved by careful up front planning. The process was accelerated by anticipating NDEP concerns and preparing arguments and data that addressed these concerns during the planning process. Finally, the baseline schedule and budget was designed to support a greater level of regulator interface and meetings. This work was supported by the U.S. Department of Energy, Nevada Operations Office, under Contract No. DE-AC08-96NV11718.

[132] In situ Plasma Vitrification of Buried Wastes

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The subterranean application of plasma arc technology would result in the in situ vitrification and remediation of virtually any buried waste or contaminated soil into a rock-like mass that is durable, strong, and highly resistant to leaching. Conceptually, a plasma arc torch, creating temperatures exceeding 7,000 °C, would be lowered into a borehole to any depth and operated to destroy hazardous compounds and to vitrify the soil and its contaminants. By producing a wasteform with long-term chemical durability and stability, in situ plasma vitrification (ISPV) is considered to be a permanent treatment technology, as opposed to interim technologies, which may require repeated applications. A buried waste deposit requiring treatment by in situ plasma remediation would be treated by inserting the plasma torch near the bottom of a borehole and vitrifying the material around the torch, producing a column of vitrified material as the torch is slowly withdrawn. Plasma arc torches operated at multi-megawatt power levels would be expected to produce vitrified columns greater than 10 feet in diameter. A matrix of overlapping columns would form a contiguous vitrified mass of treated and remediated soil. Similarly, plasma vitrification can be used for selective underground treatment; e.g., to vitrify subterranean contaminated zones and to treat “hot spots” in landfills and in aquifers, which feed groundwater contamination plumes. This process of ISPV technology is expected to be rapid, efficient, cost-effective, and simple. An industrial-scale ISPV field test using a 1 megawatt plasma torch was successfully completed at the Savannah River Site in late 1996. As a result of this experiment ISPV was demonstrated to be a practical process which can be implemented on a production scale.
A former water intake tunnel extending under the Niagara River was contaminated with DNAPLs and was closed at the request of regulatory authorities. The six-foot tunnel is nearly a mile long and accessible from just two vertical shafts, one of which is in the river. Closure of the tunnel presented a unique remediation challenge because of the limited access, considerable volume of the tunnel, and because the tunnel was full of potentially contaminated water. A plan was developed and implemented that closed the tunnel by filling it with cementitious grout while simultaneously removing and treating the displaced water. The grout used to fill the tunnel had to meet demanding requirements for both regulatory acceptance and workability. An extensive laboratory testing program was implemented to design the grout for compatibility with DNAPLs, low permeability, strength, flow, and set properties. In the fall of 2000, the tunnel was filled with over 7500 cy of grout in five days, using multiple and redundant grouting pipes while pumping from a stationary grout plant on the shore of the river. The primary filling operation was followed by secondary pressure grouting. Closure of the tunnel required underwater divers, remote-operated robots, and barge operations, as well as a state-of-the-art grout mixing and pumping plant. Field observations, sample testing, and continued monitoring indicate that the closure was successful. This paper presents a brief overview of the laboratory testing and construction phases of the project. A future paper is planned to present a more complete discussion of the project including monitoring results.

Small and large scale laboratory testing of colloidal silica was performed in support of the Brookhaven National Laboratory Linear Accelerator Isotope Producer grouting project. The laboratory testing consisted of two phases: the first being the selection of a colloidal silica (CS) variant that best reduced the permeability of the Brookhaven soils; and the second being injection of the selected CS into large sand tanks to determine in situ values of hydraulic conductivity in addition to developing soil-water characteristic curves for grouted samples excavated from the tanks. Nine colloidal silica variants having different colloid particle size ranges were identified and tested using injection columns and flexible wall permeameters. From this testing, an optimal CS variant was selected to advance to the second laboratory testing phase. The selected CS grout was injected into sand tanks placed in a load cell to simulate injection at depth. Results indicate that the selected colloidal silica variant was successful at reducing the saturated hydraulic conductivity of the Brookhaven soils by four to five orders of magnitude. The soil-water characteristic curves developed for the grouted soils were unique and supported the use of the CS material site as a barrier.
grout at the Brookhaven to isolate activated soils in the vadose zone. The project was funded by the U.S. Department of Energy National Energy Technology Laboratory under DOE Contract Number DE-AC22-96EW96405.

[136]
Performance of the Colloidal Silica Barrier Installed at Brookhaven National Laboratory, a Computer Modeling Study
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At the U.S. Department of Energy (DOE) Brookhaven National Laboratory (BNL) site, a small volume of unsaturated sand around the subsurface-located radioactive facility was impacted by radioactive contamination. To limit the contamination load reaching the water table, the contaminated soil was solidified by injections of colloidal silica that gels in place. This remedial technology was applied to alter water retention properties of the contaminated soil and consequently limit the magnitude of atmospheric-water flux that leaches the contaminants towards the water table. Because of physical limitations for testing the barrier’s performance various computer modeling approaches were exercised instead. The modeling efforts which used data collected from sand box studies, as well as from the colloidal-silica field tests, indicate that the performance goal for the barrier was met. The project was funded by the U.S. Department of Energy National Energy Technology Laboratory under DOE Contract Number DE-AC22-96EW96405.

[137]
Electrical Resistivity Tomography Imaging of a Colloidal Silica Grout Injection
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The U.S. Department of Energy (DOE) investigated the use of colloidal silica to create a viscous liquid barrier for in situ containment of radioactive waste. As part of this work, electrical resistivity tomography (ERT) was investigated for verification of the grout placement. ERT techniques for imaging viscous liquid barriers created using colloidal silica grout were field-tested following a barrier emplacement carried out in 1998 at Brookhaven National Laboratory (BNL). The results of this effort indicated ERT might be used to verify placement of the grout. In 1999, as part of the second phase of the demonstration in which a colloidal silica barrier was to be placed around a portion of the Brookhaven Linear Accelerator Isotope Producer (BLIP) at BNL, a series of controlled injection experiments were completed on a laboratory scale at the MSE test facility in Butte, Montana. ERT was used to map one series of these injections in a sand tank designed to study the interaction between adjacent grout injections. The results of this investigation showed that ERT could be used to accurately map the extent of the colloidal silica grout during the injection process. The project was funded by the U.S. Department of Energy National Energy Technology Laboratory under DOE Contract Number DE-AC22-96EW96405.

[138]
Analysis of Verification Data from the NTISV Demonstrations at Los Alamos National Laboratory using the Data Correlation Program FUSION.M
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Verifying the quality of subsurface waste stabilization and/or containment structures often involves the acquisition of several data types. Typically, each data set is independently processed and interpreted, which can lead to inconsistencies in the assessment of the quality of the structure. As a result, the DOE has funded projects involving “data fusion” as applied to site characterization, whereby multiple data sets acquired from a common site are mathematically combined into a single data set. MSE developed a “data fusion” program, FUSION.M, which correlates 2-dimensional or 3-dimensional data sets. The program allows data representing various attributes of a subsurface to be read and correlated, the resulting product is a single data set showing the most likely shape of the structure. The “data fusion” program developed by MSE was employed as part of the Non-Traditional In situ Vitrification Cold and Hot Demonstrations performed at Los Alamos National Laboratory, Los Alamos, New Mexico, during fiscal years 1999 and 2000, respectively. Results indicated that the “data fusion” program produced a more accurate image of the subsurface structure than any of the single data sets were able to. The project was funded by the U.S. Department of Energy National Energy Technology Laboratory under DOE Contract Number DE-AC22-96EW96405.
The U.S. Army, Headquarters, Operations Support Command, Safety and Radioactive Waste Disposal Office, Rock Island, IL is the Department of Defense (DoD) executive agency for low-level radioactive waste (LLRW) disposal. Because of DoD downsizing and base closure actions, we are involved with several radiological remediation projects, Nuclear Regulatory Commission (NRC) license decommissioning efforts and mixed waste treatment/disposal problems. Ongoing DU decommissioning efforts include the research and application of treatment technologies for several hundred thousand cubic feet of mixed waste at the Lake City Army Ammunition Plant (AAP), Independence, MO and a unique joint characterization/decommissioning effort between the Army and the operating contractor, Alliant Techsystems, at Twin Cities joint characterization/decommissioning effort between the Army Ammunition Plant (AAP), Independence, MO and a unique joint characterization/decommissioning effort between the Army and the operating contractor, Alliant Techsystems, at Twin Cities Army Ammunition Plant (AAP), Independence, MO and a unique joint characterization/decommissioning effort between the Army and the operating contractor, Alliant Techsystems, at Twin Cities Army Ammunition Plant (AAP), Independence, MO. Legal constraints on the Government procurement process, State and Federal regulatory requirements, limited disposal and treatment options and shrinking financial resources add to our challenge.

**[140]**

**Fenton's Reagent In Situ Chemical Oxidation of TCE Source Area, NTC Orlando, Florida, USA**

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An in situ chemical oxidation (ISCO) treatment using Fenton’s reagent is in progress at Study Area (SA) 17, Naval Training Center Orlando, Florida. The objectives are to rapidly reduce source-area chlorinated volatile organic compound (CVOC) concentrations in order to mitigate further plume expansion and to promote natural or enhanced biodegradation of the residual plume. The CVOCs present prior to treatment were trichloroethene (TCE) and its natural degradation products cis-1,2-dichloroethene (CIS) and vinyl chloride (VC), with a maximum TCE concentration of 306,000 ug/L. Gasoline-range organics (GRO) were also detected, with a maximum concentration of 78,500 ug/L. The study area is approximately 19,000 ft² in area and extends to about 26 ft below grade. During an initial injection in November 2000, 8,700 gallons of 25% hydrogen peroxide and 6,900 gallons of Fe(II) catalyst were injected via 69 injectors over the course of 17 days. Groundwater samples were collected 13 days following treatment. CVOCs were reduced an average of 92%, with a post-injection maximum CVOC concentration of 27,000 ug/L. GRO was reduced an average of 90% with a post-injection maximum GRO concentration of 9,190 ug/L. Additional polishing mobilization(s) are planned to achieve a total CVOC concentration less than 500 ug/L.

**[141]**

**Field Testing Advanced Remedial Dredging and Sediment Transport Technologies at the New Bedford Harbor Superfund Site**

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The ongoing remedial design for polychlorinated biphenyl (PCB) contaminated sediment dredging and disposal at the New Bedford Harbor Superfund site will be based on prior site characterization and pilot dredging and disposal studies. From these it has been learned that selection of the dredging technology must address needs for accurate dredging, high contaminant removal efficiency, and minimal resuspension of sediments during dredging. Also, for successful completion of the project it is important to dredge and transport sediments minimizing water addition to the waste stream and to dredge efficiently in water depths from zero to three feet. To develop cleanup design information on the capabilities of state of the art dredging equipment and verify the performance of the equipment a detailed technology evaluation was performed. New Bedford specific screening criteria were used in the technology evaluation. Two types of dredge systems were selected from the technology screening. It was decided to perform an on-site pilot dredging study of one of the dredge systems to monitor and verify dredging performance. The dredging study included monitoring of the dredging for performance parameters and environmental affects. Monitoring was done for sediment resuspension and transport (water quality), air emissions from dredging and disposal, and confirmation of PCB removal efficiency and attainment of clean-up goals. Mass balance calculations were performed to develop full-scale dredging performance parameters and to evaluate alternatives for dredged material disposal.

**[143]**

**Microchemical Sensors for In situ Monitoring and Characterization of Volatile Contaminants**

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Traditional methods for monitoring sites that may be contaminated with toxic chemicals can be expensive, time consuming, and misrepresentative of in situ conditions. A few in situ chemical
monitoring systems exist, but they do not attempt to quantify or characterize the contaminant (e.g., location, composition, etc.). This paper presents the development of a microsensor monitoring system that can be used to monitor and characterize volatile organic contaminants in the subsurface. A microchemical sensor that employs an array of chemiresistors is packaged in a unique, waterproof housing that is designed to protect the sensor from harsh subsurface environments, including completely water-saturated conditions. The array of sensors is calibrated to provide “training sets” for pattern recognition of various chemicals and chemical mixtures. The sensors and packaging have been tested in laboratory environments, and unique characterization methods are being developed that utilize contaminant transport models and time-dependent, \textit{in situ} sensor data to identify the location of the contaminant source. Additional characterization methods that can be employed during soil remediation methods such as soil venting are also being tested to determine the extent and composition of the contamination.

\[144\]
\textbf{Stochastic Simulations for Risk-Based Performance Assessments of Long-Term Cover Systems}
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The design of landfill covers for contaminated waste sites at DOE complexes has been largely governed by prescriptive criteria (e.g., maximum permeability), which are intended to minimize the amount of water that can contact the waste and leach contaminants to the water table. However, these guidelines are not site specific and may not address important features, events, and processes at the site that may increase the risk of groundwater contamination and human exposure to contaminants. This paper presents a risk-based performance-assessment method that incorporates uncertainty and variability for important parameters at each site. In addition, changes in the environmental setting (e.g., precipitation, temperature) and aspects impacting the cover design (e.g., liner integrity, bio-intrusion) are considered for long time periods (~1000 years). Regulatory requirements regarding groundwater contamination or human exposure can be used as the performance metrics for the stochastic simulations, and alternative cover designs are compared in the analyses. A preliminary example is provided using the Monticello, Utah, disposal site, which employs a long-term cover system for uranium mill tailings. The water percolation reaching the uranium mill tailings is used as the performance metric. Uncertainty distributions of the most important parameters (e.g., liner integrity, parameters affecting evapotranspiration, hydraulic conductivity) are sampled in a stochastic Monte Carlo analysis. The resulting cumulative distribution function of the percolation is used to determine risk, and these results are also compared to deterministic results to illustrate the importance of including uncertainty and variability.

\[145\]
\textbf{Column Experiment Design to Estimate Parameters for Modeling of Vapor Extraction/Bioventing Sequential Soil Treatment}
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Remediation of sites contaminated with volatile, semi-volatile and non-volatile hydrocarbons requires setting up accurate and user-friendly models of physical, chemical and biological processes. They are particularly useful for design and optimization of vapor extraction/ bioventing (SVE/SBV) systems, and prediction of residual concentrations and remediation time. Despite improving of model structures, the optimum experiments should be designed for model calibration. The feasibility of parameter estimation procedure was analyzed to obtain the input parameters of a model using first order kinetics to describe diffusion out of aggregates and biodegradation. Kinetic parameters in a non-equilibrium model were evaluated by inverse modeling of several column experiments which allowed for freedom in selection the convective gas flux during SVE/SBV. To keep the experimental procedure simple only measurements of hydrocarbon concentrations in effluent were used as input data. The procedure was sensitive to measurement errors, which can be significant, particularly during the initial phases of SVE/SBV. In most cases this can be solved by increasing sampling time and frequency.

\[146\]
\textbf{Modeling Contaminant Transport Through Clay Membrane Barriers}
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The migration of solutes in fine-grained soils of low hydraulic conductivity has become an important consideration with respect to design and performance of waste containment barriers that consist of these soils (e.g., compacted clay liners, vertical cutoff walls). In this regard, solute transport analyses for engineered barrier materials typically are performed using solutions to the advective-dispersive equation. However, advective-dispersive transport theory represents a limiting case of the more general coupled flux transport theory in which coupling terms (e.g., chemico-osmosis) are assumed to be negligible. In the case of clay soils that act as semi-permeable membranes restricting the passage of solutes, the use of advective-dispersive theory may not be appropriate. This presentation will include the development of a coupled solute transport model that can be used to simulate transient, one-dimensional solute transport through reactive (i.e., ion exchanging) clay soil membranes. Simulation results will be presented using measured values of the chemico-osmotic efficiency coefficient (\(\omega\)), the effective salt diffusion coefficient (\(D^S\)), and the hydraulic conductivity (\(k_h\)) for a bentonite-based barrier material that acts as a semi-permeable membrane. The results will highlight the limitations of coupled-solute flux transport theory in the absence of appropriately measured transport parameters.
A Microbial Screening Method for Heavy Metal Contamination in Stream Sediments

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During the summer of 1998 sediment samples were collected from Four Mile Creek (FMC) at the US Department of Energy Savannah River Site. Samples were collected every 200 m from just below a cluster of chemical seepage basins to approximately 14 km downstream. FMC has a documented history of heavy metal contamination with mercury inputs ranging from 0.45 to 9.07 kg year\(^{-1}\). Previous research has indicated a positive association between heavy metal tolerance and antibiotic resistance in bacteria collected from natural environments. We report here the results for FMC which confirm this reported relationship and further show, by statistical modeling and geostatistical variography, that metal contaminated stream reaches can be discriminated from uncontaminated reaches in FMC based on the incidence of antibiotic resistance. These preliminary findings suggest that a biological (i.e., microbial) screening method could be developed to spatially identify metal contaminated stream sediments. In addition, if the relationship between a specific metal and antibiotic can be modeled, the screening method may also allow quantitative estimates of the average metal concentration for a given reach of stream.

Intercode Comparisons for Simulating Water Balance of an Engineered Cover

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Numerical modeling is generally required to evaluate proposed cover designs and to estimate long-term performance of covers. A variety of codes are available to simulate water balance of engineered covers; however, information on intercode comparisons is limited. The purpose of this study was to compare the characteristics and performance of different codes, including HYDRUS, SHAW, SoilCover, SWIM, Unsath, and VS2DT. The codes were used to simulate the water balance of capillary barrier that is being monitored at a site near El Paso, Texas. Factors that differ among these codes include graphical user interfaces, user friendliness, dimensionality, upper and lower boundary conditions, hydraulic properties (Brooks and Corey, van Genuchten, other), and processes (liquid flow, vapor flow, hysteresis). Simulation results from all codes reasonably approximated the measured field water balance. The main difference among the various codes was in the partitioning of precipitation into evaporation and soil water storage. The intercode comparisons are being used to identify important attributes of codes to simulate infiltration into engineered covers. Such information can be to make recommendations for modifications of existing codes and/or development of new codes.

The Use of the Membrane Interface Probe (MIP) for expedited DNAPL Characterization

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The Membrane Interface Probe (MIP) is a rapid, high-resolution in situ VOC screening technology that provides real-time data about relative VOC concentrations and soil lithology, as well as the presence of ionic contaminants or a salt water intrusion. ZEBRA Environmental Corporation has successfully utilized MIP Technology on a number of sites for the purposes of DNAPL delineation and characterization. The technology demonstrated very high correlation with analytical results and provided significant cost savings by providing real-time information used for the optimization of the groundwater sampling program. ZEBRA's MIP team has implemented a number or improvements to the design of the MIP equipment that resulted in significant reduction of on-site downtime and improved overall reliability. Zebra’s MIP team developed a set of Standard Operating Procedures (SOP), QA/QC procedures and the guidelines for the interpretation of the MIP system output. The presentation focuses on interpretation of the MIP output, analysis of the most common MIP data processing errors, integration of the MIP technology with field-portable analytical instruments, and the issues of correlation with analytical data and data repeatability.
Limited sampling of an aquifer downdgradient of closed environmental sites results in uncertainty in the spatial distribution of aquifer properties. This spatial uncertainty causes uncertainty in the migration pathway of any contaminants that might leak from the closed site. Techniques for locating samples that can provide the greatest reduction in uncertainty with respect to contaminant migration from the closed site must be developed. Two different techniques are examined: a traditional method based on minimizing the kriging variance and a new method based on the sensitivity of simulated contaminant releases from the closed site to the hydraulic conductivity at every location in the aquifer. The second method considers the correlation of different performance measures to the hydraulic conductivity at every location. Those locations with the highest correlation to the transport results are targeted for additional samples. An example problem from a hypothetical aquifer allows for demonstration and comparison of the two techniques. In general, the sensitivity analysis approach produces the greatest reduction in the uncertainty of the performance metrics; however, the differences between the two techniques are minimal for this example.

The Use of Ultrasound to Restore the Dehalogenation Activity of Iron in Permeable Reactive Barriers

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In situ permeable reactive barriers (PRBs) containing iron as the reactive agent have gained popularity in the past decade as a near-passive, in situ groundwater remediation technology for halogenated solvents. Although zero-valent iron has been shown to be effective for this purpose, a continuing problem is the loss of system reactivity over time. This is due, at least in part, to a build up of corrosion products on the iron or other precipitates within the PRB. The lifetime of the barrier could be significantly extended with a technology that could remove materials occluding the surface area of the reactive iron. The purpose of this research was to investigate the field-scale application of ultrasonic energy to rejuvenate an in situ PRB with the goal of enhancing/restoring the rate of trichloroethylene (TCE) degradation. Extensive laboratory and field analyses were conducted to examine the impact of ultrasound on iron under various conditions. Results indicate that a sonication period as brief as 30 minutes has a significant positive impact on the first order rate constant for TCE degradation. Field data from the application of ultrasound to two permeable reactive barriers (one at NASA-Kennedy Space Center, FL and the other in Denver, CO) will be presented.

The In Situ Treatment of DNAPL with Zero-Valent Iron Emulsions

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This study demonstrated the feasibility of using emulsified nanoscale and microscale iron particles to enhance dehalogenation of DNAPL free-phase. The emulsified system consisted of a surfactant stabilized biodegradable oil-in-water emulsion with nanoscale or microscale iron particles contained within the emulsion micelles. It was demonstrated that DNAPLS, such as TCE, diffuse through the oil membrane of the emulsion particle whereupon they reach the surface of an iron particle where dehalogenation takes place. The hydrocarbon reaction by-products of the dehalogenation reaction, primarily ethene, diffuse out of the emulsion micelle. This study demonstrated that an iron-emulsion system can be delivered in situ to the DNAPL pool in a soil matrix by using a simulated push well technique. The data show that emulsified iron is superior in its ability to degrade free phase TCE as compared to the use of pure iron particles that are rejected by the TCE phase. Iron emulsions degraded pure TCE at a rate comparable to the degradation of dissolved phase TCE by iron particles, while pure iron had a very low degradation rate on free-phase TCE. The iron-emulsion systems can be injected into a sand matrix where they become immobilized and are not moved by flowing water. It has been documented that the iron emulsions possess the ability to pull a pool of TCE into their micellar structure where degradation of TCE takes place. Data collected thus far indicates that no chlorinated byproducts from the degradation of TCE pass out of the micelle and the only observed by-products were ethene and other trace amounts of hydrocarbons.
Ground water beneath an active wood-treating facility in Colorado contains nonaqueous phase liquids (NAPLS) which are the source of the dissolved constituents of interest (COI), including pentachlorophenol (penta) and polynuclear aromatic hydrocarbons (PAHs). Significant free-phase NAPL recovery at this facility is technically impracticable. The on-site dissolved penta concentrations range from about 1,800 to 20,000 ug/L and PAHs concentrations range from about 2,600 to 30,000 ug/L. Remediation of the shallow site ground water therefore requires water management and low-cost, in situ treatment. Assessment of intrinsic biodegradation rates and numerical modeling of various impermeable barrier wall configurations led to the selection of an in situ groundwater remedy that integrated multiple technologies. These include; an impermeable barrier wall to direct ground water flow; an in situ aerobic bioreactor to treat dissolved-phase COI; enhanced anaerobic bioremediation to help mitigate COI load into the bioreactor; and phytoremediation. The installation of a 2,400-foot impermeable barrier wall, an anaerobic treatment zone, and a 210-foot aerobic treatment curtain was completed in February 2000; phytoremediation will be implemented in the spring of 2001. System operation, maintenance, economics, and performance to date will be reviewed herein.

The Watervliet Arsenal (WVA) located in Albany, New York, discovered chlorinated hydrocarbons (CHCs) in its groundwater in concentrations that exceeded MCLs by several orders of magnitude. These CHCs were entering the WVA storm sewer system and discharging off-site. The U.S. Army Corps of Engineers and Malcolm Pirnie implemented an innovative remedial technology using an in situ permeable reactive wall. This is a passive technology based on the use of commercially available metallic iron filings. As groundwater flows through
the wall, the zero-valent iron reductively dehalogenates CHCs through the corrosion process into non-toxic chloride ions, ethanes and ethanes. Bench-scale tests were performed by EnviroMetal Technologies, Inc. (ETI) to determine required residence times to degrade the CHCs to below MCLs. Two and a half days of residence time was required to degrade vinyl chloride to below the MCL (2.0 ug/l). Two reactive walls totaling approximately 285 ft. in length were installed through overburden and weathered bedrock using conventional excavation methods. The reactive wall configurations were determined through the use of groundwater modeling. Trenches were approximately 12 ft. in depth and 30 inches wide and were keyed into competent bedrock. A mixture of iron filings and sand was used to backfill the trenches. The reactive iron filings were delivered in bulk to a batch concrete manufacturing facility located in close proximity to the site. Iron and sand were weighed and mixed at the batch plant to the required proportions. The iron/sand mixture was delivered to the site using cement transit mixer trucks. One of the reactive walls was installed to intercept groundwater immediately down gradient from the source area while the second wall intercepted the leading edge of the plume before it entered the storm sewer system. Reactive walls greatly reduce Operation and Maintenance (O&M) costs. In this case, savings are estimated at over $3 million for the 30-year life of the project. In addition, final costs ($548,000) were approximately a third of the cost of a conventional remediation technology. Though groundwater velocities are slow (0.15 ft/day), samples taken one month after installation indicate CHC concentrations below detection limits within the reactive trenches. In addition, groundwater flow modeling and particle tracking revealed important design and installation measures to preclude contamination from flowing under the reactive walls.

[157]
Barrier-Controlled Monitored Natural Attenuation
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Three existing technologies (source containment, source reduction, and monitored natural attenuation) are integrated in barrier-controlled monitored natural attenuation (BCMNA) – a new approach for managing plumes of contaminated ground water and remediating contaminated sites. The basic BCMNA concept uses a low-permeability, non-reactive barrier to release contaminants into an aquifer at a rate that optimizes natural attenuation. A simplified, one-dimensional model of the process is developed and a hypothetical example of BCMNA is presented for a site contaminated with benzene. The analytical solution is used to demonstrate how benzene concentrations can be controlled at a downgradient point of environmental compliance by manipulating design variables. BCMNA provides a greater degree of process control and risk reduction than monitored natural attenuation alone. BCMNA also holds promise for reducing remediation costs because 1) barriers can be constructed relatively inexpensively and 2) a cost-effective amount of source reduction can be applied inside the contained area with the BCMNA system remaining in place to safely complete the remediation process after source reduction is terminated. Further numerical modeling and a demonstration project are recommended to address important details and prove the concept.

[158]
The Innovative Use Of High Pressure Jetting of Thin Diaphragm Walls to Construct Hydraulic Control Barriers
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Emplacement of hydraulic control barriers and permeable reactive barriers (PRB) in unstable soils, near foundations, or near underground / overhead obstructions using conventional construction techniques can be problematic. A demonstration project of high pressure jetting was conducted at the National Test Site at the Dover Air Force Base in Dover Delaware. The demonstration project was sponsored by US Department Of Energy’s Office of Science and Technology, DuPont, US Air Force / Armstrong Labs, and the National Environmental Technology Test Sites Programs. This program demonstrated that high pressure jetting of thin diaphragm walls to be an effective technique for constructing hydraulic control barriers where conventional techniques would have been problematic. The objective of the program was to demonstrate that high pressure jetting was capable of constructing a thin diaphragm hydraulic control barrier, to verify its continuity, and to develop cost information. To demonstrate the technology, a circular cofferdam roughly 34 feet in diameter comprised of twelve intersecting thin diaphragm walls was constructed and keyed into the aquitard at depth of 36 feet. Hydraulic flood tests, pump tests, and impulse tests were then conducted to determine the bulk hydraulic conductivity and the continuity of the cofferdam. Using the data from the flood and pump tests and using Darcey’s Law the bulk hydraulic conductivity of the cofferdam was calculated to be 2.52 x 10^-6 cm/sec which also indicated 98.8 percent of the cofferdam was competent. To delineate the location of the defect, an innovative pulsed hydraulic test was conducted which clearly showed the location of the defective area of the cofferdam.
A probabilistic model was used to design a combined Permeable Reactive Barrier (PRB) and natural biodegradation remedy for a Carbon Tetrachloride (CT) plume at a former manufacturing site in California. CT degrades rapidly in the presence of Zero Valent Iron (ZVI) to non-chlorinated end products (methane and carbon dioxide), with partial conversion to Trichloromethane (TCM) and Dichloromethane (DCM). The reaction rates and yield of daughter products are dependent on the specific geochemistry of the groundwater being treated. Natural biodegradation was evaluated as the means of treating the generated DCM and TCM daughter products downgradient from the PRB. In order to measure site-specific reaction rates and daughter product yields, laboratory column studies were conducted using ZVI and groundwater from the CT plume at the site. The half-life for CT was found to be 0.2 hours, or 12 minutes. The completed reaction will yield approximately 18 percent DCM on a molar basis. The primary basis for PRB design is to provide adequate residence time in the PRB for the ZVI driven degradation reactions to proceed to the desired end-points. Residence time is a function of reaction rates (as determined by laboratory studies), influent contaminant concentrations, and desired contaminant concentration end-points. Residence time is then translated into a design thickness of the PRB using the groundwater velocity, and permeability/porosity of the iron in the PRB. Site specific distributions of values for these parameters were used as input to a probabilistic design model, which served as the basis for predicting the performance of a 6-inch thick PRB at the Site. A distribution of concentrations of CT was used as input to the model, with a most probable concentration of 80 ppm. Based upon this input concentration and the other input parameters, the Monte Carlo analysis shows that, at the 90% confidence level for a 6-inch PRB thickness, CT degrades to below detectable levels. It also shows that the effluent DCM will be approximately 8 ppm, and the effluent TCM concentration will be 100 ppb or less. The same model was then used to evaluate biodegradation of TCM and DCM downgradient of the PRB. TCM was determined to biodegrade under the conditions at the site with a half-life of 100 days or less. At a half-life of 100 days and a groundwater velocity of 1 foot per day, 100 ppb of TCM will be reduced to less than 5 ppb within 500 feet downgradient of the PRB. Similarly, DCM is known to biodegrade very rapidly under a variety of environmental and geochemical conditions with a half-life of 10 days or less. With a biodegradation half-life of 10 days and a groundwater velocity of 1 foot per day, 8 ppm of DCM will be reduced to less than 1 ppb in less than 150 feet downgradient of the PRB. Therefore, all groundwater objectives will be met prior to reaching the property boundary.

A major challenge associated with cleanup of sites contaminated with chlorinated solvents is identifying the location or source areas of dense non-aqueous phase liquids (DNAPLs). Conventional groundwater sampling technologies rely on collection of groundwater samples either from a well screen typically at least several feet long or, more recently, from discrete-depth sampling probes such as the Waterloo Profiler. Groundwater samples collected from monitoring wells may not reveal the highly elevated solvent concentrations that often suggest the possible presence of a DNAPL. The use of discrete-depth probes, while more useful in revealing high concentration groundwater zones than conventional monitoring wells, does not provide real time data, which can be highly beneficial to site investigators. Also, neither of these methods is useful in evaluating the presence of DNAPL in the vadose zone.

Two native halophytic shrubs were evaluated for phytoremediation of a nitrate-contaminated aquifer at a former uranium mill site near Monument Valley, Arizona. The shrubs, Sarcobatus vermiculatus and Atriplex canescens, obligate and facultative phreatophytes, respectively, dominate the desert plant community. Stable isotope signatures suggested that both species are rooted into the nitrate plume, a depth of more than 10 meters. Aerial photography and ground sampling indicated that populations have responded positively to the elevated nitrate levels. We quantified the amount of water and nitrate these shrubs are removing from the plume, and constructed livestock exclosures to evaluate effects of grazing. The percent groundcover of grazed populations overlying the plume ranged from 6% for A. canescens to 25% for S. vermiculatus. Percent groundcover inside the fenced exclosures increased by 50% per year over three years. Annual productivity per unit canopy area did not differ significantly between species or between grazed and fenced plants, however, S. vermiculatus had significantly higher nitrogen content than A. canescens, and fenced plants had significantly higher nitrogen content than grazed plants. Assuming 25% plant groundcover over a 24 ha area of the plume, our study suggests that these native desert phreatophytes could remove 21,510 m³/yr of water containing 4,539 kg of nitrate.
Biotreatability Studies Lead to Landfarming Innovations
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Watervliet Arsenal, located in Watervliet, New York, is the oldest continuously operating cannon manufacturing facility in the United States. Waste oil and heavy metals, presumably from handling of waste metal chips saturated with cutting oils, have been identified as the primary contaminants in the soil at the Siberia Area of the Arsenal. Malcolm Pirnie, Inc. proposed in situ bioremediation as a corrective measure for contaminated soils in the Siberia Area. To demonstrate that in situ bioremediation is a viable option, Malcolm Pirnie, Inc. performed a series of laboratory biological treatability studies. Initial studies documented the existence of indigenous microorganisms capable of degrading TPH and PAHs. Pan studies were then conducted for six months to simulate in situ landfarming techniques. Data from the pan studies indicated that mixing and aeration of soils are more important than nutrient addition in stimulating hydrocarbon biodegradation at the Siberia Area. Data collected from the laboratory studies were used to design a 16,000-square foot landfarming pilot plot to treat 3,200 cubic yards of soil. This pilot plot was constructed in August 2000 and is currently being operated by Malcolm Pirnie, Inc. Unlike most landfarming plots that are designed for treatment zone depths of 1-2 feet, the Watervliet plot achieves a treatment zone depth of 6-7 feet by using a trencher to mix the soil. Using this conventional construction equipment in an innovative application has the advantage of reducing the surface area required to treat a given volume of soil. Preliminary results from the pilot plot show significant reductions in total TPH and PAH concentrations. Degradation rates for individual PAHs appear to be comparable to those observed at bench-scale, indicating that treatment goals may be achieved sooner than originally anticipated.

Performance Evaluation of a Forced Hot Air Remediation System
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Groundwater contamination from chlorinated solvents such as tetrachloroethylene (PCE) is fairly common. These solvents often exist as dense nonaqueous phase liquids (DNAPL). Since DNAPL usually occurs in isolated pockets and is immiscible with water, it cannot be removed simply by pumping groundwater and therefore, the contamination can last for an indefinitely long period of time. For the first time, a new technology involving the use of forced hot air, was successful in remediating PCE DNAPL at a site in the Piedmont of South Carolina. The PCE DNAPL was found at depths of up to 65 feet below the water table in fractured rock and saprolite soil. Since there have been no previously known cases of successful remediation of PCE DNAPL, extensive measures were undertaken to evaluate the performance of this new technology. Forced hot air injection and enhanced vapor extraction were very effective in removing high levels of contamination since these intensive cleaning steps were focused on the mass of residual PCE contamination within the localized high concentration DNAPL source area. Crosshole hot air/water flushing through fractures was very effective in recovering immobile DNAPL, especially when using air preheated to >1000°F above ambient temperatures. By increasing the temperature of the target zone from 60°F to >250°F, PCE vapor concentrations increased (from <20 ppmv to >400 ppmv), and thus recovery rates increased by 20 times. In less than 30 days, PCE concentrations in one of the primary wells decreased 97%, from greater than 4,000 ppb to less than 100 ppb. The thermal techniques used in these tests created in situ steaming, which increased volatility and decreased subsurface absorption of residual and dissolved PCE. Temperatures of purge water from the primary well remained at or near 240°F for several days and 160°F for several weeks following the test.

Cement-based Solidification/Stabilization treatment of lead- and petroleum-contaminated soil at a brownfield remediation site in Boston.
As permeable reactive barriers (PRBs) containing zero-valent iron become more widely used to remediate contaminated groundwaters, there remains much uncertainty in the prediction of their long-term performance. While a number of accelerated aging laboratory and pilot-scale tests have not indicated any significant performance issues caused by the build-up of surface precipitates or bio-fouling, there has been relatively little performance data collected in the field at pilot- or full-scale installations. Over a six-month period, the performance of a pilot-scale PRB at the Somersworth, NH Landfill Superfund Site was evaluated. The 21-ft long PRB was installed in November 1999 to test a construction technique that uses a biodegradable polymer slurry to support an open excavation while a granular iron/sand mixture is placed into the subsurface. Criteria used to assess the PRB’s performance included (1) hydraulic testing to evaluate potential fluid viscosity effects related to the use of the biopolymer, (2) monitoring of VOCs, groundwater parameters (pH, DO, ORP, specific conductance) and inorganic parameters (including metals, major ions and nutrients), (3) microbial characterization of groundwater, (4) reactivity testing of emplaced iron material, and (5) advanced surface analysis of cored iron material. Dedicated, in-well groundwater quality probes (YSI-600 XLM) were also deployed in four wells set along a transect through the PRB to collect data that would correlate measured groundwater parameters with changes in barrier performance (e.g., biopolymer breakdown and inorganic precipitation).

A creosote wood treatment facility in Grenada, Mississippi has treated railroad ties, utility poles, and lumber in pressurized cylinders using creosote since 1904. Former waste management practices at the facility resulted in the presence of creosote DNAPL and associated groundwater contamination in alluvium and stream sediments at the site. Stream sediments along the ditch, which received discharge from former lagoon areas, were found to be significantly impacted by DNAPL. In 1999, Interim Measures (IM) were initiated to mitigate further discharge of DNAPL into the ditch. These IM activities included controlling mobile DNAPL by installing a sheet-pile barrier along the north bank of the ditch, an underdrain system to extract DNAPL beneath the relined ditch, and DNAPL recovery wells behind (and upgradient of) the sheet-pile barrier. As of January 2001, 1800 gallons of DNAPL had been extracted from the ditch underdrain system, but little DNAPL had been recovered from the wells. As evidenced by the ongoing monitoring and DNAPL recovery program, the rate of DNAPL extraction is slowing.

The source of contamination in a deep monitoring well was delineated using a numerical flow model, tritium/tritogenic helium as tracers and water-to-vapor diffusion samplers. This previously underdetermined source of contamination was found to have traveled over 1.5 miles and discharged to a local stream. The concern by the regulatory community that the plume may flow under the stream and impact a nearby community water supply well was alleviated. The site, located in Florida, has a large unsaturated zone (100 ft.) that precluded more traditional approaches to characterizing contaminant plumes. Previous efforts to determine both the source and fate of the plume were unsuccessful. Significant cost savings for site characterization are expected.

Many waste legacy sites, even after remediation, will require long-term monitoring (100 to 1000 years) to ensure that no leftover contaminants are released to local environments (groundwater and air). Engineered surface covers are being built to contain waste within remediated sites. Rugged, low-cost sensors are needed to monitor the integrity of the engineered covers over both the short and long term. This paper describes a network of radio frequency (RF) sensors, coated with a corrosion protective layer, for monitoring the migration of contaminant plumes. Input impedance of the network will vary with frequency and the dielectric properties of the soil medium, including that of contaminant plumes leached out of capped sites. The network is much like a telephone cable buried around the containment...
boundary, and the sensors are interrogated from one end of the cable. The system is passive in that the line is not powered all of the time and provides measurements only on demand. As a result, it is a simple, inexpensive, and rugged network for monitoring the integrity of engineered covers over a long period. Preliminary tests at 100, 500, 1000 MHz of an open-ended coaxial probe buried in a sand box showed good sensitivity to chemical contaminants. Research supported by U.S. Department of Energy, Laboratory Directed Research and Development, under Contract W-31-109-ENG-38.

Enhanced Dehalogenation of Halogenated Methanes by Bimetallic Cu/Al
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A low-cost and highly effective bimetallic Cu/Al has been developed for the treatment of halogenated hydrocarbons, especially dichloromethane, in water at near neutral pH. XRD analysis indicates Cu is deposited onto the Al surface through a simple two-step synthetic method. The presence of Cu enhanced the carbon tetrachloride degradation rate by a factor of about 50 compared to the Al metal alone. The Cu/Al life was preliminarily studied by a multi-spiking test with 7 complete degradation cycles of carbon tetrachloride although the catalyst aging was found. Correlation analysis indicating a strong dependence of the reaction rate constant on bond strength implies that the adsorption of carbon tetrachloride on the metal surface dissociating the carbon-chlorine bond through the direct electron transfer mechanism might be the rate-limiting step. Based on the light density of Al, bimetallic Cu/Al could serve as injectable particles for the remediation of contaminated groundwater through direct injection technology.

Characterization of the Vadose Zone using Partitioning Interwell Tracer Tests
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A partitioning interwell tracer test (PITT) was conducted in the vadose zone beneath the location of a former solvent evaporation pit at the Department of Energy’s Pantex Plant. The primary objective of the PITT was to establish whether or not residual Non-Aqueous Phase Liquid (NAPL) remained in the subsurface and if so, to quantify the amount. A soil vapor survey and soil sampling campaign had been conducted earlier and neither had yielded conclusive results about the presence or absence of NAPL. A divergent line-drive well field was installed and the zone of primary interest (i.e. 50 to 90 feet below ground surface) swept with a suite of conservative and partitioning gas tracers. Real-time analyses of the tracer concentrations in the injectate and from 16 extraction points were provided by two gas chromatographs installed in-line. Analysis of the results shows a quantity of 852 +/- 109 gallons of residual NAPL present in the swept pore volume of 523,000 gallons. This data is crucial to the construction of a geosystem model that explains the mass balance of contamination and to the guidance of remediation efforts.

Stabilization of DNAPL at a Former Creosote Wood Treating Site
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In-place stabilization of soils containing Dense Non Aqueous Phase Liquid (DNAPL) was performed at a former creosote wood treating site in New Jersey to immobilize the DNAPL, minimize future dissolution of constituents to groundwater, and expedite natural attenuation. The use of this innovative physical treatment technology was a more cost-effective remedial solution than conventional approaches to DNAPL contamination at former wood treating sites. In addition to being more cost effective, the resulting stabilized soil mass will have sufficient strength to support future redevelopment and will not require significant operation and maintenance. Following remediation, the site will be redeveloped as commercial or industrial property. The selection and implementation of the DNAPL stabilization technology was conducted in accordance with the New Jersey’s Technical Requirements for Site Remediation (N.J.A.C. 7:26E). A total of 15,000 cubic yards of soils containing DNAPL were stabilized in accordance with the NJDEP-approved Remedial Action Work Plan. The stabilized soils were stabilized to a depth of up to 7 feet and groundwater was encountered from 2 to 5 feet below the ground surface. The stabilization was conducted by adding a specific mass of Portland cement to the soils containing DNAPL in the proportion determined to be effective in the treatability study and was blended using specialized excavator-mounted mixing equipment to create a solid, homogeneous stabilized soil-cement mass. Following stabilization, confirmatory test pits were performed, which verified the effectiveness of the stabilization.
[172] Contaminant Transport through Composite Geomembrane-Soil Cut-Off Walls
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Composite geomembrane-soil cut-off walls are recognized to be effective hydraulic barriers. Although the hydraulic effectiveness of a composite geomembrane-soil cut-off wall can be indicative of contaminant transport through the wall, contaminants can also diffuse through the wall. In this paper, contaminant transport of organic and inorganic contaminants through composite geomembrane-soil cut-off walls was determined using results from a numerical model of groundwater flow and an analytical model for diffusion in composite geomembrane-soil cut-off walls. The effects of different geological conditions, characteristics of the key, and defects in the joints between geomembrane panels were included in the analyses. Results of the analyses show that the predominant pathways for contaminant transport through composite geomembrane-soil cut-off walls depend on the type and concentration of the contaminant being contained and the hydraulic effectiveness of the wall. Even for composite geomembrane-soil cut-off walls that are hydraulically effective, significant quantities of organic contaminants can diffuse through the wall. Therefore, the effects of diffusion should be considered in analyses of the performance of composite geomembrane-soil cut-off walls.

[173] Enhanced Bioremediation of Chlorinated Solvents
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Enhanced in situ bioremediation of chlorinated solvents in groundwater has been successfully demonstrated at many sites by supplying lactic acid as an electron donor. The source of lactate for these successful pilot tests is Hydrogen Release Compound (HRC®), a polylactate ester specially formulated for slow release of lactic acid upon hydration. HRC has been delivered to chlorinated solvent groundwater plumes by various means, the simplest is by being directly injected into the contaminated aquifer using a direct push technology such as Geoprobe®. Completed pilot tests show that HRC can effectively enhance the natural attenuation of chlorinated solvents with very efficient degradation half-lives which leads to economic site cleanup. A new pilot test has recently begun at a Brownfields site in Massachusetts which is in EPA’s Superfund Innovative Technology Evaluation (SITE) program. At this site a new technique for initiating the anaerobic process has been used by preceding the normal HRC injection into wells with several wellbore volumes of a new and experimental variant of HRC. The new product variant is designed to sweep the aquifer clean of competing electron acceptors more rapidly thus allowing for a potentially more rapid initiation of reductive dechlorination. Initial results show that after 3 months the oxidation-reduction potential has decreased markedly in all monitoring wells within 25 feet downgradient of the HRC injection wells, some to less than -400. Furthermore, after 5 months significant reductive dechlorination has been observed in two of the downgradient monitoring wells. Results of the progress on this SITE program pilot test will be presented as they become available.

[175] Deployment of an Alternative Closure Cover and Monitoring System at the Mixed Waste Disposal Unit U-3ax/bl at the Nevada Test Site
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Final closure of the Mixed Waste Disposal Unit U-3ax/bl at the Nevada Test Site was achieved by the successful deployment of Resource Conservation and Recovery Act (RCRA) alternative cover design. This closure is unique in that a mono-layer closure cover, also known as an evapotranspiration (ET) cover, consisting of native alluvium, received regulatory approval instead of using a traditional RCRA multilayered cover. Recent studies indicate that in the arid southwestern United States, mono-layer covers may be more effective at isolating waste than layered covers because of the tendency of layered systems to fail over time. Approval of the design was contingent on the installation of soil water content sensors within the cover to monitor performance during the post-closure monitoring period. Additional funds from Technology Deployment (TD), through the Accelerated Site Technology Deployment (ASTD) program enabled a lysimeter facility to be installed immediately adjacent to the disposal unit. This facility will provide data for a detailed evaluation of closure cover performance and running numerical models. Final closure of U-3ax/bl and deployment of the ASTD drainage lysimeter facility is a U.S. Department of Energy (DOE) Environmental Management (EM) success story, requiring involvement from Waste Management, Environmental Restoration, and TD groups, and paving the way for future mono-layer ET closure covers at other arid and semiarid DOE sites. This work was supported by the U.S. Department of Energy, Nevada Operations Office, under Contract No. DE-AC08-96NV11718.

[177] Use of Novel Reactive Barrier Materials for Treatment of Strontium, Uranium, Nitrate and Perchlorate in Groundwater
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Reactive barrier technology has been under investigation at Los Alamos National Laboratory for remediation of contaminated
groundwater. The prevalence of multiple contaminants, including \(^{87,90}\text{Sr}, {^{235}}\text{U}, \text{NO}_3^-, \text{and ClO}_4^-\), has prompted investigation of novel types of reactive media to remediate groundwater. Contaminants have been contacted with media utilizing batch techniques, kinetically limited one-dimensional (1-D) columns, and a 2-D box packed with reactive porous materials. Two materials have shown significant propensity to remove aqueous phase metals, \(\text{NO}_3^-\) and \(\text{ClO}_4^-\) from groundwater: Apatite®II and pecan shells. Apatite®II (fishbone) effectively sorbs \(^{235}\text{U}\) (92 mg \(^{235}\text{U}\)/kg Apatite®II) and provides sustenance for microorganisms that continuously reduce \(\text{NO}_3^-\) and \(\text{ClO}_4^-\) (undetected during experiments). Since Apatite®II contains significant amounts of naturally abundant \(\text{Sr}\), its capacity to sorb anthropogenic \(^{87,90}\text{Sr}\) is limited. Pecan shells provide a long-term carbon source for microorganisms that form biofilms on the surface of pecan shells. The biofilm and shells sorb \(^{87,90}\text{Sr}\) (42 mg \(^{87}\text{Sr}\)/kg shells) and microorganisms reduce \(\text{NO}_3^-\) and \(\text{ClO}_4^-\), although it is necessary to stimulate microorganisms with a carbon source such as dog food to reduce \(\text{NO}_3^-\) and \(\text{ClO}_4^-\) to undetectable levels. When placed in series, Apatite®II followed by pecan shells, these materials effectively eliminate multiple contaminants from groundwater.

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**Demonstration of Groundwater Containment Through the Use of a Barrier Wall, Surface Cover Systems and Natural Attenuation**

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Two years of groundwater monitoring data demonstrate that groundwater remedial objectives have been accomplished at a former coke and by-products facility through the integrated use of barrier wall and surface cover systems, and natural attenuation. The barrier wall system is comprised of a 3-sided, 4,500 foot long slurry wall bordering the river and enclosing the former process areas. The surface cover is processed dredge material which consists of sediments from the New York/New Jersey area waterways stabilized with Portland cement. No active pumping is required to achieve the containment. Physical data validate that groundwater flow has been controlled and redirected away from the river and seepage velocities have been reduced. Groundwater chemistry data show that the dissolved plume has been controlled, not expanded and biodegradation is occurring. Inspections along the river indicate that discharges of DNAPL have been mitigated.

[181]

**Using Web Browsers to Operate a Data Management System for the Excavation and Remediation of the Sandia National Laboratory Chemical Waste Landfill**

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The Chemical Waste Landfill (CWL) at Sandia National Laboratories, New Mexico (SNL/NM) is a 1.9 acre disposal site that was used for the disposal of chemical wastes generated by many of SNL/NM research laboratories from 1962 until 1985. SNL/NM in conjunction with URS began excavating the landfill in 1998 and treatment of the excavated soils will begin in the near future. Project generated data is accumulated during all processes of these operations. That data is used to support the project during excavation, in the reporting process, and in determination of specific treatment variables. Due to the need for accurate and timely reporting, data management has become a key component of this remediation effort. The data management system uses Dynamic Hyper Text Markup Language (DHTML) and Extensible Markup Language (XML) technologies to provide an improved method for collecting and disseminating information critical for efficient remediation operations. To facilitate communication, the management system provides an interactive Web based interface that links underlying databases together. By using web browsers to submit data or query the system, multiple novice users can access pertinent data without an extensive amount of training. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.
[182] Confined Aquatic Disposal for Dredged Material at Bremerton Naval Complex
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This presentation describes sediment remediation at the Bremerton Naval Complex (BNC) in Bremerton, Washington. The presentation will described state-of-the-art features used to design and construct the containment facility including effectiveness of environmental clamshell buckets, dGPS guidance systems, precise dump barge positioning, extensive water quality monitoring, frequent progress survey results and removal of compressed gas cylinders with a 72-inch diameter underwater magnet. Construction was started in June 2000 and dredging and disposal of over 350,000 cubic yards of contaminated sediments will be complete in February 2001. Contaminated sediment was placed into a confined aquatic disposal pit (Pit CAD) 600 feet by 600 feet by 35 feet below the mudline, which is located on Navy property in water depths of 30 feet MLLW. Project is permitted under a Corps of Engineers permit with a Biological Opinion from NMFS for protection of threatened Puget Sound Chinook salmon, and a Record of Decision for CERCLA remediation. Design of the Pit CAD and sand cover was done in accordance with Guidance for Subaqueous Dredged Material Capping published by the Corps of Engineers in 1998. A unique aspect of the project is the combination of remedial dredging with navigational dredging of sediment suitable for open water disposal. The work was done with equipment that evolved from traditional clamshell dredging and bottom-dump barge placement. This results in cost-effective remediation for large volumes of non-hazardous sediment. The cost for dredging and disposal of over 600,000 cubic yards (350,000 cy in the Pit CAD and 250,000 cy in open water) is about 12 million dollars.

[183] The Innovative Treatment and Remediation Demonstration (ITRD) Program: Lessons Learned in Overcoming Barriers to the Adoption of Innovative Technology
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The Innovative Treatment and Remediation Demonstration (ITRD) Program accelerates the use and acceptance of new cost-saving technologies to solve site-specific remediation problems at DOE sites. The ITRD process to overcome the barriers to adoption of new remedial techniques involves: 1) formation of multi-agency Technical Advisory Groups (TAG) composed of all relevant stakeholders to assess new technologies for site-specific requirements; 2) treatability and pilot studies for technologies selected by the TAG and 3) evaluation of test results to obtain cost and performance information. During FY2000 and FY2001, ITRD projects involved initial screening of 30+ technologies and deployments or detailed evaluation of 12 different technologies to remediate soils and groundwater at 9 different locations within the DOE complex. Active source removal, passive barriers, bioremediation and monitored natural attenuation were evaluated for remediation of chlorinated solvents (dissolved and DNAPL), explosives and radionuclides. ITRD projects currently underway at several DOE sites including the Paducah Gaseous Diffusion Plant, the Oak Ridge Y-12 Plant, the Hanford 100-N area, the Pantex Plant, and the Mound Plant Operable Unit-1 provide examples of the various challenges and stages in introducing innovative technologies at DOE sites. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC-94-AL85000

[185] Capturing Hydrogeologic Uncertainty in Transport Predictions at the Hanford Site, Washington
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Limited data on the spatial extent of aquifers and aquitards in the Hanford site hydrogeologic system as well as limited data on their properties and the external and internal driving forces affecting the geohydrologic system leads to uncertainty in the transport predictions used for remediation decisions. We are working to quantitatively incorporate uncertainty related to many of these factors into our transport predictions. Geostatistical methods are being used to develop alternative realizations of model structure at the site, as discussed by Kanevski and others at this conference. An initial transient inverse calibration of the existing three-dimensional Hanford Site model to estimate hydraulic parameters and boundary conditions based on our current interpretation of the aquitards was completed. We are currently using inverse methods to examine uncertainty in communication between the unconfined and confined aquifers at the site. We plan to use inverse methods that allow the inverse model to vary the extent of aquitard units within bounds determined through the geostatistical analysis. The planned inverse analysis will consist of varying the spatial distribution of the mud units, as well as flow parameters and boundary conditions, to achieve the best fit of historical measurements of hydraulic head and contaminant movement.
Sampling and Remedial System Design Optimization Through Passive Soil Gas Screening

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This presentation will discuss the use of a passive soil gas (PSG) survey employing innovative Gore-Sorber (Gore-Tex) technology to determine the extent of groundwater and soils contamination and remedial investigation solutions for a naval facility with dissolved contaminants and NAPLs in groundwater and soils. Chemical-specific PSG modules, placed in grids, are used for screening purposes to determine potential contaminant source areas and geometries of the contaminant plume(s). Results of the PSG screening survey are used to reduce and optimize the number of soil and groundwater sampling locations required to help develop risk-based remedial alternatives. Chemical-specific organic compound sensitive resins are encapsulated in a Gore-Tex sleeve that is inserted 3 feet into the ground in a predrilled hole. Because the modules absorb soil gasses over a 2-week period under atmospheric pressures and temperatures, the data are not biased by soil texture, moisture, or changing ambient surface and subsurface conditions. After 2 weeks, the modules are removed and analyzed by GC/MS. The length of time from module installation through report delivery is 6 weeks. This EPA-accepted PSG survey screening technology provides a low-cost expedient method of reducing characterization costs and optimizing sampling and remedial system design and monitoring requirements.

Sample Design Optimization and Identification of Contaminant Plumes and Subsurface Structures Through Use of Multi-tool Surface Geophysics

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Multi-tool surface geophysics (resistivity, seismic refraction/reflection, gravity, magnetics) were employed at an experimental fire fighting training facility at a naval installation to determine (1) the presence and geometry of contaminant plumes and (2) subsurface characteristics of lacustrine fill and bedrock, including morphology, faulting, and potential pathways for contaminant migration. The site is comprised of fine-grained Pleistocene playa deposits overlying Mesozoic granodiorite. The study site has one known and several suspected source areas: organic and inorganic contaminants in soil and groundwater, and an 800-foot long by 200-foot wide NAPL and dissolved-phase contaminant plume. The objectives of the study were to identify potential sampling targets, optimize sampling depths, and eliminate the installation of unnecessary exploratory borings and wells. Results of the ground resistivity survey were used to identify isolated plume areas (NAPL) within a larger dissolved groundwater plume, model the underlying bedrock surface, and show that the bedrock was unfractured. Seismic refraction results were used to map the underlying competent bedrock surface and show that weathered bedrock was not present. Results from both geophysical surveys were combined to develop a depth-to-bedrock map to help identify contaminant pathways, eliminate exploratory borings (>100 feet deep), and locate specific sampling locations.

A Cost-Effective Approach to Multi-Parameter Hydrologic Monitoring to Characterize Groundwater Flow Conditions

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This presentation introduces a cost-effective approach to characterizing groundwater movement horizontally and vertically from a naval installation to an adjacent community within three hydrogeologic zones. To accomplish this, continuous water levels and velocities are continuously measured with pressure transducers and velocity sensors at strategic locations along the naval facility property boundary, and groundwater levels are measured regionally in on- and off-site wells to characterize groundwater flow within a 36-square mile area. In situ groundwater velocity sensors (developed with the Technology Deployment Initiative Institute for the Department of Energy) and pressure transducers in monitoring well pairs are used to estimate groundwater velocities and gradients in three dimensions. Data collected continuously from the velocity sensors and pressure transducers, coupled with the water level data collected quarterly from a regional monitoring well network, serve to accomplish the following: (1) monitor changes in horizontal and vertical groundwater gradients and velocities, (2) determine the direction and rate of groundwater movement from the naval facility to an adjacent community, and (3) provide particle tracking estimates. This approach provides greater coverage over a longer duration of time than conventional aquifer testing, which is limited to a discrete zone of influence during a “snapshot” in time.
Research currently being undertaken through ANSTO, the Australian Nuclear Science and Technology Organisation, and consultant Earth Systems is the development of a new technique for building in situ sub-surface hydrologic barriers called Neutral Barrier Technology or NBT. NBT aims to control fluid flow in a wide variety of permeable rock or unconsolidated sediments. NBT enables the in situ formation of sub-surface containment structures or barriers to impede the migration of specific water flows (polluted or otherwise) into the wider environment. The technique involves selectively sealing microscopic inter-pore channels that permit the passage of water through soil, sand, and porous rock with mineral carbonates such as calcite. Applications envisaged include:

- plugging leaks in tailings dams or other water impoundments,
- restricting inflow of water into mine workings,
- as groundwater intercept barriers,
- as guides to reactive barriers, and
- reducing leachate leakage to groundwater from various waste dumps.

Unlike existing technologies, Neutral Barriers can be installed in sub-surface settings with no earthworks and negligible disruption. Bench-top and field demonstrations have created numerous barriers with a broad variety of geometries. Some configurations have demonstrated up to a 1,000-fold reduction in hydraulic conductivity across a barrier.

Fuzzy Inference System (FIS) and Adaptive-Neuro-Fuzzy Inference System (ANFIS) methods, and (3) used an ANFIS method for nonlinear time-series predictions of the TCE concentration. Comparison of fuzzy membership functions for different campaigns for TCE and PCE concentrations were used to assess the effectiveness of remediation actions. Fuzzy systems analysis revealed more details about the processes involved in remediation, which were not identified in the previous studies of the SRS demonstration. The results of our analysis can be used in developing fuzzy-ruled methods for optimization of managing remediation activities and risk assessment.

Do You Think You Manage Your Source?

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The historical problems of soil contamination are so big, we have to manage them and control the risks until remediation can be started. The presentation will focus on uncertainties in soil investigation, lab analysis and risk evaluation. Results will be presented of a round robin organised among laboratories. This round robin was the final test to be accredited to carry out soil analyses in Flanders. The results are rather shocking. Up to now, Flanders is the only European region demanding success in a round robin to get an accreditation. What’s the value of a soil investigation or risk evaluation if variations in analysis results are as high as the measured concentration? Many companies pay a lot of attention to find the most cost-effective remediation concept. Making the ground fit for use, isolation concepts and natural and stimulated attenuation seem quite interesting for large contaminated sites at short notice. The presentation will focus on uncertainties in modelling long term behaviour of pollutants, on long-term organisational and maintenance problems and costs of the most frequently used source management concepts. The main aim of the presentation is to get the audience thinking about what consultants or contractors try to sell them.
the floor of the landfill causing cementation of the loose structure of the deposited fly ash. Fly ash produced in the hard coal combustion process may have different chemical compositions depending on geological conditions of hard coal layers. These differences may cause large pH differences in water solution of fly ash and consequently in pore water. This causes a reaction between pore water and solid phase, which takes place with intensive liberation of compounds rich in silica or aluminum. These ions are necessary when the cementation of the landfill through pozzolana reactions is to be achieved. The cementation process takes place in an alkaline environment. In many cases CaO occurs in huge amounts naturally in fly ash. In these conditions, the pozzolana reaction takes place spontaneously. In neutral or acid ash, the reaction must be initiated.

[197]
Production - Scale Bioreactor for Petroleum Contaminated Soils
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A small, mobile bioreactor, intended for use in remediating limited volumes of contaminated soils, was designed and constructed by the IETU in cooperation with WSRC. The bioreactor was built as a continuous airflow, packed bed reactor. A modified, 6m³ capacity standard container for waste collection and transport was used as a vessel for the bioremediation of contaminated soil. It was equipped with false floor to provide leachate collection and uniform aeration of remediated soil as well as pumps and sprinklers to recycle the leachate through the system. Supplementary equipment was used to control bioremediation process and to provide on-line monitoring of basic bioreactor working parameters. This includes blowers to force air through the soil layer, the leachate recirculation system (which also provides a mechanism for the uniform distribution of fertilizer or other amendments), sets of soil gases sensors for measuring CO₂, O₂ and CH₄ concentrations as well as soil temperature. The data acquisition process is fully controlled by IETU-developed software (BioReDaq) working in the Advantech VisiDaq environment. Once the bioreactor was built, a soil cleanup test was carried out. Approximately 3.2 ton of petroleum contaminated soil from the Czechowice Refinery (Poland) was used for treatment. During the 97-day bioreactor operating campaign, data was collected continuously from solid state sensors. The data was confirmed by periodic sampling with a GEM 500 Landtec device. The test results show that both TPH and PAH were reduced to ~50% of initial average concentrations. The bioreactor equipped with the data monitoring/control system can be a useful tool to bioremediate small amounts of petroleum contaminated soil.

[200]
Applications of Ionizing Radiation for Degradation of Organic Pollutants in Waters and Wastes
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Antropogenic organic pollutants discharged to natural waters in the form of municipal and industrial wastes can be removed by the use of various technologies. Among numerous advanced oxidation chemical technologies, γ radiation- or electron beam-based technologies are particularly promising. These technologies have already been demonstrated in batch processes, in flow-through installations and in a mobile treatment station. Their application is based on a unique interaction of oxidizing hydroxyl radicals and/or reducing hydrated electrons with organic pollutants. Both these reactive species are formed in a very rapid process of radiolysis of water and can be utilized in different ways in the degradation of organic pollutants. A favorable increase of effectiveness for some of these processes can also be achieved by carrying them out in the presence of ozone. Besides presenting the state-of-the-art of this technology for treatment of water and wastes, results of our research on the application of this technology for removal of selected chlorophenols and herbicide 2,4-D from aqueous solutions will be given. This presentation will include detailed analytical data on the yield of processes and their products in different irradiation conditions. The optimization of these processes using both γ and electron beam irradiation has been carried out in regards of magnitude and rate of the irradiation dose, chemical conditions of the process, presence of scavengers and changes of toxicity of irradiated solutions.
[201]
A Risk-Based Methodology for Disposal of Arsenic Containing Sediments
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A cost effective risk-based disposal methodology was developed for a project with limited funds available for hazard identification and possible media disposal. Excavation in littoral and upland areas was required for an auxiliary mooring facility that had exceedences of risk-based cleanup criteria for arsenic and a polycyclic aromatic hydrocarbon (PAH). Further sampling was conducted to determine vertical and lateral extent of compound concentrations within the limits of the planned excavation (~160,000 yd³). PAHs met residential soil screening criteria. Aluminum:arsenic ratios for all samples fell within the 95% prediction limit determined for background sediments, but 27 of 67 samples exceeded the arsenic residential cleanup target level and 7 of 67 exceeded its industrial cleanup target level. In-water sediments had higher arsenic concentrations than upland soils. Volume-weighted average arsenic concentrations were calculated for the sampling points and analysis showed that by combining the in-water sediments and upland soil with arsenic concentrations greater than 3.7 ppm, offsite disposal of clean fill (i.e. meets the residential arsenic target cleanup level) could occur for 71% of the excavated material. The remainder, to be disposed of onsite, would meet industrial criteria. Iterative evaluation of disposal options allowed for maximizing safe offsite disposal that met regulatory requirements while minimizing waste disposal costs.

[202]
Locating DNAPLs with Flexible Liners
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There are two flexible liner methods for mapping DNAPLs subsurface. The first is a color reactive liner emplaced via CPT Geoprobe, core or driver casing holes in the vadose zone and saturated zone. The result is a bright stain wherever the reactive covering contacts free product. This paper describes the technique and summarizes the results at a variety of sites. New installation methods are explained. The second flexible liner method is well suited to mapping the distribution of dissolved contaminants, including DNAPLs. This method provides multilevel sampling of pore fluids with excellent isolation of the sampling intervals.

[203]
A Comparison of Field Techniques for Confirming Dense Non-Aqueous Phase Liquids (DNAPLs)
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Dense non-aqueous phase liquids (DNAPLs) are immiscible fluids with a specific gravity greater than water. When present, DNAPLs present a serious and long-term source of continued ground water and soil contamination (Pankow and Cherry 1996). Accurate characterization and delineation of DNAPL in the subsurface is critical for evaluating restoration potential and for remedy design at a site. However, obtaining accurate and definitive direct evidence of DNAPL is difficult. A field study was recently performed comparing several approaches to DNAPL characterization at a site where anecdotal, as well as limited direct evidence of DNAPL exists. The techniques evaluated included: a three-dimensional (3-D) high resolution seismic survey, field screening of soil cores with a flame ionization detector (FID)/organic vapor analyzer (OVA), hydrophobic dye (Sudan IV)-impregnated reactive Flexible Liner Underground Technologies (Flute™) liner material used in combination with Rotasonic drill cores, centrifuged soil with Sudan IV dye, ultraviolet light (UV) fluorescence, a Geoprobe® Membrane Interface Probe (MIP™), and phase equilibrium partitioning evaluations based on laboratory analysis of soil samples. Sonic drilling provided reliable continuous cores from which minor soil structures could be evaluated and screened with an OVA. The OVA screening provided reliable preliminary data for identifying likely DNAPL zones and for selecting samples for further analyses. The Flute™ liner material provided the primary direct evidence for the presence of DNAPL and provided reliable information regarding the thickness and nature of its occurrence (i.e., pooled, ganglia, etc.). The MIP™ probe provided good information regarding the subsurface lithology and rapid identification and delineation of probable free-product areas. The 3-D seismic survey was of minimal benefit to this study and the centrifuging of samples with Sudan IV dye and the use of UV fluorescence provided no benefit. Results of phase equilibrium partitioning concentration calculations for soil samples (to infer the presence of DNAPL) were in good agreement with the site screening data. Additionally, screening data compared well with previous ground water data and supported using one percent of the pure phase solubility limit of Freon 113 (i.e., 2 mg/L) as an initial means to define the DNAPL study area. Based on the results of this study, the most effective
approach for identifying and delineating DNAPL in the subsurface is to initially evaluate the study area with the MIP™ device to identify areas and lithologic zones where DNAPL may have accumulated. Core samples (either Rotasonic or Geoprobe®) would then be collected from zones where MIP™ readings were indicative of the presence of DNAPL. Soil samples from the free-product portions of the core(s) would then be submitted to a laboratory for positive analyte identification. Soil analyses would then be combined with site-specific geotechnical information (i.e., fraction organic carbon, soil bulk density, porosity) and equilibrium partitioning algorithms used to estimate concentrations of organic contaminants in soil samples that would be indicative of free product. Used in combination, the soil analysis and the MIP™ records appear to provide accurate DNAPL identification and delineation.

[204] New Ways in Detecting LNAPL Plumes in Granular Sediments Using Geophysical and Atmogeochemical Methods
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A recent series of papers was devoted to possibilities of geophysical methods for detecting long-time-residing LNAPL plumes in granular sediments. Sauck (2000) developed a new conceptual geophysical model for this case, taking into account geochemical processes caused by the bacterial biodegradation of hydrocarbons. The existence of a low resistivity zone below the LNAPL plume is the only chance to estimate the extent of the plume by resistivity survey (multielectrode measurements, vertical electrodes) and ground penetrating radar. We combined the geophysical techniques with the soil vapor survey using new methods and instrumentation (ECOPROBE 5) for direct estimation of the extent of hydrocarbon plumes. We used the cone penetration tests combined with logging for direct detection of contaminated layers in the vertical sections. The new soil vapor survey method, based on the combination of total PID and selective IR analyzers, reveals vital information about subsurface pollution and enables compensation for the influence of the most of disturbing factors. The efficiency of this approach is documented with materials from an abandoned military area in the Cretaceous region of Bohemia.

[206] MatCon Modified Asphalt Cover Containment System Demonstration
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In order to make improvements to conventional paving asphalt to make it more suitable for containment applications, Wilder Construction Co. of Everett, WA offers MatCon, a polymer modified asphalt system comprised of proprietary binder, which, when coupled with a selected aggregate type and gradation, a specialized job mix formula and installation specifications results in a potentially superior substitute for conventional paving asphalt in cover containment applications. Under US EPA’s Superfund Innovative Technology Evaluation (SITE) program, the system was installed and placed under study at two locations, with two more possible in 2001. MatCon is intended for use as a waste containment material, and can be configured to function as both a hydraulic barrier and a drainage material, to comprise a single or multiple layer cover system. MatCon is noted for its superior engineering qualities and is designed for long-term performance, yet can be applied with conventional paving equipment. The hydraulic performance of the material was examined by both removing destructive samples for laboratory testing, as well as field evaluation. While the study focuses on hydraulic properties, accompanying engineering properties were evaluated in the laboratory. Finished MatCon can serve multiple purposes such as staging for trucks and construction equipment, pavement, and light industrial facilities. This presentation provides an overview of the research approach, application history, and initial results of two years of study.
Acid mine waters can contain high concentrations of metals like iron, aluminum, zinc, uranium and various heavy metals. Research has been conducted for several years to establish the extent to which under the conditions of the former uranium mine of Königstein (Saxony, Germany) reduction of pollutant concentrations can be positively influenced and accelerated by storage of reactive materials in open mine cavities. Experimental investigations ranging in scale from laboratory and underground column tests up to a flooded heading were conducted by WISIMUT GmbH and DMT GmbH. Reactions induced by zero-valent iron form a basis for a further improvement of pollutant immobilization by additives. A mixture consisting of iron and lignite proved to be the most effective combination of materials. The structure of iron turnings and coarse brown coal remains stable in spite of partial dissolution an precipitation of reaction products. For periods of more than one year, a sufficient reaction capacity without re-release could be verified. The conveyance of reactive materials can be regarded as practical for reducing pollutant loads in mine water in open mine cavities as a supporting measure to be taken during the controlled flooding and as a safety component after conclusion of the flooding.

Test Area North at the Idaho National Engineering and Environmental Laboratory (INEEL) is the site of a 2 mile long trichloroethene groundwater plume resulting from historical injection of wastewater into the Snake River Plain Aquifer. The 1995 Record of Decision (ROD) identified pump and treat as the default remedy for total plume restoration. However, the authors of the ROD recognized that this technology may not be the most effective remedy and identified five innovative technologies to be evaluated to determine if overall plume restoration could be enhanced relative to traditional pump and treat. Completion of the technology evaluations resulted in regulatory agency selection of In Situ Bioremediation (ISB) and Monitored Natural Attenuation (MNA) as more cost- and time-effective remedies for two different plume zones. Innovative technology selection was based on 5 years of INEEL technology evaluation conducted in parallel with two and one half years of Subsurface Contaminants Focus Area (SCFA) deployment activities. The major achievements supporting selection of ISB and MNA were:

- Demonstrated groundwater restoration COST SAVINGS at INEEL of $23 Million
- Demonstrated SOURCE AREA RESTORATION with ISB
- Demonstrated use of MNA for dissolved phase remediation
- REGULATORY ACCEPTANCE of ISB & MNA for Chlorinated Solvent Remediation
- PUBLIC REVIEW & ACCEPTANCE of Proposed Plan for final selection of ISB and MNA
- RECORD OF DECISION AMENDMENT Draft Final
- Provisional PATENT APPLICATION related to ISB filed June 2000
- R&D 100 AWARD NOMINATION from INEEL December 2000
- Active DEPLOYMENT of ISB and MNA to LLNL, ORNL Y-12, Portsmouth
- INEEL innovative technology expertise supported SCFA Technology Assistance efforts

The INEEL team has deployed two innovative technologies using a successful process model demonstrating cost- and time-effective alternatives to pump and treat are available for restoration of chlorinated solvent contaminated groundwater.
concentrations of several metals in sediment. These relationships offer flexibility to sediment risk management. In the absence of acute (lethal) effects, chronic effects may be acceptable in relatively small areas. If large areas are contaminated, remediation goals may be set to assure adequate levels of invertebrate reproduction in the estuary.

[211] Bench-Scale Testing of Remedial Technologies for NAPLs Containing PCBs and Chlorinated Benzenes
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Bench-scale tests of various potential remedial technologies were performed on samples of NAPLs and NAPL-saturated soils containing PCBs and chlorinated benzenes obtained from a CERCLA site in western Pennsylvania. Two destruction technologies (in situ oxidation and a biological treatment process) were tested in a laboratory setting to determine if the technologies are capable of remediating the specific contaminants and concentrations found in site media. Solubility and viscosity tests using various solvents and at various temperatures were also performed to determine the viability of solvent washing and/or electrical resistivity heating in improving the effectiveness of NAPL recovery wells. The bench-scale oxidation tests indicate a full-scale efficiency of approximately 5 pounds hydrogen peroxide per pound of organic contaminant, depending on the silt content of the impacted soils. The biological treatment tests indicated destruction of up to 89 percent of the organic contaminants within two weeks. Solvent washing with isopropanol indicated a transfer of up to 88 percent of the organic contaminants from the impacted soil to the solvent. No hazardous intermediate or final degradation products were observed to have been formed during any of these tests.

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A Permeable Reactive Barrier (PRB), which can be hydraulically manipulated, was installed at Chalk River Laboratories in December 1998 to prevent strontium contamination of a wetland. This new technology is completely passive, allows flows and effluent concentrations to be measured directly, and uncontaminated groundwater can be diverted away from the PRB to prolong its effectiveness. A 28 m long cut-off wall extends into till or to bedrock through a 12 m thick aquifer. A 120 m³ volume (or curtain) of granular zeolite is positioned in front of the cut-off wall. Ten extraction wells, embedded at the back of the curtain, draw contaminated groundwater through the PRB. By setting the elevation head of the wells, flow rate and width of capture zone are controlled. This facility treats 1.51 x 10⁷ litres per year (7.6 gpm) of contaminated groundwater, while diverting 10⁷ litres per year of clean groundwater, which would otherwise enter the PRB. This facility has maintained pristine conditions in the adjacent wetland by preventing the discharge of 2.7 x 10⁹ Bq of ⁹⁰Sr. Samplings within the PRB, and results of tracer tests have provided evidence that the facility will be effective for 10 to 40 years.

[213] Fernald Post Closure Stewardship Technology Project
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The Fernald Post Closure Stewardship Technology Project (PCSTP) effort is designed to identify, demonstrate, and deploy technologies that will provide DOE, regulators, and stakeholders with the assurance that the site and its facilities are secure and performing as designed. For example, this effort, to the greatest extent possible and practicable, will seek to deploy technologies and integrated systems that have the capability to provide “real-time” monitoring to remote locations autonomously. The remote, real time, autonomous function of the technologies has at least three key benefits: 1) It will show whether the remedy systems are functioning as designed or if they are not, it will notify when a problem may be developing; 2) Real time systems can provide the public, stakeholders, and regulators with up to date access to information on the performance and conditions of the site and its facilities; and 3) It will lower the long-term mortgage costs associated with monitoring the site’s facilities. This presentation will describe the impetus for this project, its mission, the technology needs identified thus far for PCS at Fernald and the Integrating Stewardship Technology Team (ISTT) concept designed to execute the work scope for this project.
In Florida, innovative technologies of the 1990s and today present a key to cleanup of contaminated groundwater sites where previously no technology existed to realistically provide such remediation. The Florida Department of Environmental Protection (DEP) has approved a number of variances for Underground Injection Control (UIC), Class V injection/remediation wells for groundwater cleanup. Variances are necessary to allow an injection that produces one or more temporary exceedences of state secondary drinking water standards. Remediation technologies include the injection of oxidizing/reducing agents, alcohols, microorganisms, and/or nutrients to control DO concentrations and resulting contaminant breakdown. Direct push technology is commonly utilized for inexpensive and rapid site characterization, and for enacting treatment at contaminated drycleaners, using a variety of shallow injection methods. Pilot tests demonstrate success in the cleanup of DNAPL solvents, which prove particularly difficult due to intricate geological characteristics and contaminant solubility limitations. Using advanced technologies, petroleum contaminated sites have demonstrated cleanups that have resulted in site restoration. Several sites demonstrate the unexpected mobilization rather than breakdown of contaminants in groundwater, and also mobilization into the vadose zone, highlighting a need for soil vapor extraction (SVE) or air sparging.

DNAPLs represent a significant threat to the quality of groundwater aquifers throughout the world. DNAPLs are denser than water and are trapped by capillary forces and as pools of liquid suspended on low-permeability strata. The DNAPL pool is usually thin and horizontally widely spread. Vertical wells are proven to be extremely inefficient for collecting the DNAPLs owing to the limited contact area between the well screen and the DNAPL pool. Horizontal wells, however, can provide much better recovery because they can be oriented to have much larger contact areas with the pool. In this paper, we utilize the fact that the pressure of two-liquid flow is balanced across the interface, thus analytically solve the problem for the water–DNAPL interface. The horizontal well is treated as an infinite-conductivity boundary with a finite radius. The solution for the horizontal well source is obtained through the superposition of point source solution. The experimental study provides direct observation of the water-DNAPL interface change with time. The relationship between the interface change with thickness of the DNAPL, the well location, and the well pumping rate is investigated. The experimental study also provides the critical pumping rate at which the cusp of the interface reaches the horizontal wellbore. The experimental study confirms the theoretical results.

Azimuth controlled vertical hydraulic fracturing technology constructed a full-scale in situ iron permeable reactive barrier (PRB) at moderate depth at a Superfund site in southeastern Iowa for remediation of groundwater contaminated with chlorinated solvents. The iron permeable reactive barrier was completed in late 1999 and was two hundred and forty (240) feet in length, three (3) inches in average thickness and constructed down to a total depth of seventy-five (75) feet. The groundwater contamination is primarily trichloroethene (TCE). The permeable barrier was constructed across the contaminated plume, perpendicular to the groundwater flow direction, and is considered a source control reactive barrier with the remnant plume downgradient of the PRB being naturally attenuated. Groundwater monitoring wells were installed prior to the PRB construction both upgradient and downgradient of the proposed PRB alignment. The monitoring wells have been sampled pre- and post-PRB construction for volatile organic compounds (VOCs) and other parameters to assess the performance of the PRB. Twelve (12) months of post-PRB groundwater monitoring data confirm the PRB is abiotically degrading the halogenated volatile organic compounds into harmless daughter products. The groundwater concentrations of VOCs downgradient of the PRB have declined at rates and are at levels close to or below those predicted from the PRB design.

Hydraulic pulse interference tests involve a cyclic injection of fluid into the source well, and by high precision measurement of the pressure pulse in a neighboring well, detailed hydraulic characterization between wells can be made. The pulse interference test is highly sensitive to hydrogeological properties between the wells, and relatively insensitive to conditions outside of the wells. The time delay and attenuation of the hydraulic pulse enable the formation hydraulic properties transmissivity and storativity to be computed. The advantages of the pulse interference test are the short duration of the test, the high...
resolution and directional characterization data obtained, and that no contaminated groundwater is generated. To maximize the pulse test’s resolution, a small section of the injector well is isolated by packers, the flow rate into the source injector well is rate controlled and set at a constant flow rate depending on the site hydraulic conditions. High precision pressure transducers are located in receiver wells and isolated from receiver borehole storage effects by straddle packers. Thus the pulse is basically a point source, and borehole storage effects are eliminated from both the injector and receiver wells. The injector well is pulsed for a set time, shut in for the same time period, and the cycle repeated. The pulse source and receivers can be located at differing depth locations in their respective wells and a detailed image of the site’s hydraulic conditions can be determined. The hydraulic pulse interference test is ideal to test the integrity of a hydraulic containment system or to determine if a permeable reactive barrier (PRB) does not impact groundwater flow. Pulse interference tests conducted pre- and post-PRB installation for integrity testing of an iron PRB constructed down to a depth of 110 feet are presented.

[219]
Quantitative Characterization of an IAS Air Plume using Geophysics
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Previous investigations have shown that changes in bulk soil properties due to air sparging can be detected with geophysical techniques. However, most air plume characterization has been qualitative. The goal of this study was to determine whether geophysical techniques can be used to quantitatively describe the distribution of air in sparge plumes. Three geophysical techniques were evaluated in this study: electrical resistivity tomography, ground penetrating radar, and seismic refraction. The former technique employed measurement electrodes both in boreholes and on the surface, while the latter two techniques incorporated surface-only measurements. Air was injected into an uncontaminated glacial till at a depth of 3.3 meters. Geophysical measurements were collected both before sparging, and during two different sparging episodes where flow rates of 143 m³/day and 244 m³/day were employed. Differences between the pre- and during-sparging images where then used to map the extent of the injected air. The results suggest that these techniques can be used to spatially describe the air plume.

[220]
Cost-Reliability Relationships for Reactive Barriers and Funnel-and-Gate-Systems in Heterogeneous Aquifers
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Several reviews of the field performance of PRBs and F&G-systems pointed out that the desired hydraulic performance could not be achieved in many cases. One of the reasons is that less emphasis was placed on optimizing the hydraulic system design with respect to local hydrology and groundwater flow patterns. Furthermore, uncertainties in aquifer heterogeneity have not been addressed at all or not adequately. Obviously, such a sub-optimal performance of the remediation system also has strong implications for its cost-efficiency. In this paper, a design optimization framework will be presented, that accounts for prediction uncertainties due to aquifer heterogeneity by providing total-cost-estimates of optimized design alternatives in relation to the reliability to achieve the expected capture zone. The framework combines the geostatistical description of aquifer conductivities, groundwater flow modeling, cost-estimation-functions and optimization strategies. Results of a modeling study show that the cost-reliability relationships are strongly influenced by the degree of aquifer heterogeneity as well as by the type of containment/barrier-system (e.g., number of gates, ratio of total funnel length to gate length).

[221]
Successful Remediation of Solvent-Contaminated Groundwater Using a Funnel & Gate Constructed by Slurry Trench Methods
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One of the more difficult problems facing our cities is the reuse of former manufacturing facilities. In Seattle, WA, a former manufacturing site was contaminated with chlorinated solvents. Previous attempts to cleanup the site using pump and treat systems failed because the soils were heterogeneous, making it difficult to control the contamination. The owner and his consulting engineer decided that the technology with the highest probability of success for the site was a funnel and gate system using zero-valent iron to treat the groundwater. In 1999, reactive iron treatment was generally well accepted, but construction methods for its installation in deep trenches were still developing. As a result the owner, the engineer, and a slurry trench engineer developed and implemented an innovative plan to install a funnel and gate system up to 35 ft deep, using cement-bentonite (CB) slurry walls for the funnels and bio-polymer degradable slurry to install the iron-filled gates. One year after installation measured chlorinated solvent destruction efficiencies are greater than 95%. Downgradient from the gates, natural attenuation processes, including intrinsic biodegradation, are further reducing solvent concentrations to below surface water cleanup standards before reaching a public waterway less than 200 ft from the site.
The growing use of self-hardening slurries in barrier forms, such as in permeation and jet grouting, deep soil mixing, vibrated beam and slurry trenches, is largely due to the recognition of the materials capability of providing a low hydraulic conductivity under adverse environments. Recent testing of a self-hardening slurry using attapulgite clay and blast furnace slag cement, as used for barrier construction, has highlighted some of the unique characteristics of this material. Depending on the age and amount of solids present in a given self-hardening slurry mix, measured hydraulic conductivities better than 1x10^-9 cm/sec are typically achievable. At these low hydraulic conductivities, applied gradients of approximately thirty, the recommended maximum hydraulic gradient in ASTM Method D 5084, are typically used for testing. Testing at lower gradients, as typically found in situ, has indicated that a threshold gradient, below which no appreciable flow occurs, may exist for these materials. Other testing has indicated that the use of permeants of either high or low pH may provide a significant decrease in the hydraulic conductivity compared to that measured with water as permeant. The unique behavior of this construction materials may provide benefits if its particularities are exploited wisely.

Deterministic design procedures, while adequate for feasibility evaluation design, are not sufficient for final design of iron permeable reactive barriers (PRBs). A probabilistic design methodology is outlined, which incorporates not only probabilistic inputs for site characterization data, but also parent and daughter VOC degradation parameters. A multi-specie first order volatile organic compound (VOC) degradation model coupled with a probabilistic model is used for design of a zero-valent iron reactive barrier (PRB). This PRB is for remediation of groundwater contaminated with high levels of VOCs (5,500 ppb Tetrachloroethylene (PCE), 45,000 ppb of Trichloroethylene (TCE), 5,000 ppb of 1,1-Dichloroethylene (1,1-DCE), and other VOCs at lower concentrations). The PRB probabilistic design model allows for variability of site formation hydraulic conductivity, groundwater flow gradients, VOCs concentration levels and degradation half-lives from iron column test data, iron column generation of VOCs daughter products, PRB installation thickness and iron porosity. The PRB probabilistic model 85-percentile VOC effluent concentration levels are used to determine the minimum iron PRB average-effective thickness required to bring VOC concentrations to below MCLs. Input data sensitivity analysis is performed to quantify the impact of parameters variability on overall system performance.

Ozone sparging and recirculation is a new technology being applied to remediate organic constituents in groundwater. The process, developed by KV Associates, Inc. (KVA), combines in situ oxidation with in-well recirculation of groundwater to create a powerful mechanism for remediation of a wide range of organic constituents. The KVA C–Sparger™ system sparges ozone at two separate depth intervals, and the in-well groundwater pump distributes the oxidant and creates mixing zones within the aquifer. The design approach for two ongoing site remediations using KVA’s C-Sparger™ process will be presented for comparison. Initial field performance results will also be presented (field operations commencing in January and February 2001). The two sites vary in both their technical aspects (hydrogeology, constituent distribution) and their remedial performance goals, resulting in different design approaches for each system. The design flexibility afforded by the KVA process allowed designers to match the in situ processes to site-specific conditions. A comparative analysis of KVA’s technology to other remedial options was conducted for each site, including lifetime remedial cost estimates.
measuring radioactivity of soil, adsorbents and plant biomass. In the presence of ion exchangers and EDTA that strongly bind metal ions, plants accumulated less radioactivity than in the adsorbent-free soil. However, it was found that, against our original expectations, addition of certain adsorbents (activated carbon and natural minerals) to the soil accelerated and increased 2-4-fold the amount of radioactivity accumulated in corn, rape, sunflower, lupin and potatoes. Although not fully understood, this synergetic effect could be used for cost-effective decontamination of soil from radionuclides.

[226]
Construction of a Soil-Bentonite Cutoff Wall for Containment of Wood Treatment Products

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A superfund site required a leachate control system to isolate contaminated groundwater within the contamination area from migrating to adjacent properties. The site has been historically and currently used for wood treatment operations and lumber product manufacturing. The primary operation conducted on the site is the treatment of wood products such as railroad ties, telephone poles, guard rail posts, and manufacturing of plywood veneer. The site was placed on the National Priority List (NPL) in 1984 as a result of an investigation by the North Coast Regional Water Quality Control Board (NCRWQCB). A Remedial Investigation (RI) for the site was completed by the Untied States Environmental Protection Agency (EPA). The selected remedy included construction of a soil-bentonite cutoff wall. This paper describes the design, construction and performance of the soil-bentonite cutoff wall, which was used to isolate contaminated groundwater and soil. The cutoff wall was constructed during the period May 1999 to August 1999. Challenges to the cutoff wall construction included underground and overhead utilities, and interference with the operation of active plants. A large excavator capable of excavating to a maximum depth of 62 ft. was used to construct the cutoff wall that met a maximum permeability of $5 \times 10^{-7}$ cm/sec.

[228]
The Use of Column Experiments to Predict Performance and Long-Term Stability of Iron Treatment Walls

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Column tests are carried out to estimate reduction rates of chlorinated hydrocarbons and to predict the long-term performance of a reactive barrier, using the contaminated groundwater from a site. The results of the preliminary investigation are used to design an appropriate flowthrough thickness for a Fe₀ reactive cell. However, validating the prognoses derived from the experiments is still outstanding and so the force of expression of column tests attempts questionable. The possibilities, which are given for the examination to the prognoses by standard field investigation, can be illustrated by the example of a field application (Rheine, Germany). The comparison of field and laboratory results shows that the general change in groundwater composition within the barrier as well as downgradient can be well derived from the column experiments. The influence of microbes is only predictable by using geochemical models (i.e., PHRREQC), because of the lag time of microbial activity. Difficulties of the data comparison are due to a ambiguous hydraulic situation and a time variable water composition at the site. Therefore it can be only shown that the remediation efficiency at the field is in the same order of magnitude as the expected performance, but a direct comparison of the reduction rates is impossible. For the same reasons, it can’t be distinguished whether the loss of reactivity observed in the laboratory experiments becomes not or only not yet effective in the field.
Performance monitoring of the F.E. Warren Air Force Base, Wyoming Spill Site 7 iron-filings permeable reactive barrier (PRB) was designed to confirm that the PRB is achieving its design and remedial action objectives. A performance-monitoring program was then implemented to determine whether the PRB is: (1) reducing groundwater concentrations of contaminants of concern to below treatment goals; (2) reducing contaminant loading to adjacent waterways; (3) Impacting adjacent waterways with byproducts of the remediation process (e.g., pH, iron, chloride); and (4) affecting groundwater flow paths. All May and July 2000 contaminant concentrations from performance-monitoring well (PMW) samples in the iron and one to three feet downgradient of the iron reported volatile organic compound (VOC) concentrations below detection limits and treatment goals. Elevated VOC concentrations detected below the PRB will continue to be monitored to determine if there is bypass beneath the PRB. TCE concentrations in adjacent waterways are below treatment goals. Water quality parameters reported high pH, low Eh, and low dissolved oxygen concentrations in and downgradient of the PRB. Water-level measurements from May and July 2000 revealed a relatively flat and uniform hydraulic gradient across the PRB, indicating that the PRB is at least as permeable as the surrounding formation and, therefore, has not disrupted natural groundwater flow. The May and July 2000 monitoring results indicate that the SS7 PRB is operating as designed and reducing contaminant concentrations to treatment goals. This paper will summarize the results of the first year (three quarterly sampling events) of performance monitoring.

This paper describes the quality control and performance of a soil-bentonite cutoff wall at the Taylor Lumber Superfund Site in Sheridan, Oregon. The cutoff wall was constructed under an EPA Emergency and Rapid Response prime contract. The site is used for the wood treatment of telephone poles, pilings, and railroad ties. The cutoff wall was constructed to contain a dense nonaqueous phase liquid (DNAPL) plume, which threatened to contaminate the nearby Yahmill River. The cutoff wall with a length of 2030 ft. and a maximum depth of 26 ft. completely surrounds the wood treatment facility. The wood treatment facility remained active, and care was taken to limit the impacts of construction on the facility’s operations. Difficulties included achieving a maximum permeability of 1x10⁻⁷ cm/sec with materials containing minimal fines, excavating around utilities including live gas and sewer lines, and meeting the fast tracked mobilization and construction schedule. The project included construction of a cap over the cutoff wall, which consisted of geosynthetic clay liner (GCL), geotextile, and aggregate base. This project represents the first full closure slurry cutoff wall constructed for EPA Region 10.

Three-dimensional (3D) acoustic imaging is a highly developed technology that has produced a detailed image of the subsurface, at over 30 hazardous waste sites. 3D imaging has been used to provide the density of data necessary to analyze the pathways for fluid transport, whether in free phase or as a dissolved plume. This information has then been used to optimally locate control or monitor points. Evaluation of chemical sampling while drilling has been combined with the seismic data to address whether the plume can be contained or remediated. In 1994 the first 3D seismic survey over a hazardous waste site was performed at Naval Air Station North Island in California. The 3D seismic information, followed by confirmatory drilling, significantly changed the site conceptual model. The seismic image saved time and costs for characterization and remediation. A seismic survey at a NASA site and confirmatory drilling showed that free product was not present and that natural attenuation could be used. At Edwards AFB in California, there was concern that contaminants could migrate off base. The seismic image demonstrated that this was unlikely. The technology can be used to help determine if groundwater problems exist and for more rapid remediation when required.

Monitoring of contaminants at environmental sites throughout the United States will be required for decades after initial characterization and remediation phases have been completed. The costs for long-term monitoring may, in many cases, exceed the cost of remediation. Automating the monitoring process significantly reduces the cost of long-term monitoring by eliminating manual procedures required by current protocols. Burge Environmental designs and fabricates innovative automated ground-water sampling/analysis systems. One system incorporates a trichloroethene (TCE) specific sensor (optrode) in a multi-level sampling system. This in situ system is capable of analyzing 2 ppb TCE in groundwater from four separate sampling
Lomotive and wheel maintenance activities resulted in the release of chlorinated solvents to soil and groundwater. An interim remedial action was performed, including the removal of 6,700 gallons of liquid and sludge from the maintenance pits, and the excavation of 6,000 tons of impacted soil. Twenty-five monitoring wells were sampled in the shallow water-bearing unit and analyzed for volatile organic compounds (VOCs). The primary chlorinated hydrocarbons detected were perchloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride (VC). Total chlorinated VOC concentrations ranged from <1 microgram per liter (μg/L) to 64 μg/L and the maximum concentration of vinyl chloride (64 μg/L) indicated natural attenuation was occurring. A total of six wells in the upgradient, downgradient, lateral and source-area locations were also analyzed for natural attenuation parameters (general chemistry and hydrocarbon gases). The results indicate that PCE, TCE, cis-1,2-DCE and VC are naturally attenuating and VC is degrading to ethane and ethene under reducing conditions. Anaerobic conditions for reductive dechlorination are evident in the affected area through denitrification, methanogenesis, sulfanogenesis and ferric iron reduction. Natural attenuation is further being enhanced by relatively high alkalinity and a suitable pH range. Subsequent monitoring has been reduced to the six wells and monitoring results confirm that natural attenuation is continuing.

A new characterization technology in the vadose zone has been applied across the United States to accelerate cleanup, reduce long-term operational costs, and support closure of SVE systems. The technology, known as PneuLog®, utilizes in-well instrumentation to continuously measure air permeability and contaminant concentrations on the scale of centimeters along well screens during vapor extraction in the vadose zone. Preferential flow paths produced by soil heterogeneities are clearly observed allowing the quantification of mass transfer coefficients. Correlating PneuLog data from a representative number of wells and utilizing historical SVE data allow three-dimensional estimates for contaminant and permeability distributions and mass transfer between adjacent soil layers. This detailed data set yields a more realistic conceptual site model than conventional characterization data. The result is optimized implementation of SVE by focusing remediation on source areas and accurately forecasting performance. The improved conceptual site model also generates more realistic transport modeling for setting risk-based clean up goals. For instance, the technique easily identifies low permeability materials with high moisture contents often missed in geologic logs. Such intervals pose a tremendous barrier to vaporous diffusion and are rarely included in conventional modeling despite their dominant impact on transport. Case studies are provided.

A theoretical framework for evaluating rebound data collected after soil vapor extraction (SVE) is presented along with case studies of implementation. Rebound testing is commonly performed to assess residual contamination in the vadose zone. The underlying premise is that soils are inherently inhomogeneous and can be divided into two categories: mobile (advection-dominated) and immobile (diffusion-dominated). During SVE, vapors flow only in the mobile soils intersected by extraction wells and contaminant removal is from these soils. This extraction creates a disequilibrium, or gradient, in the concentration between the mobile and immobile soils. Contaminants residing in the less permeable soils are removed only after transport into more permeable soils where vapors are flowing. A rebound test is initiated when extraction is ceased and mobile and immobile soils are allowed to re-equilibrate. Currently, field practitioners hope rebound concentrations are indicative of residual contamination; however, little guidance is available relating mobile and immobile concentrations or the timescales for re-equilibration. In this presentation, straightforward mathematical expressions are derived describing SVE and rebound in two-region soils. The expressions are applied to data from two sites yielding estimates for the mass of residual contamination, the field-scale mass transfer coefficients, and forecasts for results of additional SVE.

A new characterization technology in the vadose zone has been applied across the United States to accelerate cleanup, reduce long-term operational costs, and support closure of SVE systems. The technology, known as PneuLog®, utilizes in-well instrumentation to continuously measure air permeability and contaminant concentrations on the scale of centimeters along well screens during vapor extraction in the vadose zone. Preferential flow paths produced by soil heterogeneities are clearly observed allowing the quantification of mass transfer coefficients. Correlating PneuLog data from a representative number of wells and utilizing historical SVE data allow three-dimensional estimates for contaminant and permeability distributions and mass transfer between adjacent soil layers. This detailed data set yields a more realistic conceptual site model than conventional characterization data. The result is optimized implementation of SVE by focusing remediation on source areas and accurately forecasting performance. The improved conceptual site model also generates more realistic transport modeling for setting risk-based clean up goals. For instance, the technique easily identifies low permeability materials with high moisture contents often missed in geologic logs. Such intervals pose a tremendous barrier to vaporous diffusion and are rarely included in conventional modeling despite their dominant impact on transport. Case studies are provided.
Optimization of Groundwater LTM Programs
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Each year DoD spends millions of dollars on groundwater Long-term Monitoring (LTM) programs. Sampling and analytical costs alone can exceed one million dollars per year at some sites. Many LTM programs currently in place at federal facilities have been developed based on EPA regional guidance for data collection strategies typically designed for Superfund Remedial Investigations/Feasibility Study (RI/FS) decision-making requirements. These are not necessarily appropriate for “end-of-the pipeline” programs. Opportunities do exist to improve the LTM process and dramatically reduce the costs. For new programs: a systematic planning process should first be developed to define the site-specific project goals and data quality objectives. Part of this process would include the use of computer programs to optimize monitoring well networks and thus reduce the number of monitoring points. The systematic planning process would also include optimization criteria for modifying the analyte list based on periodic trend analysis. Other ways to eliminate or reduce unnecessary costs include non-purge groundwater sampling, the use of dedicated sample collection pumps, elimination of excessive/unnecessary QC, and a reduction in the monitoring time period. For existing programs: It is important that periodic LTM assessments be conducted to allow for course corrections. The application of a systematic planning process will result in a “graded approach” where the scope and of the data collection effort is matched to the end uses of the data for that particular LTM program.

Use of Blast Fracturing and In Situ Treatment Agents for Passive Treatment of a Chlorinated Solvent
Plume in Bedrock
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Groundwater beneath the Princeton Plasma Physics Laboratory (PPPL) site Area C is contaminated with chlorinated volatile organic chemicals (CVOCs). The primary chemicals of concern are PCE, TCE, TCA and their natural breakdown products. Groundwater beneath the site occurs in a weathered and fractured bedrock aquifer in the Triassic-aged Stockton Formation. Vertical CVOC distribution is generally limited to the shallowest 30 feet of the bedrock aquifer near a former source location at Area C. Contaminated groundwater is captured by PPPL’s Area C building foundation drain system and is not flowing off-site. PPPL proposed, and had accepted by the NJDEP, a “natural remediation” remedy that will require site-wide groundwater monitoring for an extended period of time. Successful clean ups have been implemented using “Permeable Reactive Barriers” (PRBs) in unconsolidated aquifers, however very little field experience exists for applying PRBs to fractured bedrock aquifers. PPPL sought and has identified a proposed method of effectively treating low-level chlorinated VOCs in this fractured bedrock aquifer. The system is intended to create significant baseline cost savings by reducing the area of the site requiring groundwater monitoring (thus reducing the number of wells to be sampled) and by significantly reducing the duration of monitoring. The project involves design and deployment of a bedrock blast-fractured trench in two parallel alignments, and installation of in situ treatment in each alignment. This program provides the opportunity to combine a set of three previously developed, but never combined, innovative remediation methods – bedrock blast fracturing to refractively channel flow of groundwater, reactive iron (abiotic) treatment, and a hydrogen slow-release agent (enhanced bioremediation). Blast fracturing involves design and placement of an engineered alignment of relatively high permeability blast-fractured bedrock. The blast fractured trench is intended to passively (i.e., without pumping) collect contaminated groundwater flow across a significant portion of the plume; refract the collected flow into the blast fractured zone and through the installed treatment zones, reducing or destroying the contaminant concentrations; and then disperse the treated water back into the native bedrock formation. The reactive iron and hydrogen release agents will be installed separately in the two parallel blast-fractured alignments to separately evaluate their effects on hydraulics in the blast-fractured zones, treatment results, and geochemical characteristics. PPPL desires to use the relatively limited, shallow plume at Area C to characterize the hydraulics resulting from application of the blast-fractured refractive flow system, results of each treatment separately, and reduce monitoring requirements. Factors in scaling the application to other sites will also be determined. Resulting data can be used for design and application to other, more significant bedrock plumes near PPPL Area C and other DOE facilities with bedrock contaminant plume issues.
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**Paper Clay Utilization in Engineering Applications**  
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The application of biosolids on land is probably the largest beneficial use, but is relegated to the utilization of municipal wastewater sludge due to its composition consisting of nutrient-rich organic material. Paper mill biosolids (Paper clay) have a different composition and therefore require a different application to benefit from its reuse. The use of paper clay as a construction material is a relatively new innovative application, and this paper looks at the various applications where paper clay can be used, and also at the physical behavior of this material. Generally high water contents, high organic contents, high compressibility’s and low shear strengths characterize paper clay. Exploitation of these characteristics will determine what uses this material can be applied to. Various researchers have shown that paper clay can be utilized as a landfill-capping barrier primarily due to its ability to achieve low hydraulic conductivities, and several nations around the world are currently investigating this proposed use. Due to the high organic content of this material, its ability to adsorb various contaminants such as heavy metals warrant investigation of its use in geo-environmentally related containment systems. A combination of this material with other materials to enhance various properties is also investigated.

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**Fenton-Based Remediation of a Chlorinated Solvent Groundwater Plume using Segmented Injection Wells - a Field Study**  
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A Fenton-based chemical oxidation pilot test was performed at a former dry cleaning facility in South Florida to evaluate the possible full-scale use of this remedial approach for a volatile organic halocarbon (VOH) groundwater plume at the site. Principal contaminants consist of tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (Cis-DCE), trans-1,2-dichloroethene (Trans-DCE), and vinyl chloride (VC). A total of six injection wells (IW) were installed in the apparent source area, where prior assessment work had detected Total VOH concentrations of up to 100,111 ug/L. Injection wells were spaced no more than 15 feet from one another to achieve overlapping radial influences. Each 4-inch-diameter PVC IW is screened from 6 to 30 feet below land surface (BLS), with 2 foot-thick bentonite seals constructed in the annular space to create separate screened “intervals” at 6 to 12 feet BLS, 14 to 20 feet BLS, and 22 to 30 feet BLS. The “segmented” IW allows the use of a specially designed injector, equipped with K-packers that coincide exactly with the bentonite seals, to direct chemical oxidant to a specific depth interval. Two injection events, separated by six weeks, reduced Total VOH concentrations by 63 percent. PCE and TCE concentrations were reduced by 95 percent and 97 percent, respectively.

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**Uranium Mill Tailings Covers: Evaluating Long-Term Performance**  
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The Department of Energy (DOE) applies three tools to project the long-term performance of engineered covers for uranium mill tailings: monitoring, modeling, and natural analog studies. Field demonstrations and monitoring using lysimetry and soil water sensors, although expensive, provide direct measures of performance and are used to test the credibility of models. Numerical models engender an understanding of the complexity of environmental processes acting on engineered covers and can be used to link performance with risk. Natural analog studies help to identify and evaluate likely changes in cover environments that cannot be captured using relatively short-term monitoring and modeling. Natural analog studies have been particularly useful for understanding possible long-term effects of climate change, ecological change, and pedogenesis on the performance of engineered covers. Analogs of local responses to climate change exist as proxy ecological and archaeological records of similar paleoclimates. Influences of ecological change are inferred from the ecophysiology of plant communities representing successional chronosequences. Pedogenic effects are inferred from the physical and hydraulic properties of soil profiles considered to represent future states of engineered covers. This paper presents examples of performance monitoring and natural analog studies conducted in support of the long-term stewardship of uranium mill tailings sites.
Solidification/stabilization of soil reduces the mobility of hazardous substances and contain the pollutants in the environment. Unlike other remedial technologies, soil stabilization seeks to trap or immobilize contaminants within their host soil medium, instead of removing them through chemical or physical treatment. A relatively new technique electro-kinetic grouting may be applied to solidify soil, reduce its permeability and thereby contain the pollutant within a specified area. The study deals with the injection of a most common chemical grout, sodium silicate, into soil by electro-kinetic method. When a d.c. current is applied across a sandy soil mass, and sodium silicate is kept in cathode compartment and reactants like calcium chloride in anode compartment, it is expected that anionic silicate will migrate towards anode due to electro-migration (movement of charged particles towards opposite charged electrodes) and cationic metal ions will migrate toward cathode. When these charged ions meet, the pH of the sodium silicate is reduced and it forms gel within the soil and grout/solidify the soil. In silty soil, where electro-osmosis (pore water flow from anode to cathode) occurs due to application of d.c. electric field, it is expected that water-soluble sodium silicate grout is carried away by electro-osmotic flow from anode towards cathode. When the pH of this grout is reduced by the $H^+$, generated and migrated (electro-migration) from anode, the sodium silicate grout will form gel and stabilize the silty soil. These basic concepts are used in the study to stabilize and solidify sandy and silty soils. Laboratory 1-D column tests experiments show success. Sandy soil and silty soil show sings of solidification, increase of strength. From cost estimate, this new method of grouting seems to be cost effective than other conventional grouting method for waste contamination and mitigation in silty soil.
Shale as a Sorbent Additive to Increase Containment
Barrier Efficiency

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A variety of sorbents have been suggested for use as additives to soil containment barriers to reduce transport of organic chemicals from hazardous waste sites to the outside environment. This study investigated sorption capacities and mechanisms for a natural shale rock and four synthetic organoclays, along with the effects of addition of these sorbents on soil-bentonite containment barrier diffusive transport and hydraulic conductivity. Transport model simulations combined these factors to generate estimates of contaminant breakthrough. Shale exhibited substantial sorption capacity for a variety of organic contaminants, and proved to be an exceptionally cost-effective sorbent. In addition, the shale and a short-chain organoclay had no adverse impacts on soil-bentonite barrier hydraulic conductivity. In contrast, addition of 5% (w/w) hydrophobic long-chain organoclay sorbents increased hydraulic conductivity by up to an order of magnitude. Sorbent addition had little effect on barrier tortuosity, and diffusion coefficients were not significantly affected. Overall, shale was shown to have tremendous promise as a sorbent additive as a result of its high sorption capacity, lack of adverse effects on soil-bentonite barrier hydraulic conductivity or diffusive transport, inherent long-term viability, and availability in many areas at minimal cost. Shale would also likely be ideal for flow-through reactive barrier applications.

In Situ Soil Stabilization of a Former MGP Site using Shallow Soil Mixing (SSM)

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Cambridge Research Park, Massachusetts consists of a ten acre property that was the location of a former Manufactured Gas Plant (MGP) where past operations resulted in the release of hazardous chemicals to the soil and groundwater. The hazardous chemicals that are present in the soil and groundwater exceed the Upper Concentration Limit (UCL) established by the Massachusetts Contingency Plan (310 CMR 40.0996) in a 2.82 acre area of the property. Shallow Soil Mixing (SSM) was selected as the method for performing the in situ soil stabilization of approximately 103,500 cubic yards of non-aqueous phase liquid (NAPL) impacted soils. To successfully remediate the soil, demolition of subsurface structures and obstructions was completed prior to performing the stabilization. The stabilization was performed using a 10 foot diameter auger. During the stabilization process, a mixture of reagents that included cement, bentonite, and water, were injected into the soil to stabilize the mixture and immobilize the NAPL. The soil mixing equipment was equipped with a vapor collection system that extracted vapors and dust generated during mixing operations and treated using granular activated carbon. Samples of the stabilized soils were collected and analyzed for NAPL saturation, residual NAPL saturation, TCLP volatiles and semivolatiles, and hydraulic conductivity.
The Permeable Reactive Barrier (PRB) is a new form of technology involving the emplacement of zero valent iron for purpose of the in situ treatment of contaminated groundwater by intercepting contaminant plumes and transforming them into environmentally acceptable forms. The PRB can be used to treat several forms of contamination such as chlorinated solvents, dissolved metals, and petroleum hydrocarbons. This project involved the installation of a PRB using the Biopolymer Slurry Trench method at the Somersworth Landfill in Somersworth, NH. This method allows the construction of deep and narrow trenches supported only by an engineered fluid or slurry. The biopolymer slurry is used to temporarily support the trench walls while the iron/sand backfill is placed in the trench. Prior to the addition of the backfill, the material is thoroughly saturated with water to completely fill the voids within the mixture, minimizing the segregation of iron and sand during placement. Placement of the iron/sand backfill is performed using a process similar to the tremie method. This particular PRB was divided into eight separate sections, ranging between 100’ to 175’ in length. Each section was installed using different proportions of iron/sand backfill to accommodate the varying concentrations of contaminants within the groundwater.
This paper describes the construction and subsequent quality assurance testing of a 915 foot long zero valent iron (ZVI) permeable reactive barrier (PRB) at the Somersworth, NH Sanitary Landfill Superfund Site. The PRB was installed along the downgradient perimeter of the landfill to degrade chlorinated organic compounds in overburden groundwater as part of the Preferred Remedial Action Plan for the Site. The application of a ZVI PRB at this Site is unique because: (1) the PRB was installed immediately downgradient of a landfill; (2) the PRB extends over 40 feet into highly permeable sand with cobbles; and (3) the installation was conducted using an open trench supported by bio-polymer slurry. The PRB was installed in 30 to 50 foot long sections separated by metal I-beams, which allowed individual sections to be excavated and backfilled without impacting activities in adjacent sections. The placement of the ZVI was complicated by: (1) the large quantity of ZVI used (over 3,500 tons); (2) the use of different ZVI/sand mixtures along the length of the PRB; and (3) the installation was conducted using an open trench supported by bio-polymer slurry. The PRB was installed in 30 to 50 foot long sections separated by metal I-beams, which allowed individual sections to be excavated and backfilled without impacting activities in adjacent sections. The placement of the ZVI was complicated by: (1) the large quantity of ZVI used (over 3,500 tons); (2) the use of different ZVI/sand mixtures along the length of the PRB; and (3) the placement of ZVI/sand mixtures through bio-polymer slurry. Following construction, the PRB was sampled using a modified Shelby tube method to verify lateral and vertical consistency of the ZVI throughout the PRB.

Successful Strategies for Integration of In Situ Oxidation with Existing Technologies to Support Site Closure
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Closure of sites where groundwater is contaminated by chlorinated solvents often requires achievement of very low concentrations (low parts per billion). Lacking cost-effective technologies, site closures are often projected in terms of decades while pump and treat and/or hydraulic containment technologies are employed. IT Corporation developed PermOX-IT™ as a cost-effective technology for performing in situ oxidation of contaminants in groundwater. To date, IT has worked with regulatory authorities to perform pilot tests of PermOX-IT™ at over 40 sites and full-scale applications at 8 sites. In a diversity of hydrogeologic settings and with starting concentrations for chlorinated ethenes ranging from separate phase to low parts per million, PermOX-IT™ has shown that it can be a cost-effective strategy as a stand-alone technique or integrated with other site activities to achieve closure in significantly reduced timeframes. This paper presents case histories for six different sites to illustrate differing closure strategies and regulatory approval processes. Specifically, IT’s PermOX-IT™ technology has been used as follows: to replace more costly and/or less effective technologies identified in a Superfund Record of Decision; to achieve source removal; to treat entire plumes; and to achieve more stringent cleanup standards than required by regulation to enhance property values and/or reduce liability.

Case Studies in Enhanced Reductive Dechlorination
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Case histories are presented from three sites of chlorinated solvent contamination. At each site, carbon injections induced sulfate reduction and limited methanogenesis. At Site 1, a sandy aquifer formation was contaminated by perchloroethene (PCE) at 316 ug/L and trichloroethene (TCE) at 768 ug/L. During the first 6 months of carbon injection PCE and TCE concentrations declined, while cis-1,2-dichloroethene concentrations began to increase. Cis-1,2-DCE peaked at 2,700 ug/L after 9 months of injection, then was reduced 37 ug/L after 12 months. Less than 0.4 percent of the cis-1,2-DCE was converted to vinyl chloride (9 ug/L). Case histories for Site 2 (fractured bedrock) and Site 3 (permeable sand aquifer) show comparable results.
DOE, DOD, USEPA and NASA, formed the Interagency DNAPL Consortium to jointly fund a large scale field demonstration of three chlorinated solvent remediation technologies, at NASA’s Launch Complex 34, located at Cape Canaveral, Florida. In situ chemical oxidation using potassium permanganate was chosen as one of the demonstration projects and was successfully completed in May 2000. The site geology consists of several stratigraphic units containing layered, heterogeneous lithology with permeability contrasts of two orders of magnitude. TCE was present before treatment at up to 30,000 mg/kg in soil, and 1,500 mg/L in groundwater. Approximately 6,100 kg of TCE (including 5,039 kg of DNAPL) was estimated by Battelle and EPA to lie within the 50 foot by 75 foot by 45 foot deep demonstration plot. The permanganate injection strategy consisted of direct push pressure injection (lance permeation). Over 150,000 pounds of permanganate were injected at two-foot discrete intervals at numerous locations across the cell in a three-phase injection program. The total reduction in TCE mass was calculated through collection and analysis of over 192 discrete soil samples. The results show that the overall mass of TCE within the cell was reduced by 82% and that 84% of the DNAPL was eliminated.

In situ chemical oxidation of HE using KMnO4 was tested for the treatment of HE compounds, including hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), 1,3,5,7-tetranitro-1,3,5,7-tetrazacyclococtane (HMX), and 2,4,6-trinitrotoluene (TNT), and HE degradation byproducts including 2-amino-4,6-dinitrotoluene and 4-amino-2,6-dinitrotoluene (DNT). This testing was performed as part of an ongoing evaluation of alternatives for remediation of HE contaminated groundwater at the USDOE Pantex Plant in Amarillo, Texas. Oxidation laboratory testing showed that KMnO4 effectively oxidizes RDX, TNT, DNT, HMX, and other HE compounds. HE degradation by-products for treatment using KMnO4 were also evaluated, and preliminary results indicate these by-products were transient, and not persistent in the presence of KMnO4. In situ chemical oxidation of HE using KMnO4 was also evaluated in a field scale test consisting of a series of single-well push-pull tests. The reaction kinetics and stoichiometries determined from the lab and field tests were used as input to a 2-D numerical simulation of HE and KMnO4 reactions and transport during large-scale treatment.
[268] Performance Monitoring of Permeable Reactive Barriers: Hydrologic and Geochemical Assessment
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Permeable reactive barriers are finding widespread use as a cost-effective and minimally intrusive method for remediating a growing range of hazardous and radioactive contaminants. Monitoring the performance of these barriers over time and understanding the processes that impact barrier integrity are critical to addressing issues such as barrier design, predictive modeling, and regulatory compliance. An extensive hydrologic and geochemical dataset has been obtained from a fieldsite in Monticello, Utah, where a zero-valent iron barrier is being used to treat uranium-contaminated groundwater. Barrier performance was evaluated using piezometric measurements, slug tests, borehole flowmeter tests, tracer tests, water quality analyses, and modeling. These data sets provided the basis for evaluating (1) the impact of aquifer and barrier heterogeneity on transport through the barrier, (2) the relative effectiveness of various monitoring techniques, and (3) the effectiveness of barrier design support models and underlying assumptions for predicting and monitoring long-term barrier performance. *Managed for the U.S. Department of Energy under contract number DE-AC05-00OR22725 with University of Tennessee-Battelle LLC.

[269] Rapid Characterization and Removal of Hazardous Gas Cylinders
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A combination of INEEL developed field instrumentation was used to characterize a CERCLA site containing buried gas cylinders suspected of containing anhydrous hydrofluoric acid (HF). Remedial action was accelerated due to increased risk posed by wildfires, and the site’s proximity to a facility with more than 1,000 occupants. The fast, accurate characterization obtained using the rapid geophysical surveyor (RGS) and portable ionization neutron spectrometer (PINS) made possible a safe, successful, cost-effective and quick remediation of this acutely hazardous site. The RGS is a high-resolution wheeled magnetometer that collects and stores closely spaced magnetic field data. Data stored on the RGS was downloaded to produce maps indicating the spatial distribution and extent of the buried gas cylinders. The PINS assesses the chemical contents of an enclosed cylinder using gamma radiation and a spectrometer. The relative ratio of the elements clearly identifies the specific chemical compounds in the cylinder. The PINS instrumentation confirmed the presence of HF. Once located, the cylinders were hand-excavated, ultrasonically examined and remotely handled. The valves were tested using a manifold system purged with argon gas. Cylinders were then depressurized, sampled for HF, removed and readied for safe disposal at an approved treatment facility.

[270] Demonstration of Non-Traditional (Sub-Surface) In Situ Vitrification Technology at Los Alamos National Laboratory
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MSE Technology Applications, Inc., (MSE) in conjunction with DOE’s Subsurface Contaminants Focus Area (SCFA), is conducting an evaluation of non-traditional in situ vitrification (NTISV) technology as a potential remedy for treatment of the mixed-waste-contaminated absorption beds at the Los Alamos National Laboratory (LANL), Technical Area 21(TA-21), Material Disposal Area-V (MDA-V) site. A cold demonstration of the technology was conducted in an uncontaminated simulated absorption bed at the LANL site in April 1999. A hot (radioactive) site melt was completed in April 2000 within the MDA-V Absorption Bed 1 at LANL TA-21. The absorption bed and the underlying volcanic tuff contain various radionuclide, inorganic and organic contaminants. The NTISV project successfully demonstrated the planar subsurface GeoMelt process for treatment of subsurface contamination zones. New treatment depth records were achieved, and the potential for attainment of even greater depths was clearly shown. Several geophysical tomography techniques were evaluated for providing images of the completed subsurface melts. The imaging results from seismic tomography showed good agreement with physical measurements on the extent of subsurface treatment achieved. The demonstrations showed the advantages of subsurface melting over conventional top-down ISV melting including improved processing efficiency, decreased exposure potential for workers, and reduction in amount of secondary wastes produced. The vitrified product produced in the cold demonstration was determined to be homogeneous and extremely resistant to leaching. These results provide confidence that the vitrified product resulting from the hot demonstration will have similar characteristics.
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[271]

**Expedited site Assessment at a Large Naval Fuel Terminal**

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Craney Island Naval Depot, Portsmouth, Virginia is a large fuel terminal with the mission to supply fuel to the Navy’s Atlantic Fleet. Implementing expedited site assessment procedures at this site saved money, compressed reaction time, and impacted contaminant migration. The terminal offered excellent conditions for implementing expedited site assessment procedures - established site model and understood contaminant conditions. Expedited site assessment procedures afforded quick, concentrated action - release discovery to interim solution in less than 1 year. In May 2000, a petroleum release was identified in a stormwater outfall near a fuel farm. A site characterization using the Navy’s Site Characterization Analysis and Penetrometer System (SCAPS) was performed in May 2000. Data interpretation provided the vertical extent of contamination, identification of the optimum intervals for sampling, and the placement of monitoring and recovery wells, including their respective screen intervals. Field decisions allowed contaminant trends to decide push locations. A non-aqueous free petroleum product plume covering 3.5 acres and up to 8 feet thick was detailed. The tank was drained and taken out of service in May 2000; demolished in November 2000; stop gap interim action taken in January 2001; and corrective action plan submitted in February 2001.

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**Groundwater Central Demonstration:**  
**Groundwater Remediation Technologies Analysis Center (GWRTAC)**

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The Ground-Water Remediation Technologies Analysis Center (GWRTAC), operated by CTC and the University of Pittsburgh since 1995, provides innovative groundwater and soil remediation technology information to interested stakeholders through a variety of avenues: its website (www.gwrtac.org), conferences, exhibits, and on-line training sessions. GWRTAC information includes reports developed by independent experts for GWRTAC, and information developed by others. Over 80,000 customers (representatives of federal/state governments, private companies, and academicians) have accessed the website, downloading over 100,000 copies of GWRTAC reports. GWRTAC has recently begun a new initiative, Groundwater Central©, which will be demonstrated at the meeting. Groundwater Central© is a centralized portal where links to existing web-based information are organized into a user-friendly, searchable framework. Information such as on-line publications, technology performance and cost, case studies of site problems and solutions, site demonstrations, announcements for conferences and workshops, RFPs, etc. are included. This unique effort to link these resources together at the sub-page or downloadable file level at a single, searchable web-site location will be a valuable, time-saving resource for environmental management and technical personnel. The on-line debut of Groundwater Central© is scheduled for fall 2001, with continuous expansion planned for the future.

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**Biological Treatment of a Tritiated HPLC Mixed Waste to Meet RCRA Requirements**

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The United States biomedical R&D community produces a mixed waste containing tritium and solvents used in high-performance liquid chromatography (HPLC). The HPLC mixed waste normally has a 20 to 40% organic content with relatively low radioactivity (several hundred mCi per batch). Based on the HPLC waste characteristics and RCRA requirements, incineration is the best available treatment technology. However, incineration is expensive and releases tritium to the atmosphere. Berkeley Lab policy is to minimize all tritium releases wherever possible. Biological treatment of organic solvents followed by solidification and burial of the tritium residue hold promise as a practical, economic alternative to incineration for HPLC mixed wastes. Bacterial cultures capable of biodegrading acetonitrile, methanol, and other solvents found in HPLC mixed wastes have been developed in the laboratory and are being applied for the treatment of HPLC waste mixtures. Surrogate studies have been conducted to measured bacterial degradation kinetics and design of a prototype treatment process has begun. At completion, the biological treatment system will be transferred to a containment facility and used to treat tritiated HPLC wastes. Our results suggest that biological treatment can be used to help resolve a national mixed waste problem faced by the DOE, other research organizations, and the pharmaceutical industry.
[274] Remediation of Chlorinated Solvent Groundwater Plume Using NoVOCs Recirculating Well Technology - A Field Study
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During a site assessment conducted in 1997, dry cleaning solvents compounds exceeding exceeding regulated standards (natural attenuation default concentrations and groundwater criteria), were detected at the Nu-Look Cleaners facility in Coral Springs, Florida. The solvent PCE was detected at a maximum concentration of 1,900 µg/L, thereby providing presumptive evidence of DNAPL. The maximum sum concentration of PCE and its degradation compounds was 21,000 µg/L. A comparison of remedial techniques concluded that NoVOCs recirculating well technology would facilitate removal of dissolved phase contaminants while maintaining existing in situ anaerobic reductive dechlorination conditions. The system was operated in a closed loop configuration (connected blower effluent and influent) to minimize introduction of atmospheric oxygen into the in-well stripping column. Additionally, the system provided flexibility, in that, following removal/degradation of PCE and TCE, it could be re-configured into the open loop configuration to increase the oxygen levels and promote aerobic degradation of DCE and vinyl chloride, if necessary. A single recirculating well was installed and tested over a 30 day period. Test data indicated a radius of influence of approximately 62 feet. The area of contamination exceeding natural attenuation default concentrations was reduced from 10,000 square feet to 1,500 square feet.

[276] Catalytic Oxidation of Tritiated Mixed Waste with High-Specific Activity for RCRA Delisting Petition
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Researchers in the United States pharmaceutical industry and academic institutions conducting life science and biomedical research regularly use tritium and carbon-14 in research and development projects, and process solvents are contaminated. These activities generate mixed waste with Curies (Ci) of tritium activity, or mCi of carbon-14. The hazardous component of this waste includes F-listed spent solvents, is designated as ignitable D001. Because dual regulation of mixed waste under the Atomic Energy Act and the Resource Conservation and Recovery Act (RCRA), there are very few disposal sites can accept the mixed waste with high tritium content for disposal. Hence, the biomedical research community faces very limited disposal options for the mixed waste. In order to develop alternatives for tritiated mixed waste, Lawrence Berkeley National Laboratory (LBNL) initiated a treatability study using catalytic chemical oxidation (CCO) technology as part of LBNL’s pollution prevention program. We have also ensured the appropriate legal status of this waste by obtaining an Equivalent Treatment Determination for the CCO and by delisting the treatment residues. Our more than 80 test results demonstrated that (1) the treatment residues did not exhibit RCRA characteristics, (2) met the concentration-based land disposal restriction (LDR) and universal treatment standards, and (3) the D001 designation of the waste met the technology-specific LDR of combustion. Thus, (a) the F-codes of the treatment residues could be delisted and the D001 and F003 codes of the treatment residues could be deleted, and (b) the treatment residues can be disposed as low-level radioactive waste, or tritium in the residues might be recycled.

[277] Resolving Problems Associated with the Biological Treatment of MTBE Contaminated Ground Water
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As a consequence of its use in gasoline, MTBE has become a widespread groundwater contaminant. MTBE has complicated the remediation of gasoline contaminated sites. Biological treatment has been the preferred method for treatment for gasoline contaminated groundwater, but biological treatment of MTBE is unreliable. Data from field and laboratory studies will be presented that explain why MTBE treatment is unpredictable. It is proposed that the manipulation of specific MTBE degrading bacteria can be used to increase the reliability of MTBE biotreatment. Using a series of field studies in fluidized-bed biological reactors treating MTBE contaminated groundwater, the root causes of poor MTBE treatment have been determined. Major problems are that MTBE-degrading bacteria do not establish themselves well in reactors and are subject to inhibition by gasoline hydrocarbons. These characteristics are not optimal for the start-up and maintenance of biological treatment under field conditions. Bacterial cultures grown on iso-pentane, a component of gasoline, consistently co-metabolize MTBE. It can be demonstrated that these bacteria can be used for MTBE treatment in field and laboratory reactors. It is proposed that application of co-metabolic degradation processes to MTBE treatment will resolve many of the limitations of biological treatment under field conditions. The application of the lessons learned in ex situ treatment to in situ treatment will be discussed.
A field demonstration of Steam Stripping/Hydrous Pyrolysis Oxidation (SS/HPO) was conducted at a TCE DNAPL site at the Portsmouth Gaseous Diffusion Plant in Ohio. The DNAPL TCE was located in an aquifer sandwiched in between two low-permeable strata (clays, silts and shale), and was distributed at the base of the aquifer and the upper two feet of the underlying, organic-rich shale. A target area of 120 by 180 ft was selected for remediation. Detailed soil sampling and analysis resulted in an estimated TCE mass of approximately 900 lbs within the treatment area. Approximately 825 lbs were removed, and an unknown quantity of TCE (estimated between 100 and 500 lbs) was degraded by HPO reactions. The migration of steam and hot condensate was monitored using dedicated thermocouples and Electrical Resistance Tomography (ERT). This breakthrough demonstration showed that DNAPL can be removed from low-permeable layers by in situ boiling and capture of the vapors by vacuum extraction. It was predicted that the entire 50 acre site can be remediated with an operations time of 6 months, and that DNAPL TCE can be removed from the target layers without spreading to the surrounding areas.

Recent groundwater remediation research efforts have focused upon developing innovative, in situ methods for treating impacted aquifer zones. One such method is the use of in situ permeable reactive barriers (PRBs). These systems entail placing reactive materials into the subsurface to intercept a groundwater plume and treat the dissolved contaminants as they flow through the barrier. Various in situ emplacement methods are available for PRB installation, however many questions arise regarding how the emplacement methods may affect ultimate wall performance. To address these questions, 3-D, steady-state MODFLOW modeling was performed to simulate contaminant plume capture and groundwater flow through a reactive barrier. Model simulations were run to provide a conceptual understanding of how changes in PRB design parameters affect the wall capture performance. Variations in wall hydraulic conductivity, wall orientation, wall continuity, wall “skin effects”, and aquifer heterogeneity were investigated. Results from the modeling investigation were used to optimize the design of a pilot-scale PRB treatment wall, monitoring well network, and performance monitoring program.

Performance of three sulphate reducing bacteria (SRB) reactors during a two-year operational period is reported in this paper. The reactors were constructed to demonstrate the removal of heavy metals from water by SRB. The stream on which the technology was tested emanates from an abandoned hard-rock mine dump. SRB are capable of immobilizing dissolved metals by precipitating them as sulfides, and to reduce acidity of the influent, if a favorable biochemical environment is created. Such environment was engineered within the three field bioreactors that differ in size, content and the above or below-ground placement. There is also referred to as the Primary Subliner monitoring subsystem (PSL) is capable identifying leakage quantities as small as 600 gallons. An additional moisture monitoring subsystem, the Vertical Sensor Array, consisting of 22 time-domain reflectometers provides a backup to the PSL. These two vadose zone monitoring systems allow for real-time leak detection and long-term assessment and assurance of containment cell performance.
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indication that the reactor’s performance is sensitive to construction details including the amount of reactive media and its placement method. This demonstration project is funded by the U.S. EPA and is jointly administered by the EPA and the U.S. DOE. The project is implemented by MSE Technology Applications, Inc., Butte, Montana.

[284] Remedial Action Using HRC Under a State Dry Cleaning Program
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Hydrogen Release Compound (HRC™) was introduced into the subsurface at a former dry cleaning site in April 2000 under the Florida Department of Environmental Protection (FDEP) Drycleaning Solvent Cleanup Program (DCSP). HRC was selected because it is a passive, cost-effective remedy for anaerobic degradation of chlorinated solvents. The site, located in Jacksonville, Florida, has three distinct aquifer zones, all of which are impacted by typical components of drycleaning solvents at levels well above regulatory cleanup criteria. Groundwater monitoring has taken place at the site on a quarterly basis since HRC application. The current data indicate reductive dechlorination is proceeding at an acceptable pace, though additional monitoring is necessary. A buildup of total dichloroethene (DCE) and vinyl chloride may lead to further site remediation using an aerobic mechanism.

[285] Steam Remediation of Chlorinated Solvent Sources
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Two sites with chlorinated solvent contamination are locations for ongoing work utilizing steam remediation technologies. The sites provide an interesting opportunity to compare and contrast steam remediation technologies in context of the same general goal: to remove a chlorinated solvent source from a specified target region. The two sites are locations of ongoing work by Integrated Water Resources, Inc. and IT Corporation, with projects to remove PCE and TCE at Savannah River Site, South Carolina, and to remove TCE from a source zone at Cape Canaveral, Florida. At the Savannah River Site project, IWR is deploying steam remediation technologies developed at Lawrence Livermore National Laboratory, including; (1) Dynamic Underground Stripping – Engineered combination of steam injection and vapor and groundwater extraction; (2) Hydrous Pyrolysis/Oxidation (HPO) — Destruction of underground contaminants through oxidation in the presence of injected steam; and (3) Electrical Resistance Tomography (ERT) – Geophysical imaging technique for tracking subsurface thermal changes during DUS/HPO operations. The technologies are being used to extract PCE and TCE (principally PCE) from the subsurface, where 13,000 kg of solvent is estimated to exist in the target zone. Target zone sediments extend to 160 below ground surface and are both saturated and unsaturated. After the first 4 months of operations, most of the target zone is at the boiling point for PCE, with increasing mass removal rates and over 2 tons of PCE and TCE recovered to date. At Cape Canaveral, IWR is the project lead for the final technology deployment of the Interagency DNAPL Consortium’s (IDC) technology comparison test at Launch Complex 34. Because of a very thin vadose zone and relationships between stratigraphy and NAPL distribution, IWR’s application of steam remediation technologies at Cape Canaveral includes the use of co-air injection during initial phases of work, as a means of mobilizing TCE in vapor phase ahead of the active steam heating zone. This site is somewhat smaller but exists within a larger source; the estimated mass of TCE for steam remediation removal here also is approximately 13,000 kg. Comparison of steam remediation technology deployment at the two sites includes: site conditions, manner of technology selection, design of subsurface facilities and surface treatment system, operations, monitoring techniques; and performance goals and analysis.

[287] A Combined Biological/Phytological Design for Remediation of Chlorinated Solvents in a Low Permeability Aquifer
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Pro2Serve® Technical Solutions in conjunction with Bechtel Jacobs Company LLC, and U.S. Department of Energy1 has designed an in situ system that combines enhanced bioremediation with phytoremediation to remediate trichloroethene (TCE) contaminated groundwater in a shallow unconsolidated aquifer at the Portsmouth Gaseous Diffusion Plant (PORTS), Piketon, Ohio. Enhanced bioremediation including injection of co-metabolites can be combined with the natural pumping capabilities of a phytoremedial system to induce flow that increases the distribution of the co-metabolite between injection points in the low permeability aquifer. A full scale phytoremediation pilot study in progress at PORTS provides evidence that special planting designs help hybrid poplar trees influence groundwater flow even in semi-confined aquifers below the root zone. Additionally, the hybrid poplar varieties currently utilized at PORTS, have specialized anatomical features that enable root growth in low oxygen areas such as stagnant water. Specific poplars and willows are capable of growth in these environments because they have a mechanism for aeration of the water through translocation of oxygen acquired from the atmosphere into the root zone through specialized tissues. The Corrective Measures Implementation on the target plume is scheduled for installation in Spring 2002.
A non-aqueous phase liquid (NAPL) containment system has been designed for the former Northern Indiana Public Service Company Manufactured Gas Plant (MGP) located on a three acre site adjacent to the St. Mary’s River in downtown Fort Wayne, Indiana. The former MGP office building, is now the very popular “Gas House Restaurant”. Construction is scheduled for fall 2000. Extensive site investigations revealed the presence of discrete pockets of coal tar product, a dense non-aqueous phase liquid (DNAPL), and varying concentrations of dissolved phase contaminants. DNAPL contamination is generally present throughout a large vertical portion of the soil column to a depth of 35 feet and a wide areal extent; however, there is no evidence to suggest a widespread continuous (i.e., hydraulically connected) DNAPL layer at the site. The main remedial action objective is containment to prevent seepage of NAPL into the river. A slurry wall was selected to physically contain the coal tar product and dissolved phase contaminants. The feasibility study determined that excavation and DNAPL removal was prohibitively expensive due to the 35 foot depth and depth to groundwater of 12 feet. A 4% bentonite/soil mixture will be used to construct a 3 foot wide containment wall with a maximum permeability of 10^-7 cm/s. The slurry wall will be 540 feet long by 35 feet deep (a minimum of 5 feet into the till layer) and will enclose the site along the river and the northern boundary of the site. A secondary remedial objective is to recover DNAPL coal tar product. The proposed DNAPL recovery system will consist of six (6) discrete, 30-32 foot deep by 50 to 125 foot long pea gravel trenches that total 585 feet, eight (8) 4-inch diameter groundwater extraction wells, and six (6) 4-inch diameter DNAPL extraction wells. The trenches will provide an increased hydraulic gradient within a capture zone much larger than that of single wells. The groundwater table will be lowered up to 10 feet; thereby mobilizing coal tar previously bound by buoyancy forces in the upper part of the saturated zone. Depressing the groundwater table inside of the slurry wall will create an inward gradient toward the contaminated areas of the site, thus creating a hydraulic barrier to dissolved phase migration. A slurry wall backfill, which will be compatible with the site groundwater and DNAPL, was selected following extensive laboratory testing. Test protocols were altered after new research (McCaulou and Huling, 1999) indicated that hydrated soil/bentonite soil mixtures might develop desiccation cracks when permeated with DNAPL. Filter cake tests determined that bentonite appeared more resistant to desiccation than attapulgite. Soil/bentonite mixture compatibility and permeability was then evaluated by permeating different percent bentonite mixtures sequentially with site groundwater and DNAPL. Permeability tests showed that site groundwater had no effect on either of the 4% or 6% bentonite mixtures. Despite surface cracks, short-circuiting of DNAPL was not observed and Darcian flow was maintained. Based on these results, a 4% bentonite mixture with site soils was selected as the slurry wall backfill. A 48-inch, brick combined sewer overflow (CSO) line (constructed in 1881) and a 36-inch storm drain cross the northern portion of the site. The containment wall in the area of the drains will be constructed by jet grouting methods in order to avoid excavation across and below the drain lines. In order to eliminate this pathway for NAPL and dissolved phase discharge to the river, a construction contract for rehabilitation of the brick CSO line by the cured-in-place liner method was completed in the summer of 2000.

A backfill mixture for a slurry wall at a former mid-western manufactured gas plant (MGP) was selected using a three-phase laboratory permeability testing program. The specifications required a mixture with a permeability below 10^-7 cm/s and compatibility with the site’s groundwater and dense non-aqueous phase liquid (DNAPL), coal tar. Samples were tested in triaxial and rigid wall permeameters. Potable water was used as a permeant in Phase 1 to estimate average permeabilities for each of the three geologic units at the site. In Phase 2, soil/bentonite mixtures were permeated with potable water to select a mixture that had a permeability below 10^-7 cm/s. Phase 3 evaluated the compatibility of commercially available bentonite and attapulgite with the coal tar found at the site. The Phase 3 test protocol was altered after new research (McCaulou and Huling, 1999) indicated that hydrated soil/bentonite soil mixtures may develop desiccation cracks when permeated with DNAPL. Filter cake tests were utilized as a screening tool to determine whether bentonite or attapulgite appeared more resistant to desiccation. Compatibility was then evaluated by permeating viable mixtures sequentially with site groundwater and coal tar. The average permeabilities of the fill, alluvium, and till from Phase 1 tests were 1.3x10^-4, 1.0x10^-3, and 8x10^-8 cm/s, respectively. Phase 2 tests indicated that either the 4% or 6% bentonite mixture would have an acceptable permeability (<5.08x10^-8 cm/s). Phase 3 filtrate testing showed bentonite to be more compatible with the site’s DNAPL. Site groundwater had no effect on either of the 4% or 6% bentonite mixtures. Subsequent permeation with DNAPL decreased permeability slightly (2.5x10^-8 cm/s). Photographs taken after testing show 1/8”-1/4” cracks that penetrated 1/8”-3/4” deep into the top of the sample. Despite the surface cracks, short-circuiting of DNAPL was not observed and Darcian flow was maintained. Both mixtures are conservative since the gradients used in the lab are much higher than those expected in the field. Moreover, groundwater extraction pumps at the site will create an inward gradient away from the slurry wall.
Chlorinated Solvent Remediation and Plume Management at a Dry Cleaning Facility using an Enhanced In Situ Biodegradation Technology

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Injection of a time-release source of lactic acid (HRC®) into a plume of PCE-contaminated groundwater in a shallow aerobic aquifer at a dry cleaning facility resulted in (1) a significant increase in the rate of degradation of PCE and its daughter products and (2) a greater than 95% reduction in PCE concentrations near the source area in a 6 month period. Rates of degradation were lower in the mid-plume and at the plume margin than near the source area. The injection of a lactic acid source created an anaerobic and nutrient-rich aquifer environment, thus accelerating reductive dechlorination of the chlorinated solvents. The accelerated degradation occurred at different rates within different areas of the plume. Enhanced degradation occurred most rapidly near the source area where a historic discharge of No. 2 fuel oil may have provided a carbon source for reductive dechlorination and an acclimatized bacterial population may have been present. A lag effect for the onset of accelerated degradation was apparent in other areas of treatment zone due to differing initial conditions and groundwater flux. Ongoing groundwater monitoring indicates that more than one year after injection, the aquifer remains anaerobic, and PCE concentrations continue to decrease.

Use of In Situ Chemical Oxidation (Fentons Chemistry) to Remediate Tetrachloroethene (PCE) in Groundwater

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A Remedial Action Plan (RAP) created for the Swift Cleaners site in Jacksonville, Florida is being conducted under the Florida Department of Environmental Protection (FDEP), Drycleaning Solvent Cleanup Program (DSCP). Site assessment at the Swift Cleaners indicated the presence of a soil source area with levels of tetrachloroethene (PCE) as high as 21,000 µg/kg. The groundwater PCE plume originates at the area of soil contamination and migrates vertically to a depth less than 60 feet bgs and laterally westward approximately 340 feet. Concentrations of PCE in the groundwater were found as high as 4,500 µg/L in the intermediate zone and 10,000 µg/L in the deep zone. The results of a pilot test, conducted between September 1999 and December 1999, were mixed with groundwater concentrations decreasing in some areas and increasing in others. The majority of the saturated zone source mass is located between 35 and 45 feet bgs. The dissolved concentrations in this interval fluctuated during the pilot test. Indicating a large source mass and conflicting manifestations of desorption, solubilization and destruction. Data indicate that in situ chemical oxidation with hydrogen peroxide is capable of remediating both dissolved phase and adsorbed phase PCE at this site. Full-scale remediation efforts are scheduled to begin in March 2001. Results of the full-scale remediation and how they compare to the pilot test results will be presented.
[293]
**Permeable Reactive Barrier for Metals Treatment at the Newport, Delaware Superfund Site**

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DuPont has developed permeable reactive barrier (PRB) technology to treat metals, primarily barium and zinc, from a landfill at the Newport, Delaware Superfund site. For the first half of the 20th century, DuPont’s Newport plant produced Lithopone pigment (BaSO₄•ZnS) by roasting barium and zinc ores. Waste sludges were deposited in a landfill, the waters of which today contain metals that exceed environmental standards. An EPA Record of Decision required the landfill to be remediated by in situ treatment. Innovative technology has been developed which reduces the cost from $17,000,000 for the ROD remedy to $5,000,000, while being more protective of human health. It employs a PRB using calcium sulfate to precipitate barium, zero-valent iron for the adsorption of zinc and other metals, and magnesium carbonate to suppress manganese solubility, in a matrix of local mortar sand. The key to a projected PRB life measured in centuries is a low-permeability cap over the landfill that reduces infiltration and subsequent groundwater flow leaving the landfill to extremely low levels. This minimizes reactant losses from reaction and solubilization. Development of the technology included laboratory batch and column tests and thermodynamic modeling. The final demonstrations were field tests in zones of different groundwater contaminant composition.

[295]
**Enhanced Bioremediation of Chlorinated Solvents in Groundwater: Using Mulch Derived from Waste Organic Material at Cape Canaveral Air Force Station (CCAFS), Florida**

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The use of mulch as a media for the treatment of contaminated groundwater has received increased attention in recent years. Chlorinated hydrocarbons have been shown to degrade via reductive dechlorination under anaerobic conditions, and the anaerobic decay of mulch may increase reducing conditions in groundwater and stimulate dechlorination. Two in situ methods are being developed for the use of mulch in the remediation of contaminated groundwater contaminated: permeable reactive barriers and surface amendments. A barrier wall would rely on natural groundwater gradients to carry contaminated groundwater through a permeable mulch membrane. A surface amendment would rely on the contact of groundwater with leachate generated within the decaying mulch. Both methods of implementation will be pilot tested at Cape Canaveral Air Force Station, Florida (CCAFS). A surface amendment will be implemented during March 2001, and a mulch wall will be installed later in the year. The surface amendment will consist of three cells covering at total area of 0.4 acres. The mulch to be used during this pilot test will be generated from the removal of nuisance vegetation present at CCAFS. Performance assessment will be on going throughout an 18-month period following implementation and will be updated continually.

[297]
**Cost Efficient Long-Term Monitoring (LTM) of Chlorinated VOC Plumes through the Utilization of Passive Diffusion Samplers**

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The 45th Space Wing Installation Restoration Program (IRP) office conducted a pilot test of passive diffusion samplers at two sites at Cape Canaveral Air Force Station (CCAFS) in October 2000. The pilot test was conducted to compare sample analytical results obtained through the use of passive diffusion samplers with the analytical results of samples collected using low-flow purge sampling methods. The purpose of the pilot test was to determine whether the use of passive diffusion samplers for long-term monitoring (LTM) of volatile organic compounds (VOCs) groundwater would provide viable data at a cost saving to the US Air Force. The passive diffusion samplers, which consist of sampler bags constructed of a semi-permeable membrane filled with analyte-free water, were tested at two abandoned launch complexes at CCAFS, Space Launch Complex 11 (SLC-11) and SLC-12. Both sites are being monitored under the 45th Space Wing IRP office’s LTM program for dissolved chlorinated VOCs. The pilot test was conducted by installing the passive samplers in groundwater monitoring wells at SLC-11 and SLC-12, and allowing sufficient time for the VOCs in the groundwater to diffuse into the sampler bags (a minimum of two weeks). After the four-week period had passed, the sampler bags were retrieved from the wells, and the water in the bags were transferred to glass vials. Immediately following collection of passive diffusion samples, the wells were sampled using program-approved low-flow purge methods. The two sets of samples were submitted to an analytical laboratory for VOC analysis by SW8260. A comparison of the analytical results for indicates that, in general, the results of the
In recent years, dissolved phase contaminant fate and transport model has gained more and more attention in the decision making process of selecting appropriate remedy for DNAPL contaminated sites. The modeling effort can serve as the basis of the technical effectiveness evaluation of the remedy selection process. The model can be used to simulate different remediation scenarios and answer the following under each option: 1) what will be the physical aspects of the plume with time, 2) how long will the contaminant plume persist, and 3) which options provide the most benefit in term of cost effectiveness and protective of the human health and the environment? However, due to the heterogeneous nature of the subsurface environment and the inherent complexity of numerical model itself, it presents a challenge in selecting an appropriate model that will suite the site-specific hydrogeological and geo-chemical conditions. This presentation discusses criteria for selection and application of the numerical models where DNAPL is present as the feeding source and sequential biodegradation of dissolved phase chlorinated solvent is occurring.

To generate a unique solution under above conditions, the model must have the ability to track both the contaminant and the electron acceptor plumes, as well as the ability to simulate the interaction between the contaminant and electron acceptors under different kinetic scenarios. The application of two currently available models, RT3D and Sequential Electron Acceptor Model for 3D transport (SEAM3D) will also be discussed.

Trace metal partitioning between authigenic minerals and aqueous solutions is an important chemical process for waste containment. In this paper, we have developed a linear free energy correlation model that correlates metal partition coefficients with metal cation properties:

\[ -2.303RT \log K_{p} = a_{0,x}(\Delta G_{0,u}^{0} - \Delta G_{0,u}^{r}) + \beta_{u,x}(r_{u} - r_{H}) - (\Delta G_{u}^{0} - \Delta G_{u}^{r}) \]

where \( a_{0,x} \) and \( \beta_{u,x} \) are constants and can be determined by a regression analysis. Host minerals from an isostructural family have the same linear free energy relationship, as long as the relationship is expressed as a function of the differences in cation properties between substituent and host metals. We have applied our model to both isovalent and non-isovalent metal partitioning in carbonate minerals. The model closely fits experimental data, demonstrating the robustness of the proposed linear free energy relationship. Using the model, we have predicted the partition coefficients of divalent and trivalent metals between various carbonate minerals and aqueous solutions. Magnesite is predicted to have the largest partition coefficients among the carbonate minerals with a calcite structure and therefore can be a good scavenger for toxic metals. The implication of this prediction to the Waste Isolation Pilot Plant is discussed. The model developed in this paper provides a useful tool for predicting unknown partition coefficients and therefore help select effective containment materials.
Abstracts 302, 303, 304

[302]
In Situ remediation at a Brownfield Site in Pennsylvania using Reinjectable Points
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A new in situ bioremediation technique to accelerate the rate of degradation of residual dissolved contaminants including BTEX and MTBE was implemented at a former gasoline station in Boyertown, Pennsylvania. The new owner, a regional bank, required the remediation technique to be unobtrusive due to the sensitivity of its customers. Using a slow-release oxygen compound, the remediation was undertaken via a direct push method for slurry injection into the former heart of the plume while 35 reinjectable injection points were constructed along the perimeter of the property. The compound is reapplied through these reinjectable points on a 6-month basis using a high-pressure positive displacement pump to deliver the compound to the impacted aquifer. Results after 21 months indicated that the levels of the primary contaminants of concern have been reduced at the sentinel well to a level below the cleanup goal. Benzene levels dropped from 1.425 mg/L reduced to .026 mg/L and MTBE concentrations dropped from 2.072 mg/L to .070 mg/L. The remediation continues as residual values in the former heart of concentrations dropped from 1.425 mg/L reduced to .026 mg/L and MTBE sentinel well to a level below the cleanup goal. Benzene levels dropped from 1.425 mg/L reduced to .026 mg/L and MTBE concentrations dropped from 2.072 mg/L to .070 mg/L. The remediation continues as residual values in the former heart of the plume decline so that natural attenuation alone can be used to manage any off-site migration of the contaminants of concern.

[303]
Mass Reduction versus Mass Movement of Chlorinated Aliphatic Hydrocarbons during In Situ Chemical Oxidation Pilot Test
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Pilot scale remediation using in situ chemical oxidation with traditional Fenton’s chemistry, requiring aquifer acidification, resulted in significant reduction of chlorinated aliphatic hydrocarbons (CAHs) and other volatile organic compounds (VOCs) at Installation Restoration Site 5, Unit 2, Naval Air Station North Island, San Diego, California. The three-injection event pilot test first raised then answered questions regarding the movement of contaminant mass through phase transport processes in response to chemical injection. Groundwater results observed after the first and second injection events indicated a dramatic reduction in dissolved-phase contaminant concentrations. However, a gradual rebound in these concentrations near the injection well to levels above baseline concentrations, as well as the apparent increase in sorbed-phase concentrations in soil at the water table, emphasized a need to verify contaminant mass reduction as opposed to mass movement prior to full-scale application of the remedial technology. Contaminant mass estimates provided a basis upon which to evaluate the mass reduction versus movement phenomenon. Estimation of contaminant mass in the various media was undertaken prior to and after the pilot test’s third injection event. Estimates were based on VOC analysis of paired soil, groundwater and soil vapor samples collected from within a 15-foot radius of the injection well before and after the event. The exercise revealed that roughly 95 percent of total VOC mass resided in soil at and below the groundwater table. Mass estimates for target contaminants including cis-1,2-DCE and vinyl chloride, the primary contaminants in groundwater, indicated that 75 to 80 percent of their mass also resided in water-saturated soil. Mass estimates performed after the third injection event showed reduction in total mass of approximately 68%, indicating that although movement of contaminant mass from the sorbed to dissolved and vapor phases apparently occurs in response to chemical injection, contaminant mass reduction is by far the predominant phenomenon occurring as a result of the technology at the site. Given the success of the pilot scale remediation, IT will take the technology to full-scale application during Spring 2001.

[304]
New Approaches to Solve Remediation Challenges using Technological Applications at the Sandia National Laboratory Chemical Waste Landfill
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The Chemical Waste Landfill (CWL) at Sandia National Laboratories, New Mexico (SNL/NM) is a 1.9 acre site used for the disposal of chemical wastes generated by many of SNL/NM research laboratories from 1962 until 1985. SNL/NM in conjunction with URS began excavating the landfill in 1998. The remediation project includes waste segregation, characterization, and appropriate storage for future treatment and disposal of excavated material. Many of the technological advances implemented at the site were derived from in-field experience and evaluation of new approaches and engineering designs to meet remediation challenges associated with the project. Five (5) technically significant achievements are examined: (1) The process of screening debris from excavated soils has experienced successful improvements through field evaluations of a series of site-built and commercial design applications; (2) The debris segregation process enhancements are a reflection of practical design modifications; (3) Explosion protection equipment and
practices have advanced from the application of technology-based assessment and modeling tools; (4) The use of smoke grenades as a practical and effective emergency response indicator for site workers and neighbors; and (5) Study of actual heat stress potential through comprehensive field assessments and the use of commercially available heat stress reduction equipment and techniques. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

[305]
Operation and Maintenance of the Frozen Barrier at the HRE Pond
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The frozen barrier at the HRE Pond at Oak Ridge National Laboratory (ORNL) was implemented in September of 1997 to contain radiologically contaminated subsurface waste using hybrid thermosyphon technology. This barrier was installed as a full-scale demonstration project for the DOE. During the 12-month demonstration period, the barrier was evaluated by the EPA's SITE program and found to be effective in impeding groundwater flow. After the demonstration period was completed, the barrier has remained on-line and was incorporated into the daily operations of ORNL. The hybrid thermosyphon technology used for this project is an effective and efficient freezing system for creating and maintaining a long-term containment barrier. This technology transfers heat via evaporation and condensation of a two-phase working fluid. The working fluid used is benign to the barrier and the environment and requires much smaller piping than a single-phase fluid. Conventional ground freezing systems that are used for short-term construction ground freezing projects typically utilize single-phase (antifreeze) liquids that can cause barrier degradation if a leak were to occur. Additionally, single-phase systems inherently have lower efficiencies due to heat gain through piping components not within the proposed frozen zone. On the average, the frozen barrier at ORNL uses less than 290 kwh of power per day. The contracted maintenance and preventative maintenance expended during FY-00 was $17,110 with an additional $10,400 going toward technical support, data collection and data storage. This included the costs for completely replacing one of the refrigeration compressors at the site after a bearing failure. Further discussions of equipment and lessons learned are detailed. Projected costs for larger scale frozen barriers are presented.

[306]
Waste Pit Imaging at the Idaho National Engineering and Environmental Laboratory using the Very Early Time Electromagnetic (VETEM) System
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The Very Early Time Electromagnetic (VETEM) system, developed with support from the Department of Energy Environmental Management Science Program, was deployed at Pits 4, 9, and 10 in the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). Monitoring well data indicated that contaminants were migrating from these pits. Remediation was planned in portions of these pits to mitigate contaminant migration. VETEM was used to provide geophysical images of the location and estimated depths of some of the metal waste in Pit 9. The images were used as a guide to position stainless steel probe tubes for nuclear logging. The nuclear logs were necessary to definitively locate and identify radionuclides in the waste. VETEM is designed to produce high-resolution images of the shallow subsurface when the electrical conductivity is too high for ground-penetrating radar (GPR) to be effective, such as in the clay capping material over waste pits like Pits 4, 9, and 10. The University of Illinois developed an inversion algorithm, appropriate to VETEM data that was used to provide depth estimates to highly conducting objects in Pit 9. Subsequent to the successful results at Pit 9, data were collected over the approximately 41,000 m² of Pits 4 and 10. The data from Pits 4 and 10 are of high quality and were the first to be produced using a new all-terrain-vehicle-towed version of VETEM with an integrated real-time kinematic global positioning system that can provide decimeter level positional accuracy. The high-resolution time-slice images of Pits 4 and 10 reveal lateral location of buried waste and of conductivity variations in the subsurface. Inversion of these data for depth using the University of Illinois code is planned.
In situ bioremediation technologies rely on indigenous microorganisms to transform contaminants to harmless by-products. The inability to establish and maintain an effective in situ biological system that overcomes adverse environmental effects has severely limited the effectiveness of bioremediation. Most biological treatment technologies lack the ultimate transformation of parent compound, which severely limits the credibility of certain remediation technologies. In order to design a process with high microbial activity, we need to establish and maintain a biological system with a high density of active microorganisms capable of biodegrading organic compounds. To better understand the environmental factors, which promote or inhibit the biodegradation of organics, we need to establish a controlled process, which shields the viable cells and prevents their loss under stress conditions. To provide the best possible environment for microbes to grow and be protected against environmental stresses, we investigated a highly effective biological system that takes advantage of a unique immobilized cells technique (PTO No. 09/432,092). This technology is called Biological Permeable Barrier (BPB). BPB is an innovative combination of two cost effective in situ remediation technologies: in situ bioremediation and permeable barrier walls. BPB entails immobilizing microbial organisms, which are acclimated to the target contaminants, in unique polymeric beads (Bio Beads). The “activated” beads are then placed in an engineered well or trench across the flow path of the contaminated groundwater. Contaminated groundwater enters the BPB to which oxygen (under aerobic condition) and nutrients are supplied, and the remediated groundwater exits the BPB. BPB technology can be designed to co-treat several organic compounds in the same barrier. The proposed immobilized cells system has significant advantages over conventional free cell system such as higher cell density per unit volume, greater operational flexibility, and resistance to high concentrations of toxic or inhibitory chemicals. BPB has been evaluated for over 350 days to remove 2,4,6 trichlorophenol from groundwater under a variety of operating conditions. Not only BPB technology provided the perfect environment for TCP-degrading bacteria to grow but also shielded the viable cells from environmental stresses.

This paper describes the development and deployment of a chemical extraction soil washing process to dramatically reduce the cost of soil remediation at facilities with radioactively contaminated soil. The carbonate extraction process flow will be explained and the substantial cost savings that have resulted in processing over 14,000 tons of contaminated soil thus far will be defined. In addition, regulatory issues such as; permitting, volumetric free release of clean soil product, long term stabilization of residual uranium in the product, and disposal of plant residuals will be explained. Finally, current efforts to expand the soil washing process to other contaminants such as Technetium-99, Radium, Thorium, and TCE will be discussed. Earthline Technologies in Ashtabula, Ohio has developed a remediation approach for removing uranium contamination from soil. The treatment approach has been developed from bench scale testing and pilot plant operations through construction and successful operation of a 10 ton per hour chemical extraction soil washing plant. Soil treatment using carbonate extraction reduces the volume of contaminated material requiring off-site disposal which has the positive effect of lowering total project costs associated with soil remediation from $45 Million for ship and bury to $25 Million for treatment. This paper describes the design, construction, shakedown, and operation of this first of a kind, 10 ton per hour, continuous flow, soil treatment production plant. The soil washing process flow employed in Ashtabula is applicable to numerous radionuclide and hazardous contaminants present at many environmental remediation sites. The soil treatment production plant is the culmination of a 3 year effort to develop a cost effective method of remediating uranium contaminated soil.

The developed carbonate treatment approach solves the difficult technical problem of treating contaminated high-clay content soil. This paper is unique in that it describes the operation of a first in the world chemical soil processing facility. The paper describes the project approach for minimizing capital investment risk as well as the multiple decision points used by Earthline to ensure the ultimate success of the soil treatment approach. Finally, the paper describes a wide range of technical issues which were addressed during the design and construction effort such as ensuring residual uranium in treated soil product was stabilized so as to avoid negatively impacting the site groundwater. The Earthline Technologies soil washing plant has successfully processed over 14,000 tons of contaminated soil. The operational lessons learned from plant operations will be presented. In addition, a contaminant mass balance and cost savings summary will be presented. Finally, plant improvements to allow treatment of soil contaminated with technetium-99, thorium, radium and also TCE will be discussed.
source zone. Monitoring over two years of the resultant natural gradient plume using detailed transects at several locations along an 80 m fetch showed extreme variability in solute concentration distribution that displayed multiple high concentration zones. The concentration maxima declined over the plume length by a factor of 30 with no evidence of sorption or degradation. Dissolved solvent concentration values at effective TCM solubility are found in sampling points as far as 5 m down-gradient from known free-phase locations; solute concentrations at 30% of the effective TCM solubility exist 80 m down-gradient of the source. Prior to the DNAPL experiment the groundwater flow system was characterized by a natural-gradient bromide tracer test with independent darcy-flux and hydraulic conductivity (K) measurements. The variable direction flow field (50°) had minimal impact on the width of the plume. The variability in the detailed K measurements did not adequately predict the observed average linear groundwater velocity. The nature of the solvent plume is much different than would be perceived from conventional monitoring wells.

[310] Construction of a Deep Permeable Reactive Barrier in a Slurry-Supported Trench
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A deep permeable reactive-iron barrier (PRB) was constructed to contain and treat groundwater contaminated with chlorinated solvents at the Lake City Army Ammunition Plant, Independence, Missouri. The plume occurs in unconsolidated sediments of residual and colluvial clay overlying Pennsylvanian claystone. The bulk hydraulic conductivity of the unconsolidated sediments at the PRB is approximately 7 x 10^4 cm/sec. Concentrations of individual compounds are 1,000 µg/L or less. Treatability tests confirmed acceptable contaminant degradation by zero-valent iron that had been in contact with a guar gum-based biopolymer slurry. A long-stick hydraulic excavator was used to excavate the trench while biopolymer slurry provided liquid shoring. A mixture of sand and iron was placed in the trench, with temporary steel endstops separating the backfill from the active excavation. Construction was delayed due to an unstable working surface for the excavator and premature breakdown of the slurry, but was completed after resuming excavation from the far end of the PRB alignment with an improved working surface. Post-construction testing is being done to assess the distribution of treatment media. The 400-foot long barrier is keyed into bedrock, with an average depth of 43 feet and a maximum depth of 64 feet.

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DOE’s Environmental Management (EM) does not currently have credible, comprehensive estimates for the cost and quantity of waste that will be generated from its deactivation and D&D activities over the next several decades. In addition, viable estimates do not exist for the cost and waste generation for the deactivation and D&D of DOE Defense Program and Nuclear Energy program facilities. Those facilities are currently slated for transfer to EM over the next several decades. Long-term cost and waste volume estimates are needed to assist EM in developing strategies for establishing site baselines, reducing the funding gap, and evaluating mortgaged activities. The ROM methodology rapidly establishes cost estimates for all phases of future D&D projects. The ROM methodology also rapidly provides waste volume estimates for hazardous, radioactive, mixed, asbestos, and industrial landfill wastes that will be generated during deactivation and D&D activities. The presentation and paper will provide an overview of the ROM methodology and a description of the benefits to the EM program.

[312] Auger Drilling into a DNAPL Invaded Clayey Aquitard Cross-Contaminates an Overlying Sand Aquifer
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An experimental infiltration release in 1991 of 770 liters of PCE DNAPL into the Borden sand aquifer, contained within a double-walled sheet pile cell, resulted in downward DNAPL flow through the sand and then entry into the underlying stratified clayey aquitard where it moved laterally in thin sand microbeds to locations beyond the cell. In the characterization of the extent of this escaped DNAPL in the aquitard (1991-1994), auger drilling with split-tube samplers were used to collect continuous cores. The augers brought DNAPL contaminated cuttings from the aquitard up into the overlying aquifer, resulting in a 80m long persistent low-concentration plume extending to a stream. The degradation products (TCE and cis-DCE) make up a small fraction of the plume mass. A detailed search found no DNAPL in the sand, however, evidence indicates that DNAPL residual caused the plume and that much of this mass has been depleted by dissolution since augering more than 7 years ago. Given that auger drilling is the most common method for monitoring well installations in unconsolidated deposits at contaminated sites, it is likely that upward cross-contamination has led to erroneous interpretations of pre-characterization contaminant distributions at sites and, in some cases, explains many of the dispersed and anomalous concentration zones at many sites, otherwise attributed to site operations.
Abstracts 313, 314, 315, 316

[313] In Situ Chemical Oxidation of a Perchloroethene Source Area Using Potassium Permanganate

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A solution of potassium permanganate ($\text{KMnO}_4$) was flushed through a PCE source area at the Naval Training Center, Orlando, Florida. The $\text{KMnO}_4$ oxidized residual PCE and dramatically reduced PCE concentrations in groundwater. The pilot study was conducted at Operable Unit 4 at the Naval Training Center (NTC), Orlando, Florida. Operable Unit 4 consists of the former base dry cleaning facility. Groundwater PCE concentrations within the source area were measured at concentrations as high as 28,000 $\mu$g/L. The entire source area is estimated to be approximately 80 feet wide, 200 feet long, and 30 feet deep. Three groundwater extraction/reinjection well pairs were used to create a 65-foot-long recirculation cell. Groundwater was extracted, dosed with $\text{KMnO}_4$, retained in mixing tanks to allow the PCE in the extracted groundwater to oxidize, and then reinjected, while meeting strict Florida UIC regulations. A series of monitoring points were used to measure contaminant concentrations, $\text{KMnO}_4$ consumption, and changes in groundwater inorganic concentrations. This paper will present the results of the pilot study and discuss the full-scale design basis.


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The Department of Energy’s, Office of Integration and Disposition, places specific emphasis on establishing a prescriptive, systems engineering approach towards an accelerated clean up vision. Key elements used to achieve the cleanup vision was to integrate cleanup activities among eleven major DOE sites, establish DOE baselines and to identify and evaluate technically defensible integrated alternatives. The INEEL Complex Wide Integration and Disposition group in support of EM-20 has developed environmental restoration waste disposition maps and deactivation and decommissioning Life Cycle Maps that identify technology needs, programmatic barriers to waste disposition and life cycle cost impacts. Implementing waste disposition and life cycle maps assist DOE achieve increased program efficiencies to accelerate cleanup. The goal of waste disposition and life cycle maps is to communicate program activities, provides sites with the capability to develop long-range planning cost and waste volume projections. The maps are instrumental in developing site level regional and complex wide integration strategies pertaining to TSD capacities, removing “stovepipes,” applying successes and lessons learned and employing innovative technologies.

[315] Delivery of Permanganate Solution to a DNAPL Zone Using a Direct Push Tool and Density Induced Flow

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A pilot-scale trial of the semi-passive potassium permanganate method was conducted in a sand aquifer inside a large steel sheet pile enclosure where a thin layer of TCE DNAPL exists at the bottom, resting on a silt aquitard. The $\text{KMnO}_4$ solution (40g/L) was injected during a two day period through a short well screen driven by a direct push rig to a position 1.0m above the aquitard. Then, the movement of the permanganate solution was monitored to determine the effects of density-induced flow. The solution sank and spread out across the top of the DNAPL zone where oxidation of TCE occurred, as was anticipated in the design of the test. For comparison, the redistribution of the permanganate solution was monitored by three methods: the Waterloo profiler, bundle piezometers and subsampling of continuous cores. Immediately after injection the areaal diameter of the $\text{KMnO}_4$ zone was less than 3m and, after spreading due to density, the zone had expanded asymmetrically from the injection location to a diameter exceeding 10m. This trial shows that episodic injections with subsequent density flow can be an effective way to distribute high-concentration permanganate across DNAPL layers resting on aquitards.

[316] Accurate Assessment of Natural Attenuation using Depth Discrete Multi-level Monitoring: Evidence at Three Chlorinated Solvent Sites

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Releases of PCE and TCE decades ago at 3 industrial sites in Florida, New Hampshire and Ontario formed suspended DNAPL source zones and dissolved phase plumes within sandy aquifers. Detailed multi-level monitoring of groundwater concentrations along transects orthogonal to flow was performed at all 3 sites to examine natural attenuation processes. The Waterloo Profiler and permanently installed multi-level bundle samplers were driven by an Enviro-Core direct-push rig at more than 70 locations and used at a vertical spacing as close as 15 cm to determine peak concentrations within the source areas and downgradient dissolved phase plumes, where conventional monitoring wells had underestimated peak concentrations and even the location of the plume. Continuous cores used to determine stratigraphy and concentration profiles showed that the maximum concentration peaks along vertical profiles were extremely sharp and varied a maximum of 4.5 orders of magnitude over a vertical interval as
small as 30cm. The high resolution sampling showed that 90% of the mass discharge occurs within less than 20% of the transect cross-sectional area at each site. All 3 sites showed strong attenuation of peak concentrations from solubility to less than 15%, 10% and 1% of solubility within 10 m, 5 m and 30 m at the Ontario, New Hampshire and Florida sites respectively. Dispersion was the dominant attenuation mechanism at all three sites and degradation accounted for considerable attenuation at the Florida Site.

**[318] The Effects of In Situ Chemical Oxidation on Aquifer Hydrogeology and Geochemistry**

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*In situ* chemical oxidation is a developing class of remediation technologies in which organic contaminants are degraded in place by powerful oxidants. Although the degradation effectiveness of these oxidants has been demonstrated in numerous laboratory and field-scale tests, the overall effects of the treatment on the aquifer material have not been clearly established. A full-scale test of *in situ* chemical oxidation using potassium permanganate was conducted in a silty-gravel aquifer contaminated by trichloroethylene (TCE) at levels near saturation. Evidence for TCE degradation was found in soil and groundwater samples collected immediately after oxidant injection. Sampling at the field site 10 months after the test was completed revealed significant long-term changes in the hydraulic and geochemical properties of the aquifer. The focus of the presentation will be on the results of the long-term sampling effort as well their implications on the regulatory acceptance of *in situ* chemical oxidation. *

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**[320] Aerated Landfills, Changing the Subtitle D Dry Tomb Paradigm**

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Leachate from landfills at many sites has contaminated groundwater with heavy metals, petroleum hydrocarbons and chlorinated solvents. The current subtitle D regulations require that landfills be created as dry tombs, with liners and caps. This only increases the long-term liability and life-cycle costs of operating a landfill. Simple regenerative blowers and leachate recirculation pumps can transform a landfill into an aerobic bioreactor. *In situ* aerobic bioremediation of landfills degrades contaminants and organic components in the refuse mass faster, decreases green house and toxic gas emissions, decreases or eliminates the need for leachate treatment, increases subsidence, decreases odors, and decreases the need for covers and liners. Since direct air injection into the subsurface will also increase metal precipitation and decrease metal solubility by increasing the pH and redox potential it also may indirectly control metal mobility form a landfill. The over all effect of landfill aeration is to stabilize the landfill sooner at a fraction of the cost of a conventional dry tomb. Full-scale field demonstrations using air injection and leachate recirculation at several landfills in South Carolina and Georgia are presented for support.

**[321] Bioremediation: The Hope and the Hype**

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Bioremediation has proven to be one of the most cost effective and environmentally sound remediation technologies available at sites where it will work. Though the petroleum industry has been using bioremediation to handle oil sludges (petroleum land farming) for more than 50 years, and a patent was issued for *in situ* bioremediation of gasoline spills in 1974, this technology is perceived as being “new”. Indeed, the first patent on life, a precedence setting court case, was an oil degrading bacteria patented by GE. A plethora of new strategies have shown that chlorinated solvents, PAHs, PCBs, UXO, metals, and radionuclides can be bioremediated, biotransformed, or bioimmobilized. These techniques include passive and active aeration, injection of various electron donors and acceptors, slow oxygen releasing compounds, chelating agents, surfactants and coupling with intrinsic processes (natural attenuation). In fact, a number of companies are importing contaminant biodegraders from Russia and other countries. A number of issues are emerging that have implications for use of bioremediation to environmental cleanup, eg. release of non-indigenous species, release of genetically modified organisms, horizontal and vertical gene transfer, etc.
[322] Safe, Effective Steam Remediation: Constraints on Removal Mechanisms and Optimum Operational Strategy
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Thermal treatment using steam has proven to be an effective remediation method. An ongoing concern is the potential for mobilization and potential downward migration of large volumes of DNAPL. Finite element models of steam injection using simple homogeneous lithology predict development of a separate-phase DNAPL bank ahead of the steam front. If sufficient connected DNAPL develops along an underlying aquitard, the phase pressure can eventually overcome capillary forces, allowing the DNAPL to move downward into or through the “floor” of the steamed interval. Using a multiphase, nonisothermal unsaturated flow and transport code (NUFT), we have been performing engineering calculations to examine the behavior of all phases in both homogeneous and heterogeneous systems undergoing steam remediation. These analyses consider the effects of heterogeneity at the site, a factor that has been shown to be important to contaminant flow and transport. Using realistic heterogeneity for alluvial systems, TCE accumulations do not form due to the separation of the steam front into a number of small, advancing fronts along slightly more permeable strata. One approach proposed to mitigate downward DNAPL migration is co-injection of air to reduce steam zone temperature and provide a “carrier” gas to remove volatilized DNAPL. However, the injection of large volumes of air can present other problems regarding control of the vapor phase transport of contaminants in the relatively uncontrollable gravity-driven flow of the gas phase. When we simulate co-injection of air with the steam, the air flow tends to bypass DNAPL accumulations because of the pressure generated by vaporization of DNAPL. Thus large amounts of air move through the system without remediating the DNAPL, and creating the potential for dispersal of contaminant if vacuum collection wells are not perfectly placed.

[323] Environmental Contamination Recovery System Utilizing Soil Freezing and Jetting
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This paper discusses a new environmental contamination recovery system, which enables positive clean up of contaminated soil in a relatively short time. The system integrates the soil freezing with the jetting technologies widely used in the construction industry. The soil freezing gathers the contaminants at a point on the phenomenon that impurities are excluded from water solution when it freezes. The two-phase jet consisting of water and nitrogen gas washes contaminants off soil particles then enhances the formation of frozen soil barrier. Thus, the contaminants are not only enclosed in the frozen soil barrier but easily collected and recovered. This presentation will discuss features of the system, the principle behind the technology, the mechanism of application, an example of the application, and future developments.
Comparative Effects of HRC Barrier Applications at Three Project Locations

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Three sites were the venues for pilot testing of an injectable, semi-solid bioremediation product (HRC™) to enhance the reductive dechlorination of chlorinated solvents. Each site exhibited bioattenuation of parent compounds such as PCE, TCE, or chlorofluorocarbons, but at very slow rates. Enhanced bioattenuation was desired so an injection of HRC™, a food grade, polylactate ester was made in a barrier array using direct push technology. When injected, the HRC™ product remains in place, forming lactic acid and hydrogen plumes as a result of microbial activity upon the product, thus creating a reactive barrier around the injection area. Groundwater samples were collected from a monitoring array at each site and analyzed for selected MNA parameters, parent/daughter compounds, and field parameters. Microbial acclimation periods occurred over 1-2 months. The emergence of lactic and other acids were observed in specific monitoring wells within 1-3 months. Analytical results indicated that lactic acid often travels along preferential flow paths, but the areas impacted showed mass reduction of chlorinated compounds between 40 and 80% within 4 months. Observations have been made on the persistence of HRC™ effects depending upon the soil type present, the groundwater flow velocity, and the configuration of the injection locations.

Advanced Oxidation in Casting Emissions Reduction Program: Underwater Plasma, a New Remediation Technology for MTBE and BTEX

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The Casting Emissions Reduction Program (CERP) is a full-scale research and development foundry facility funded and run jointly by the U.S. government, U.S. automobile manufacturing companies and private industry. Located at McClellan Airpark in Sacramento, CA, CERP’s goal is to identify lower emission processes within the metal castings industry. This research is important to ensure that the U.S. remains competitive in automobile manufacturing and that the U.S. Department of Defense capabilities (as a major consumer of castings) are not compromised. As part of CERP, proprietary advanced oxidation (AO) technology is being used to treat effluent cooling water from the castings processes. Specifically, the AO system converts oxygen to ozone, introduces hydrogen peroxide, then runs the effluent mixture through an ultra-sonic process to increase chemical reaction. As might be expected, many currently operating metal casting foundries are located in industrial areas with significant groundwater contamination. To maximize the opportunities provided by the CERP research foundry, Teknikon, LLC and Concurrent Technologies Corporation (CTC) are designing a bench-scale process to research the AO system to treat groundwater contamination. The research focus is using extracted contaminated groundwater in the cooling system loop to define the AO system effectiveness for groundwater and emissions contaminant reduction.

Long-Term Effect of Biotic Reductive Dechlorination on Permeable Treatment Walls

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Increased half-life is a potentially important phenomena with respect to the cost effectiveness of zero-valent iron permeable barriers. A column study followed by a batch testing using microcosms was performed to analyze biotic reactions and their impact on field kinetic rates. In the column study ethylene formation as a by-product of the TCE degradation was decreasing gradually after 200 pore volumes. cis-DCE was the sole byproduct in the TCE degradation. These observations suggested that TCE degradation was largely the result of microbial activity. Iron participation in the TCE degradation was decreased due to various precipitates blocking reaction sites and depleting the iron reactivity. Scanning electron microscopy (SEM) was used to investigate organic and inorganic precipitates on the iron surface. For biological analysis, a fluorescent microscope was used to identify any biological film developed at after 200 pore volumes.
All rock masses are fractured to some extent. When the rock matrix has low to moderate permeability, but significant porosity, fractures form the main pathways for fluid flow and have to be well characterized when one is designing contaminant recovery programs. In nearly all cases, while fractured rock masses, including at the contaminated site scale, are characterized by strong anisotropy and heterogeneity, flow and transport in most fracture systems are controlled by individual fracture planes. While the permeability of the individual fracture planes can be quite high, they have to be interconnected one with the other to provide a pathway for flow through the rock mass. Flow and transport in a fracture plane are calculated using the parallel plate model and the cubic law such that flow rates are proportional to the cube of the aperture. However, for natural fractures that are subjected to significant normal and/or shear stresses, the parallel plate model with smooth walls is not considered valid and the flow rate versus aperture relationship shows deviation from the cubic law. When the two fracture walls are close together, fracture pore space geometry is characterized by open pore spaces and contact areas between the two adjoining fracture walls. Overall, the flow rate and fluid velocity within fracture planes are controlled by the fracture pore space geometry, i.e., heterogeneity of pore space, connectedness of open pore space and distribution of contact areas. In this current study, the pore space geometry for two discrete fracture planes was characterized using a resin impregnation method that consisted of sectioning, grinding, photographing and digitizing the resin impregnated fracture planes. The pore space data obtained showed that the two pore space data sets are characterized by bimodal distributions, consisting of contact areas and log-normally distributed open pore spaces. Recreating the pore space using simulated annealing demonstrated the controlling influence of the pore geometry on both flux and transport. In addition, the fracture pore space maps demonstrate the variability in free product entry pressures for these natural fractures and the contaminant trapping capacity produced by the heterogeneous pore space which is clearly responsible for the major problems that are encountered when attempting remediation in fractured rock masses.
MIP/GeoProbe® investigation yielded similar analytical results as the Waterloo® investigation. The direct push methods utilized in both approaches have the advantage of producing very little investigative waste, and can generally collect more and better cores per day than traditional drilling methods with split spoon sampling.

[Blast Fracturing and In Situ Treatment Agents for Passive Treatment of Chlorinated Solvent Plumes in Bedrock
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Successful cleanups have been implemented using Permeable Reactive Barriers (PRBs) in unconsolidated aquifers, however little field experience exists for applying PRBs to fractured bedrock aquifers. Example case study sites will be described which are contaminated with chlorinated volatile organic chemical (CVOC) parents and their natural breakdown products. CVOC penetration is along native bedrock fracture networks, where lateral and vertical plume configuration typically falls along orthogonally oriented stress-relief fracture systems, and manmade features (utilities that penetrate bedrock, foundations, etc.). The features complicate plume control and remediation, particularly if remediation through a PRB type system is sought. PRB implementation in bedrock involves design and deployment of a bedrock blast-fractured trench in specifically oriented alignments, and installation of in situ treatment at key treatment locations in or along the alignments. Examples will be described where the opportunity exists to combine previously developed, but never combined, remediation methods – bedrock blast fracturing to refractively channel flow of groundwater, reactive iron (abiotic) treatment, and enhanced bioremediation. Example applications of reactive iron and hydrogen release agents -installed separately in blast-fractured alignments to separately evaluate their effects on hydraulics, treatment results, and geochemical characteristics – will be described. Example modeled configurations will also be provided to demonstrate plume flow toward, through, and out of the systems.

[Multi-Agency Modeling Platform Supporting Long-Term Site Issues
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A multi-agency effort is under way to complete the development of a modeling platform that allows for communication between disparate models and databases, which supports site-specific, regional, and national environmental assessments. The Pacific Northwest National Laboratory (PNNL), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE) with technical support from the U.S. Department of Defense (DoD) Army Research and Development Center and U.S. Nuclear Regulatory Commission (NRC) are engaged in merging the EPA-sponsored Multi-media, Multi-pathway, Multi-receptor Risk Assessment (3MRA) methodology as applied to the Hazardous Waste Identification Rule (HWIR) with the DOE- and EPA-sponsored Framework for Risk Assessment in Multimedia Environmental Systems (FRAMES). 3MRA-HWIR was designed to perform national risk assessments, while FRAMES was designed to allow analysts to link models and databases to support site-specific assessments. Combining these two systems will allow for the greatest flexibility in analyzing a wide variety of assessment strategies. Both systems have been deployed and are currently available for use. The new merged system could very easily be extended to link site assessments with remediation technologies and strategies, barriers and permeable reactive treatment wall modeling, monitoring and calibration, regulatory and compliance assessments, biological site remediation technology modeling, life-cycle issues, and economic analyses.
Combining Biostimulation for Source Area Treatment with Monitored Natural Attenuation for Restoration of a Large TCE Plume
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A nearly 3 km trichloroethene (TCE) plume emanates from a former wastewater injection well completed from 60 to 90 m below land surface in fractured basalt at the Idaho National Engineering and Environmental Laboratory. A residual source of TCE, other chloroethenes, and tritium is present to a radius of about 30 m from the injection well. A 1995 Record of Decision (ROD) selected pump-and-treat as the site’s default remedy; however, five innovative technologies were identified to be evaluated for their potential to replace pump-and-treat. A field evaluation of enhanced in situ bioremediation was performed in the residual source area, while natural attenuation was evaluated for the large, dissolved plume. Lactate was injected into the former wastewater injection well to stimulate reductive dechlorination. Within 8 months of the initial lactate injection, complete reductive dechlorination to ethene was observed 40 m downgradient of the injection well. In addition, accelerated degradation of the residual source was observed along with the cessation of contaminant flux to wells just outside the residual source area after about 21 months of operations. For the large, aerobic plume, natural attenuation was evaluated primarly by comparing the transport of TCE to both tetrachloroethene (PCE) and tritium. Using these compounds as “tracers”, a method was developed to distinguish dispersion and degradation. It was determined that TCE is disappearing from the plume with a half-life of 10-20 years relative to the co-contaminants. Geochemical and microbiological data suggest intrinsic, aerobic cometabolism is responsible, in spite of the oligotrophic conditions. Based on these studies, enhanced in situ bioremediation and monitored natural attenuation have been selected by the regulatory agencies through a ROD amendment to replace pump-and-treat for the residual source area and most of the plume.

Operational Complications Associated with Application of Steam Extraction Technology to Recover Diesel Fuel
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The application of steam technology presents a unique challenge to remediation engineers, both in the design, and in the operation of a steam extraction system. This paper presents the operational complications encountered and solutions applied while operating a large-scale (approximately 4 acres) steam injection, product recovery and soil vapor extraction system at a brown field located in Minnesota. While every steam extraction application is unique, the operations experience gained from the operation of this system may be applicable to other sites. The presentation will include a brief overview of the system, where the major complications or problems occurred, root causes and a brief outline of the successful solution. The major problems encountered during the four-year operation of the system include unexpected product mobilization, vapor cooling and condensate handling and product emulsification. The emulsification of recovered diesel or fuel oil is common and can be very difficult if not impossible to break. This paper and presentation will include a detailed look at the components of this emulsion and an innovative-engineered approach to separation and control of the diesel emulsion.

Treatability Studies: An Essential Component in the Successful Design of In Situ Permanganate Systems
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The fundamental information that a well-designed treatability study can provide is essential to the success of in situ permanganate (MnO₄⁻) systems. Components of natural organic matter (NOM) can exert a significant demand during in situ chemical oxidation, reducing the mass of oxidant available for the destruction of contaminants of concern (e.g. tetrachloroethene, trichloroethene, cis- and trans- dichloroethene, and vinyl chloride). In fact, the natural oxidant demand (NOD) can be several times greater than the demand exerted by the contaminant(s) of concern. Competition for available oxidant can also lead to a reduced rate of chemical oxidation of the target compound(s). Since site characteristics vary considerably, a made-to-order treatability study approach is required. Depending on the site conditions and remedial objectives, components of the treatability study may include natural oxidant demand batch or column experiments with groundwater, soil and/or intact cores collected from the site. If sufficient information is not available in the literature regarding the rate and extent of chemical oxidation, a kinetic study may also be required.
For this former wood treating facility, simple demonstrated containment technologies were applied in combination with innovative engineering to develop a cost-effective remediation system for migration control and degradation of dense non-aqueous-phase liquid (DNAPL) in groundwater. The site, located along the banks of the Merrimack River, contains a DNAPL plume consisting largely of creosote compounds. Groundwater has been impacted and DNAPL seeps occurred in the riverbank. A system of conventional screened extraction wells has had limited effectiveness and was costly to operate. The site owner and regulators needed a more effective approach that would 1) prevent the seeps, 2) allow for natural attenuation in groundwater, and 3) allow for ceasing the pump and treat program. An innovative remediation system was installed in 1997 consisting of a 650 foot long sheet pile wall, with selective DNAPL extraction wells immediately up gradient of the wall. The rate of groundwater seepage is designed to allow groundwater and dissolved constituents of concern flux beneath the wall at a rate that can be mitigated to an acceptable level through natural attenuation. Monitoring has shown the system is functioning, and approval to cease the pump-and-treat system has been obtained. The system is providing a cost effective long-term solution.

For this former wood treating facility, simple demonstrated containment technologies were applied in combination with innovative engineering to develop a cost-effective remediation system for migration control and degradation of dense non-aqueous-phase liquid (DNAPL) in groundwater. Multiple DNAPL plumes totaling 7 acres in size occur in shallow terrace deposits in several areas of the site. A conventional pump-and-treat containment system is currently in use at the site. A long-term system was designed to take advantage of the natural vertical containment provided by a shallow clay layer and the natural attenuation capacity within the terrace deposits. Iterative 3-dimensional migration modeling was performed to design several U-shaped “biotreatment containment walls” (BTCWs). Each of the BTCWs is designed to be a low permeability slurry wall extending from the surface to the clay layer. The walls are configured to prevent migration of DNAPL while allowing controlled ground water “flushing” within the containment areas. Groundwater flow into the containment provides oxygen and nutrients to enhance biodegradation. Groundwater flow out carries a controlled flux of constituents of concern. The iterative modeling resulted in a flow that will result in a low flux of compounds of concern out of the containment area that will be mitigated through natural attenuation. The Environmental Protection Agency is currently reviewing the design.

A hindrance to the acceptance of direct push (DP) wells for long-term compliance monitoring is lack of scientific studies that compare the performance of conventionally drilled monitoring wells to those installed using direct push technology (DPT). This project evaluates the potential for using DPT in place of conventionally drilled wells, and to evaluate the potential for reduced installation and sampling costs associated with traditional monitoring wells. The following five demonstration sites are being used for this study: (1) Tyndall AFB, FL, (2) Hanscom AFB, MA, (3) Dover AFB, DE, (4) Naval Facilities Engineering Services Center (NFESC), CA, and (5) the U.S. Army’s Cold Regions Research Engineering Lab (CRREL), NH. DP wells are placed next to new or existing conventionally installed (hollow-stem auger) wells. These DP wells were designed to match the screen lengths and depths of the conventional wells, and were installed and developed in accordance with ASTM, federal and state guidelines. Groundwater samples are being collected using recommendations in EPA/540/S-95/504, Low-Flow Ground-Water Sampling Procedures. Samples are being collected from approximately 100 wells during five separate sampling rounds. These samples will be analyzed for a variety of groundwater contaminants, such as BTEX, chlorinated solvents and MTBE. Samples also are being analyzed for inorganic anions and cations. Results from the organic and inorganic analyses, as well as groundwater quality parameters will be subjected to statistical testing for evaluation and comparison between the different well types.
[343] The Effect of Barometric Pumping on Field-Determined Respiration Rate for Bioventing Process
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Field measured respiration rates are necessary to size the appropriate oxygen supply equipment and to determine the proper injection/extraction flow rate and operating mode in the design of a bioventing system. Respiration rates are also used to estimate the amount of contaminant metabolized during the bioventing process. Almost all respiration tests are conducted in an open system subject to air diffusion and interaction with the lower atmosphere. Oxygen supply to shallow surface soil by diffusion can be significant, as indicated by field collected data. Temporal variations in barometric pressure due to weather patterns may induce air intrusion into the subsurface. Their results indicate that “fresh” air can migrate several meters into the subsurface with homogeneous soils in response to a typical barometric pressure cycle. However, the effect of fluctuations in barometric pressure is generally ignored/neglected in in situ respiration tests. In this paper, the effect of barometric pumping on oxygen intrusion from the atmosphere to the shallow vadose zone is investigated using computer simulation. A model is also presented to correct the impact of barometric pumping on field-determined respiration rates.

[344] In Situ Application of Potassium Permanganate Solution for VOCs-Impacted Groundwater Cleanup — The Regulatory Perspective
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In situ chemical oxidation has been an attractive option as an expedited restoration of aquifers impacted by chlorinated volatile organic compounds (VOCs). Both pilot tests and full-scale application of potassium permanganate (KMnO4) solution have been demonstrated in the field. Compared to typical pump-and-treat technologies, use of chemical oxidation can be significantly faster and more cost-effective to reach cleanup goal. In this paper, the pros and cons of using KMnO4 solution in in situ restoration of VOCs-impacted aquifer are discussed from a regulatory perspective.

[345] Remediation of Volatile Organic Contamination from a Radioactive Environment Using Thermal and Catalytic Treatment Technologies
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The Idaho National Engineering and Environmental Laboratory (INEEL) is currently involved in a remediation effort aimed at control and remediation of vadose zone organic contamination. The selected remedy consists of the extraction and destruction of organic contaminant vapors present in the vadose zone beneath and within the immediate vicinity of the Radioactive Waste Management Complex (RWMC) on the INEEL, and the monitoring of vadose zone vapors and the Snake River Plain Aquifer in the vicinity of the RWMC. To meet Record of Decision (ROD) objectives, vapor vacuum extraction units with recuperative flameless thermal oxidation (RFTO) and catalytic treatments were designed, built, and installed within the boundaries of the RWMC. Thermal oxidation units are single chambered vessels, equipped with a propane burner and a stack. Catalytic oxidation employs a catalyst bed, commonly platinum or palladium, to oxidize the contaminants at lower temperatures. This paper will focus on issues such as process performance including progress toward remediation goals, effectiveness of the two types of processes, and costs accrued over five years of operation. Historical vadose zone and groundwater monitoring data will be discussed as process performance indicators.

[346] Field Demonstration of Surfactant-Enhanced DNAPL Remediation - Case Studies
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Three surfactant flushing field demonstrations were recently completed at different DNAPL-contaminated sites. Results from these demonstrations, Alameda Point, CA (formerly Naval Air Station Alameda), Spartan Chemical Company Superfund Site, MI, and Dover AFB, DE are presented. The main contaminants at Alameda Point were trichloroethylene and trichloroethane. Five-pore volumes of surfactant solution were flushed through the DNAPL-impacted test area resulting in over 320 kg of recovered DNAPL and 95% mass reduction (refer to Figure 1). Post remedial groundwater concentrations were reduced by 50%-80%. Full scale cost analysis showed the technology could be implemented for 1/3 the cost pump and treat. The main contaminants at the Spartan Chemical site were methylene...
chloride, trichloroethylene, ketones and BTEX. Contaminant mass removal was increased by up to forty fold during surfactant flooding activities (refer to Figure 2). The Dover AFB site was a control release of PCE into a fully contained cell. These highly successful field demonstrations are all the more impressive given the widely varying site conditions which ranged from coarse sand (Spartan Chemical) to fine sand and silt (Dover AFB). Additional details on the site conditions, performance evaluation criteria, integrated processes used, cost comparisons and results are presented.

[347]
LandTrek
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LandTrek, the web site, is an interactive web-based tool used to facilitate environmental clean up, closure, transfer and reuse of contaminated sites. LandTrek was designed to improve access to information and to encourage collaborative decision making among federal facility project managers, federal and state regulators, and other stakeholders associated with federal facility restoration projects and activities. LandTrek provides “road maps” and lessons learned to guide users through the entire life cycle from contaminant identification to site restoration, closure, transfer, and reuse. LandTrek was initially developed as a cooperative effort by the U.S. Department of Energy (DOE) and a twenty-seven-member group representing federal, state, commercial, regulatory, financial, and stakeholder organizations. Successful pilot efforts have been performed at sites in Idaho, Colorado, Ohio, New York, and California. Follow-on efforts and new pilots are in process. The current status and results will be presented at this conference and can be viewed by going to its web site, http://www.landtrek.org. This web site is constantly being updated with new information from the LandTrek pilots. The LandTrek Program is presently implemented using a highly effective, “grass roots” team consisting of DOE, the Environmental Protection Agency, the Department of Defense (DoD), various DOE/DoD Federal Site Leads, state/local regulators, site contractors, and LandTrek contractors/consultants. The LandTrek Program is designed to provide expert advice and custom design support to those that want to participate in this effort.

[348]
Enhanced Anaerobic Benzene/Hydrocarbon Biodegradation via Sulfate Amendment for Aquifer Remediation at a Refinery
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Laboratory and field evidence indicates that enhancing microbial sulfate reduction can be used to treat a large benzene plume (~0.5 square miles) in a sandy hydrocarbon impacted aquifer. Groundwater throughout the plume is depleted of electron acceptors including oxygen, nitrate, and sulfate. Groundwater in regions containing high concentrations of gasoline range hydrocarbons is saturated with methane, suggesting that hydrocarbon biodegradation occurs under methanogenic conditions. However, benzene biodegradation was not observed in incubations prepared with sediment and groundwater under methanogenic conditions. Upon the addition of sulfate however, benzene biodegradation was observed in samples collected from twenty locations throughout the site. The concentration of dissolved benzene fell to below 5 ug/L within five months in many of the samples that were supplemented with sulfate. Benzene biodegradation was also stimulated in the presence of free-phase hydrocarbon and relatively high concentrations of benzene (10 mg/L). Thus, hydrocarbon toxicity did not preclude benzene biodegradation. Further, the high capacity for the sediments to precipitate sulfide (>30 umol HS^-/g sediment) limits the potential for dissolved sulfide accumulation. The field-scale remediation effort, consisting of injecting anaerobic water supplemented with sulfate and a conservative tracer (bromide) is underway. The cost to implement the technology is a fraction of the cost of more conventional approaches including air sparging and soil vapor extraction.

[349]
Hydraulic Conductivity of Cement-Bentonite-Slag Slurry Wall Barriers
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In both the United States and the United Kingdom slurry walls are used for the containment of contaminants and control of groundwater flow. The United States mainly uses a soil-bentonite slurry wall that is comprised of bentonite-water slurry mixed with a select soil to form a backfill. In contrast, in the United Kingdom the wall is comprised of a mixture of cement, blast furnace slag and bentonite-water slurry which is left to harden in place. This paper examines the hydraulic conductivity and unconfined compressive strength of three different cement-slag slurry mixtures prepared using materials originating in the US. Unconfined compression tests were performed after one month of curing, while permeability testing was performed at one, two, three and six months. The data at six months shows that the mixture of 20% cementitious material with 70% slag replacement has the lowest permeability of 6.9 x 10^-8 cm/sec. In general, the trend in the data shows that permeability is constant from 0-70% slag replacement, and then dramatically decreases as the slag content increases from 70 to 80%. As expected, samples with 20% cementitious material had higher unconfined compressive strength than samples with 15% cementitious material, which likewise were stronger than samples with 10% cementitious material. The relationship between strain at failure and slag replacement was also examined.
Most heavy metals (i.e., Pb) have limited bioavailability in the soil. In case of so-called “induced phytoextraction”, chelating agents, as EDTA are added to soil. They facilitate the transfer of lead into the soil solution. EDTA is rather persistent and can affect soil microorganisms growth. The study was conducted with heavy metal contaminated soil in Poland (Upper Silesia Region). The aim of the study was to estimate the influence of the amendment added to the soil on growth of soil microorganisms, soil microbial activity and plant biomass production. During the field studies the effects of EDTA application to the soil on soil microorganisms, soil metabolic activities and enhance uptake of Pb to the plants (Brassica juncea) were observed. Soil samples were microbiologically examined in order to determine: the total number of heterotrophic soil bacteria, the number of Pseudomonas, soil fungi, nitrifying and denitrifying bacteria. Also the activity of dehydrogenase, urease and phosphatase were examined. The results showed that EDTA generally had no negative effect on microorganisms and soil metabolic activity. It apparently stimulated growth of Pseudomonas and denitrifying bacteria. EDTA had no significant effect on fresh and dry matter weight of Brassica juncea and Zea mays. Increased biomass of Brassica juncea and Spinacia oleracea was also stimulated in the presence of EDTA.

The processes by which microorganisms interact with toxic metals are very diverse. However, in practice, there are three general categories of biotechnological process for treating soil containing toxic metals: biosorption (bioacumulation), extracellular precipitation and uptake by purified biopolymers and other specific molecules derived from microbial cells. Biosorption is a physico-chemical process of metal binding to microorganisms and bioaccumulation is an active process using natural or recombinant microbial biomass to absorb metal ions. Among them, the biosorption (bioaccumulation) has been one of the most active processes. The aim of this study was to determine if a bacterial biosorption and bioaccumulation systems could be used to remove metals from polluted soil and whether the organic acids - compounds produced by plants (e.g. carboxylic acids) have effect on these processes. Organic acids of small molecular weight (oxalic and malonic acids) and organic acids, which have a long chain (succinic and glutaric acids), were used. The soil heavy metals-resistant isolates defined as Pseudomonas sp. and Arthrobacter sp. have the capacity to remove large quantities of Ni, Pb and Cd from Minimal Medium. There was a direct correlation between the chain length of organic acids and the extent of bioaccumulation of Ni and Cd. Generally organic acids with smaller molecular weights were more effective than the organic acids which have a long chain. Such correlation was not observed in case of Pb. The smaller effect on bioaccumulation was observed for Arthrobacter sp. in the presence of organic acids than for Pseudomonas sp.

In situ ozonation has been successfully applied to remediate soil and groundwater contamination at facilities contaminated by chlorinated solvents, wood treating chemicals and polycyclic aromatic hydrocarbons (PAHs). In situ ozonation initially oxidizes target contaminants and subsequently enhances aerobic biodegradation. At a Dubuque, Iowa site a fast track implementation of an ozone sparging system was constructed within a confined aquifer to chemically and biologically oxidize manufactured gas plant contaminants. Evidence of desorption and migration to recovery wells of coal tar DNAPLs was seen within two months of the start of ozone sparging. After the first quarter of ozone treatment in Long Beach, California groundwater sampling revealed that initial dissolved contaminant concentrations were reduced to below detectable levels. In particular, benzo-a-pyrene was reduced to below the MCL level of .2 µg/L. Separate phase mixtures of heavy oils and PAHs accumulated in wells after three months of ozonation, indicating significant desorption from soil of MGP residues. After two quarters of soil sampling showed no consistent trends, soil concentrations began to sharply decrease during the third and fourth quarters. The site has been closed using an industrial risk scenario.

IT has completed remediation work at the Umatilla Army Depot and the Sunflower Army Ammunition Plant. The former burn
area of the Umatilla site was contaminated with explosives and metals. The Sunflower site had ditches and ponds contaminated with propellants and lead. At both of these sites, thermal treatment options were ruled out for the remedial action due to public opposition. Soil washing and bioremediation were demonstrated to be ineffective, based on treatability testing. Therefore, organic stabilization was selected for the remedial action. The primary goals of the remediation were to limit the solubility of the chemicals of concern, both organic and inorganic, to minimize their leachability. The remedial action involved excavation of the impacted soils, stabilization treatment of the impacted soils, and disposal of the treated soil in a non-hazardous landfill. The presentation will describe the design and implementation of the organic stabilization at these two projects and discuss operational metrics of the full-scale treatment systems.

[354]
Regulatory Acceptance of Organic Stabilization
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The stabilization of organics in sediments, soils, and wastes has been employed since the mid-1980s. IT has successfully completed ten full-scale remediation projects involving the stabilization of organics in the U.S. and abroad. These projects have involved the stabilization of explosives, propellants, dioxins, PAHs, PCBs, pentachlorophenol, pesticides, and volatile organics. With each project, IT has been faced with obtaining regulatory approval and acceptance of organic stabilization. The presentation will describe the process, which IT employs to obtain this regulatory acceptance.

[355]
Technical Methodology for Evaluating Risk and Cost Information for Long-Term Resource Management of Contaminated Sites
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There has been a significant investment in Long-Term Stewardship, but most studies have focused on the political and planning component of this issue. This paper summarizes a technical approach to linking the established baseline and remedial risk information (e.g., risk and installation cost) with post-cleanup operations and maintenance to provide estimates of life cycle risk and cost. The key linkage was to map risk assessment land use patterns with Long-Term Resource Management (LTRM) levels. The established baseline risk assessment process is linked to a concept of LTRM levels based on human health risk metrics (e.g., cancer incidence and hazard quotient). Four different levels of LTRM were defined based on a wide range of risk values to allow decision-makers to evaluate different waste sites under different management conditions and regulations. These LTRM levels were back calculated to the baseline risk assessment and also calculated to cost to provide a complete life-cycle methodology of risk and cost information for a waste site. An example case study was conducted using this technical approach and the preliminary results will be presented along with plans to advance this approach.

[356]
Containment of Phenolic Contaminants in Soils by Peroxidase Addition
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Adsorption-desorption and binding behaviors of several phenolic chemicals (phenol, o-cresol, 2,4-dichlorophenol and 1-naphthol) were studied on two sandy loam soils collected from field and forested sites. ¹⁴C-labeled chemicals were used to track the distribution of the contaminant in the soil matrix. The effectiveness of horseradish peroxidase enzyme in enhancing adsorption and reducing desorption was evaluated for various soil-chemical combinations. Adsorption of single solutes and binary mixtures was studied. The degree of adsorption and binding was determined by quantifying the water extractable, solvent extractable, alkali extractable and soil-bound fractions. Addition of the enzyme resulted in dramatic increases in sorption and binding of phenol, cresol and dichlorophenol in single and binary solute systems. Desorption was little or negligible for these chemicals and hysteresis was significantly enhanced upon enzyme addition. A large amount of the radiolabel was associated with the humic/fulvic acid and soil/humin fractions. Containment of the target contaminant in soil was attributed to the production of strongly hydrophobic polymers in the aqueous phase and new “organic matter” on the soil.

[359]
Water Balance Data from the Alternative Landfill Cover Demonstration
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A large-scale field demonstration comparing final landfill cover designs was constructed and is currently being monitored at Sandia National Laboratories in Albuquerque, New Mexico. Two conventional cover designs (a RCRA Subtitle ‘D’ Soil Cover and a RCRA Subtitle ‘C’ Compacted Clay Cover) were constructed side-by-side with four alternative landfill test covers designed for dry environments. The demonstration is intended to evaluate the different cover designs based on their respective water balance performance, ease and reliability of construction, and cost. This paper presents a general overview of the data collected to date from the ongoing demonstration. Study conclusions are not presented in the report because data is still being collected and trends are still developing.
[360] Cr(VI) Reduction in Continuous Flow Soil Columns

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Bioremediation of chromium (VI) contaminated groundwater using innate bacterial consortia is being investigated as a novel remediation alternative. Laboratory scale soil column experiments are being performed to test our understanding of chromium (VI) reduction in an anaerobic environment simulating aquifer conditions. The column contains coarse sand inoculated with a Hanford site (Richland, Washington), subsurface bacterial consortia. The feed solution is a simulated groundwater media (SGM) amended with sucrose (150 mg/L), yeast extract (15 mg/L) and Cr(VI) (2 mg/L). In addition to monitoring column effluent for degradation products, biological markers are being used to monitor community dynamics within the column. The column data will be used to assess the applicability of batch reactor kinetics to continuous flow systems and to expand our understanding of population dynamics in subsurface systems.

[361] The Retention of Fe and Mn in Wetlands in Former Brown-Coal Mining Area

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Several hundred km² of landscape in Northwestern Bohemia (Czech Republic) has been converted into open cast mines, spoil heaps and other vegetation free, drained areas since 1960. After mining is finished, the area is restored mostly in agriculture land and forest. Costs and effect of small created wetlands on retention of Fe and Mn has been studied on selected sites of a large spoil heap (volume c. 3 000 million m³, area 2000 ha). The small wetlands made by explosive and by dredging are able to accumulate up to 1 kg of iron and manganese per m² per year. Although their low costs, high efficiency in mass retention and cooling effect, wetlands cover less than 2% of land restored after open cast mining. Important role of wetlands in mass retention, water cycle and local climate is stressed and wetlands are recommended for restoration provided that the static of spoil heaps is not endangered.

[362] New Method & Instrumentation for the In Situ Soil Contamination Survey

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The new soil vapor survey method, based on the combination of total PID and selective IR analyzers reveals vital information about subsurface pollution. The whole system is able to compensate for the influence of the following disturbing factors: presence of natural methane, soil permeability, natural subsurface barriers, type of contaminant, age of a contaminant, zoning, surface contamination, soil moisture and soil temperature. Simultaneous measurement of total soil gas/vapour concentration (PID) together with IR selective analyses for methane, carbon dioxide, and petroleum hydrocarbons, complemented by oxygen, soil temperature and pressure data brings in situ correlation graphs that give completed information about subsurface location and/or migration of the contaminant plume. Correlation among individual measured values and the interpretation of the simultaneous in situ data are explained and discussed in this contribution.

[363] Measurement of the Aerosol Size Distribution and Its Implications for Dose Calculations

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A rotating drum impactor was co-located with a high volume air sampler for ~1 y at the fence line of the U.S. Department of Energy’s Fernald Environmental Management Project site. Data on the size distribution of uranium and thorium bearing atmospheric aerosols were obtained and used to compute dose using several different models. During most of the year, the mass of 238U above 4.3 µm exceeded 80% of the total uranium mass from all particulates. During any sampling period the size distribution was bimodal. Thorium concentrations were comparable to the uranium concentrations during the late spring and summer period and decreased to ~25% of the 238U concentration in the late summer. The seasonal average of the Activity Medium Aerosol Diameter, based on the impactor data was approximately 6.5 µm. The current calculational method used to demonstrate compliance with regulations assumes that the airborne particulates are characterized by an activity median diameter of 1 µm. This assumption results in an over-estimate of the dose to offsite receptors by as much as a factor of seven relative to values derived using the latest ICRP 66 lung model with more appropriate particle sizes. Further evaluation of the size distribution for each radionuclide would substantially improve the dose estimates.
[364] Optimization of Remedial Design for Remediation of SRS's Radioactive Seepage Basins by In Situ Stabilization/Solidification
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The Savannah River Site recently began remediation of several radiologically contaminated basins using in situ stabilization. These unlined basins contain radiological contaminants, which potentially pose significant risks to human health and the environment. The Records of Decision and conceptual remedial design for these remedial actions were approved by the U.S. Environmental Protection Agency and the South Carolina Department of Health and Environmental Control. The selected remedy entails in situ stabilization/solidification of the contaminated wastes (basin and pipeline soils, pipelines, vegetation, and other debris) followed by installation of a low permeability soil cover. The remedial action will ensure that the following remedial objectives are met: minimize contaminant migration and treat potential threat source materials; protect site workers and future residents from direct exposure to radiation; and reduce infiltration, intrusion, and surface erosion. In situ stabilization/solidification of one basin was completed for one basin in late spring of 2000, while remediation of other basins continues. Shallow soil mixing technique was used for the stabilization/solidification treatment. Lessons learned from these projects are being used to optimize the remedial design and construction requirements for stabilization/solidification of other radioactive basins at SRS, where the same remedy can be applied.

[367] Case Study of Remediation of Pesticide Impacted Soils in Florida using On-Site, Ex Situ Thermal Desorption
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The remediation of 5000 tons of pesticide impacted soil was accomplished using on-site ex situ thermal desorption and completed in August of 2000 at the FMC Corporation facility in Tampa, Florida. This abstract highlights the design approval stages with regulatory agencies, bid preparation and the competitive bidding process and remedial implementation. Numerous issues were brought to solution in ways that cost effectively achieved the required soil cleanup goals. A two-part project structure was developed. Part one involved approval of the remediation approach with the regulators. Among the many issues addressed were regulatory and technical acceptance, public acceptance, local permitting, and process quality control and sampling to support compliance decisions. Due to the severe drought, reclaimed water was used in lieu of potable water to serve the thermal process that consumed water in excess of 100,000 gpd. Part two of the project structure involved planning, design and construction management practices to limit potential cost liabilities and risks, including the use of pre-approved excavation cutlines, ITRCG guidelines, and bid specifications that reduced risks, downtimes, and costs. The field duration was less than eight weeks from beginning of mobilization to completion of demobilization, with a recognition of cost savings in excess of $250,000.

[370] Long-Term Stewardship: Do We Need a New Paradigm?
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The authors are conducting an evaluation of stewardship requirements for contaminant isolation facilities. Logic diagrams have been developed. They are being used to provide a basis for scenario evaluation and probabilistic estimates of the likelihood of potential failures and consequences. This will lead to evaluation of appropriate responses with a goal of more realistic cost estimates and improved designs and technologies. It appears to us that there is a major conflict between the current approach to contaminant isolation and the requirements for effective long-term stewardship. Sophisticated systems with many components are being designed with the goal of no maintenance or monitoring after some period of institutional controls. Yet these systems will eventually fail. Waste pretreatment approaches, which minimize consequences in the event the system fails, need more attention. Also, system complexity poses challenges to monitoring and even more serious challenges to repair or replacement in the event failure occurs. Consequently, there is merit to looking at simpler designs, which are easier to monitor and repair or replace. However, they will require active long term monitoring and maintenance. The results of our work will be presented along with suggested approaches to control long-lived wastes.
An innovative decontamination technology known as Georemediation™ is currently being pilot-tested by BEM Systems, Inc. (BEM) for the decontamination and beneficial use of NY/NJ Harbor sediments under the State of New Jersey, Office of New Jersey Maritime Resources (NJMR). Georemediation™ technology, patented and developed by Aleph Group of Ithaca, New York and marketed exclusively by BEM, uses a proprietary chemical reagent that degrades and mineralizes organics and immobilizes metal contaminants. The Georemediation™ proprietary reagent contains a mixture of dispersants, clay pillaring agents, oxidative reagents, metal salts and pozzolans. The pozzolans provide increased surface area for oxidative reactions, that is further enhanced by the dispersants and clay pillaring agents which separate the fine slag and sediment particles in the waste. The oxidation of organics is further enhanced by metal salt reagents, which facilitate greater electron transfer. The inorganic contaminants are converted into highly insoluble hydrated precipitates and further immobilized into a crystalline lattice. Georemediation™ treatment process is simple, employs off-the-shelf equipment, and produces no excess contaminated water and/or air emissions. The reagent is slurried and then mixed with the dredged sediments using pug mill, etc. The homogenized material is cured in open curing cells for approximately 30 days. The end-product is environmentally benign, looks and behaves like soil, and can be used as structural or non-structural fill material. Georemediation™ process has been successfully employed at bench, pilot and full-scale levels for a wide range of contaminated wastes such as lead (Pb) contaminated soils from shooting range, TPHC, PAH, PCB, and dioxin contaminated sediments from harbors and lagoons, and oil drilling mud wastes.

At present, because of the general environmental pollution, the water reservoirs and freshwater basin can be deemed storing sites for gas, liquid and even solid wastes. The research of reaction of heavy metals compounds, organic and anorganic components of sediments and their systems with water in natural environment is oriented at the migration of chemical elements within the water-sediments systems. By determining physical and chemical features of pollutants and their interconnections to disclose the conditions of their origination, stability and mobility of individual phases. For the purposes of establishing the degree of contamination of sediments some major water reservoirs in the basin Ohre (Eger) river and drinkable water reservoirs were selected, because the Ohre river basin is situated in the north part of Bohemia, which has been heavily exposed to effects of industrial, power generation and mining activities and the flow of the river is a major recipient of mud carried to the Labe (Elbe) River. Although the current level of atmospheric pollution is largely reduced due to suspended industrial activities in the Czech Republic, installed efficient scrubbers and other end-of-pipe equipment controlling the outputs from chemical industry and due to efficient pollution control in the lignite-powered electric plants, levels of accumulated pollutants into the bottom sediments in the water region from the past are still high. Our results of the research have shown that the bottom sediments are from the point of view of concentration of trace and heavy metals considerably contaminated by antropogenous activities and they approximate limits of contamination when the use of sediments for potential agricultural purposes will be restricted.
[373] Finding Containment, Remediation and Site Characterization Solutions in Fractured Rock: The Smithville Strategy
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In 1993, the municipality of West Lincoln and the Ontario Government agreed to remediate a PCB spill site in Smithville’s Industrial Park where DNAPL contaminants had entered fractured bedrock beneath the site. The agreement recognized that technologies for characterizing and remediating DNAPL-contaminated fractured rock sites were very limited or did not exist at all. The need to establish partnerships, joint venture agreements and collaborative efforts to develop and evaluate potential solutions was recognized and a strategy adopted to accomplish this. An early success of the Smithville strategy to find partners was the securing of a collaborative research agreement with the EPA, Environment Canada, the University of Waterloo and other universities. In 1998, further agreements were forged with the EPA, DOE, Queen’s University and the Ontario Ministry of the Environment to collaborate and share information on site characterization and remediation techniques applicable to contaminated fractured rock sites. This paper presents the lessons learned at Smithville and proposes a possible future collaborative initiative among public and private sectors in Canada and the United States which would involve the establishing of a set of testing locations for developing and evaluating characterization and remediation technologies in representative fractured rock settings.

[376] Barrier Wall Installation on the Vermilion River
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Commonwealth Edison and Nicor Gas have been working to return to productive use a property that was the site of the Former Manufactured Gas Plant located in Streator, Illinois. The plant was located alongside the Vermilion River that runs through the center of this community. Several tar seeps into the river were observed across from a town park and water access area. Geo-Con, Inc. was retained to conduct the construction activities at the site including the installation of a permanent barrier wall. This presentation will chronicle the activities of turning this former MGP site into a community Greenspace. The Vermilion River meanders northward through the community of Streator. Seasonal rainfall and snowmelt varies the river’s depth and velocity from low flow, nearly dry conditions to several feet in depth at nearly 100 cubic feet per second. The riverbed is sandstone with rock outcrops, which overlay a shale bed. The site investigation revealed that the seepage into the river was NAPL migrating through fissures in the sandstone layers. Site topography and the riverbanks, some approaching 30 feet on less than 1:1 slopes, provided a challenge for construction activities. Close coordination with the Illinois EPA, Corps of Engineers, Commonwealth Edison, Design Consultants (ThermoRetec) and the local community was required and achieved in order to provide the necessary permits to construct the recovery trench design proposed. It was decided that a 500 linear foot recovery trench would be installed along the inside edge of the river into the sandstone layers using 80 mil HDPE membrane as a barrier. The liner barrier would be installed in a single lift and placed within the 20 foot deep trench. The recovery trench would be used to collect NAPL and contaminated groundwater that would be treated onsite and released. The construction activities included removal of 12,000 cubic yards of material in order to provide a working platform along the river’s edge; a rock trencher to excavate a 500 foot long by 20 foot deep by 3.5 foot wide trench, installation of a river diversion dam system, installation of the impermeable barrier and associated collection and treatment equipment, and restoration. This allowed Commonwealth Edison and Nicor Gas to remove a liability and provide the Streator community with a new park area.
Co-Oxidation treats DNAPL using a combination of an oxidizing agent and a cosolvent. The cosolvent increases the solubility of the contaminant into the aqueous phase, where oxidation reactions break them down. With currently available *in situ* oxidation technologies, mass transfer limitations prevent rapid dissolution of DNAPL into the aqueous phase, limiting the effectiveness of the technology. Mass transfer is primarily governed by the solubility of the contaminant in water, the mass transfer coefficient, and the surface area available for transfer. For compounds such as chlorinated solvents, the rate of mass transfer to the aqueous phase is very slow, which greatly increases cleanup time and cost. The Co-Oxidation process has advantages over the use of oxidants or cosolvents alone. By adding cosolvent to the oxidant solution, transfer from the DNAPL to the aqueous phase is greatly increased, allowing rapid oxidation of the chlorinated solvent by the oxidant. The co-oxidation mixture may also allow savings in treatment costs of extracted fluids. Finally, the co-oxidant may be used in the static mode (no simultaneous extraction of groundwater). This approach minimizes oversight and operation costs, and allows operation of the project in locations with limited available space.

*In Situ* Stabilization of Uranium Contaminated Groundwater in Low Permeability Clay using Phosphate Amendments with Prefabricated Vertical Drains

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*In situ* remediation of contaminated groundwater in low permeability, high clay fraction soils poses a significant technical challenge. Conventional technologies such pump and treat groundwater remediation is typically ineffective when applied to sites with low permeability soils. Earline Technologies proposes to use Prefabricated Vertical Drains (PVDs) to perform *in situ* stabilization of uranium in contaminated groundwater using phosphate amendments in low permeability clay soils located at the Ashtabula Environmental Management Project (AEMP), Ashtabula, Ohio. The PVDs are an innovative groundwater remediation technology which has been successfully tested over the last three years at the AEMP in cooperation with the US Department of Energy (DOE) National Energy and Technology Laboratory (NETL) and North Carolina State University (NCSU). The previous PVD pilot and field demonstration at the AEMP focussed on the mobilization of Trichloroethylene (TCE) through soil flushing and soil vapor extraction. PVDs are utilized in lieu of conventional wells or sumps to extract groundwater and inject flushing solution. PVDs are constructed of a geosynthetic composite system consisting of an inner core, and an outer filter jacket. Installed at relatively close spacing (<3 ft), the PVDs shorten groundwater drainage paths and accelerate the soil flushing process. The PVDs are cost effectively installed using direct push technology. Small diameter injection and extraction tubes may be installed between the inner core and filter jacket to transport the flushing and extraction fluids. After installation, the PVDs are connected at the surface with a manifold to permit injection of the flushing solutions, or a vacuum can be applied to extract the groundwater. Bench scale treatability studies have proven the concept that phosphate chemistry can satisfactorily reduce the uranium in groundwater below the 20 ppb MCL. Results of the treatability studies will be presented at the conference, as well as presentation of the conceptual design of the remediation system.

Site Characterization Technology for Long-Term Monitoring System Application

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The U.S. Army Engineer Research and Development Center (ERDC) developed sensor and sampler technologies in response to a critical need of the U.S. Government to rapidly characterize Department of Defense installations for soil and water contamination. The ERDC, under the sponsorship of the U.S. Army Installation Restoration Research Program, the Tri-Service Site Characterization and Analysis Penetrometer System (SCAPS) Research Program, and the Department of Energy EM-50 Office of Science and Technology, developed a suite of direct push sensor and sampler technologies with the capability to interrogate subsurface soil and/or groundwater *in situ*. The SCAPS multisensor penetrometer system provides a rapid cost-effective screening method for determining geophysical and contaminant properties of subsurface media in near real-time. The SCAPS multisensor penetrometer probe configurations have demonstrated the capability to provide simultaneous interrogation of subsurface soil and/or groundwater for multiple contaminant speciation and quantification, for soil geophysical properties, and for soil classification of subsurface layers *in situ*. The utilization of multisensor site characterization technologies and the deployment of multisensor long-term monitoring systems provide near real-time onsite interrogation results and typically save from 25-50 percent per site when compared to conventional sampling and offsite laboratory analysis techniques. This paper addresses the utilization of single and multisensor site characterization technologies in long-term monitoring applications for the detection, speciation, and quantification of contaminants such as heavy metals, volatile organic compounds, radionuclides, and other contaminants applicable to long-term monitoring.
New Remediation Techniques for Polluted Water and Contaminated Sediments by Application of Minerals

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Water, soil and sediments with heavy metallic ions, arsenic and etc., have been developed with applications of minerals in association with selected inorganic materials. Hazardous waste materials are produced in urban areas, through industrial productions and through mining operations. The pollutants also occurred in natural conditions with some contaminated sediments. Treatments for polluted waters, including of underground water, are required as neutralization, adsorption, concentration and precipitation. For the adsorption with hazardous elements and condensation of the precipitation, inorganic mixture, silica, alumina and iron with alkaline earths and natural zeolite powder (TRP) are used. When high-grade pollution by arsenic, ferric sulfate is added to the mixture. To prevent polluted soils and sediments provided by heavy metals, arsenic and etc., weathered soils, such as volcanic loam, and natural zeolites with calcined limestone and dolomite are applied. The volcanic loam composed with quartz, feldspars, with clay minerals, halloysite, smectite and etc., allophane, hydrous amorphous compounds and two kinds of natural zeolites, clinoptilolite and mordenite, are main minerals for this techniques. Small amounts of calcined carbonates mixed to the material, also. After this mixture of minerals was mixed with polluted soil, hazardous ions were cation-exchanged in zeolites, first, then fixed in a new crystal phase of hydrous alkaline earth alumino-silicate as minor elements, and this new phase becomes a stable one along time.

Recent Developments in Bioremediation of PCBS in Dredged Material Confined Disposal Facilities

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Land treatment and composting bioremediation technologies for dredged material were investigated in laboratory/pilot and demonstration scale studies, respectively. Laboratory mesocosm studies on one freshwater and one estuarine sediment showed significant reduction of polychlorinated biphenyl (PCB) concentrations after simulated land treatment. Mesocosm results for the freshwater sediment were confirmed in a pilot-scale test of land treatment technology at the Bay City confined disposal facility (CDF) Saginaw, MI. Composting dredged material with wood chips and biosolids, however, was not effective in reducing PCB concentrations in demonstration-scale tests at the Jones Island CDF, Milwaukee, WI and the Bayport CDF, Green Bay, WI. Explanations, based on the work of others, for the lack of success with composting are offered. The effectiveness of various bioremediation technologies for PCBs in dredged material appears to be highly variable and dependent on the technology applied.

Design Features of Confined Disposal Facilities (CDFs) for Contaminated Sediments

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Confined disposal facilities (CDFs) are one of the most widely used options for placement of contaminated sediments. These facilities must be designed to retain the suspended solids and contaminants during pumping and provide adequate storage during hydraulic placement of dredged sediments. Following placement, the finer sediments consolidate and dewater. Containment features such as liners, surface covers, and low permeability dike materials, cores, or cutoff walls can be considered as control measures for contaminated sediments. These features may serve to improve the effectiveness of CDFs in retaining contaminants and reducing the potential for contaminant losses to surface water, ground water, air, plants, and animals. This paper describes the major design considerations and several case studies illustrating containment features and discharge treatment options for CDFs.
PRBs present unique and challenging problems in terms of design and performance evaluation. There are sharp discontinuities in both physical and chemical parameters between barrier materials and the native aquifer, the chemistry occurring within the barrier may be complex, and the long time horizons of interest in barrier performance make the use of physical scale models difficult. Consequently, mathematical models are essential tools for PRB design. In this paper, we report on the implementation of a competitive cation exchange model for evaluation of Sr-90 removal in a natural zeolite PRB. The setting for this work is the West Valley Demonstration Project in western New York State where a pilot-scale zeolite PRB has been installed to remove Sr-90 from groundwater. The motivation for a cation exchange model is that it represents a more realistic representation of reactions occurring in the zeolite PRB than the traditional K_d approach. The cation exchange reaction module has been incorporated in a 1-D transport model that has been adapted so as to take advantage of the efficiencies offered through multi-processor parallel computing. The paper will examine advantages of the modeling approach, data needed to support the model, as well as numerical and computational issues important to the successful implementation of the competitive cation exchange model.

Borehole conductivity probes have been traditionally used to identify bulk formation resistivity changes in uncased and non-metallic cased holes for nearly two decades. Advances in microelectronics have made it possible to build borehole conductivity probes of much smaller diameter, allowing the probes to be run in 2-inch PVC wells widely used to monitor environmental conditions at contaminated sites. The presence of significant quantities of high resistivity Light Non-Aqueous Phase Liquid (LNAPL) hydrocarbons (motor fuels) measurably impacts the bulk resistivity, and in most cases, can be easily identified outside of the borehole. The transmitter-receiver spacing can be configured to “mull” signals inside and near the borehole, neglecting the influence of borehole fluids, casing, and sand pack, and to measure the bulk resistivity of the formation 12 to 36 inches from the borehole. Stratified floating product LNAPL can easily be identified throughout the borehole, including product perched on clay layers above the water table, outside the borehole, if present. In one study involving an old petroleum refinery, more than 70 boreholes were logged with the conductivity probe to evaluate its effectiveness in detecting free product thickness outside of PVC casings. The data from the borehole geophysical logs were confirmed with adjacent borehole drilling data (Shelby tubes) and in situ fluorometric data from a probe designed to detect subsurface hydrocarbons. A comparison between the various methods of detecting LNAPLs indicated that correlation of the conductivity with probe data, and the presence of LNAPLs, were in very good agreement.

Attempts to remediate groundwater contamination associated with the presence of dense, non-aqueous phase liquids (DNAPLs) such as trichloroethene and perchloroethene have met with limited success. The depth and areal distribution of DNAPLs often precludes any attempts at excavation while the effectiveness of pump and treat is limited by the low solubility of these contaminants, weak dispersive mixing, and slow mass transfer rates. Increasingly, source removal technologies such as in situ chemical oxidation (ISCO) using either Fenton’s reagent or permanganate are deployed to aggressively remove DNAPL mass. The performance of ISCO is dependent upon mixing between the oxidant and the contaminants, which in turn is controlled by site-specific conditions and the design of the oxidant delivery system. Key factors influencing the performance of the technology at the field scale include oxidant selection and dosing, injection strategy, and site conditions (especially geochemistry). Representative examples drawn from both detailed field and numerical modeling studies will demonstrate both the mode of DNAPL removal by the oxidant as well as the impact of various operating parameters on the performance of this technology. Finally, the implications for the design of monitoring programs to assess the long-term performance of ISCO will be assessed.
Enhanced Delivery of *In Situ* Chemical Treatment using the On-Contact Process

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EBSI is a rapid remediation service company featuring the On-Contact Remediation Process® family of technologies for soil and groundwater. The most common On-Contact configuration is a multi-stage *in situ* process utilizing subsurface propagations to transmit remediation chemistry to contaminated areas with real-time monitoring. All for a cost less than single phase / well based services. A single injection point can do the work of 9 to 36 wells and can be installed under buildings and in the presence of active USTs. Multi-stage chemical formulations for remediation are matched to contaminants, geology, and site conditions. The Contact Remediation Process® follows a model of four stages: physical, preparation, conversion, and restoration. Each of these stages will be discussed during the presentation. The On-Contact® family also includes a tension application system for groundwater remediation in fractured rock, pump and treat augmentation, a percolation bin system for shallow soils, sediment access system and new experimental wide-area *in situ* system to be commercially available in 2001. One of the major innovations of the On-Contact® family is the use of sub-surface electronics to monitor the condition and travel of remedial chemistry and the real-time survivability of the contaminants! Real-time monitoring allows for tuning of application stages, ending the unpredictability of batch *in situ* application especially through uncontrollable wells.

Enhanced *In Situ* Reductive Dechlorination of Chlorinated Ethenes in a Contaminated Aquifer

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Contamination from tetrachloroethene (PCE) and its reductive dechlorination products was discovered at a textile knit facility in eastern North Carolina. The concentrations of total volatile organic compounds (TVOCs) in the source area wells ranged from 30 micrograms per liter (µg/L) to 34 milligrams per liter (mg/L). *In situ* bioremediation was explored as the remedial approach for the saturated zone. A laboratory treatability study was conducted to determine the suitability of selected organic substrates to enhance reductive dechlorination by the indigenous microorganisms. The results of microcosm assays indicated that several organic carbon sources served as the substrates for the indigenous microorganisms and resulted in the complete dechlorination of PCE to ethene. An infiltration gallery was installed in the former PCE storage area to infiltrate a water-molasses mixture into the saturated zone. Food-grade soybean oil was selected for application via direct injection to create a biologically active zone at lower depths without the need for a continuous operation. The geochemical data suggested that environmental conditions have been established that are conducive to the reductive dechlorination processes. Significant reductions of PCE and trichloroethene (TCE) have been observed in some source area wells originally contaminated with the highest levels of PCE and TCE.

The Design and Construction of an Evapotranspiration Landfill Cover for a Semiarid Site

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The design, construction, and performance monitoring of an 8.1 ha evapotranspiration landfill cover (ETLC) within an U.S. Army facility located in central Colorado are described. The numerical, unsaturated flow model, UNSAT-H, was used to assess cover thickness and potential performance of the ETLC. A soil survey of the borrow area was conducted to inventory soil horizons that were suitable based on hydraulic and plant productivity characteristics. A lysimeter field test was conducted to assess the field water storage capacity of the cover. The construction of a 122-cm thick clay loam cover was completed in August 2000. Eight monitoring stations were established on the cover in September. Soil profiles have been monitored monthly using neutron probe technology, thermocouple psychrometers, and lysimeters to assess soil water storage and water flux rates. The plant species selected for the cover included a combination of warm and cool season native prairie grasses that were planted in late October. Management practices that were used to establish the prairie grasses included, biosolids application, soil fertilization, mulching, and installation of erosion control fabric.
**Abstracts 395, 399, 400**

**[395]**

**Coupling Natural Attenuation and Phytoremediation to Cleanup a Shallow Chlorinated Solvent Plume at the Former Naval Training Center in Orlando, Florida**

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Laboratory treatability studies were conducted to evaluate the feasibility of natural attenuation of a shallow chlorinated organic solvent plume that upwell into lake Druid from OU4 at the former Naval Training Center (NTC) in Orlando, Florida. The results of batch microcosm tests indicated that trichloroethylene (TCE) and perchloroethylene (PCE) were not completely dechlorinated to ethene in deep core samples obtained from the shallow aquifer. However, the aquifer material amended with different carbon sources enhanced the degradation of PCE and TCE to ethene. Recognizing that in the rhizosphere of some plants, released plant exudates and enzymes stimulate biochemical activity and enhance the biodegradation of environmental contaminants, phytoremediation treatability studies of PCE and TCE were performed in the greenhouse. The phytoremediation tests confirmed the reductive dechlorination and mineralization of PCE and TCE in the root-zone (rhizosphere) of willow and cottonwood trees. As a result, phytoremediation is being implemented at OU4-NTC to achieve three goals: (1) as a polishing step for the residual chlorinated solvents following source removal, (2) reduce the high recharge to the shallow aquifer and minimize the rate of discharge into lake Druid, and (3) enhance natural attenuation by increasing dissolved natural organic carbon (source of electrons) in the aquifer.

**[399]**

**Assessment of Sediment Quality in Baltic Sea Coastal Waters**

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The investigations on the quality status of the sediments in the German Baltic Sea coastal waters focused on the natural background as assessment basis. On this basis, the chemical sediment quality can be evaluated. Furthermore, the decision about the relocation of dredged material from federal waterways depends on this assessment. The sediment quality of the German Baltic Sea coastal waters between the Kiel Bay and the Stettin Lagoon has been analyzed in order to obtain guide concentrations of the natural level. Relevant parameters had been selected according to the Helcom Liste of priority harmful substances e.g., metals (Hg, Cd, Cr, Cu, Pb, Ni, Zn and As), PAHs, PCBs, PCDD/F and nutrients. The results show that regional differences exist, so that a regionally differentiated assessment is required. With regard to the removal of dredged material, a hierarchical decision support system for the re-use of that material was developed including a disposal on land and in water. Ecological and economic conditions have to be compared in this decision making process. This procedure is illustrated at the example of the enlargment of the harbour excess in the Wismar Bay.

**[400]**

**A Laboratory Test to Evaluate Potential for Steam Enhanced Removal of Coal-Tar in a Sand Matrix**

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A laboratory scale treatability study was conducted to determine the feasibility of removing coal-tar constituents of concern from a sandy soil by passing steam through the contaminated matrix. This limited laboratory test was conducted over a period of 4 hours and was not intended to determine an ultimate percentage of tar mass or of individual constituents that could be removed by steam extraction technology. The experiment was conducted in a 8” long, 2” ID stainless steel column with a packed soil volume of approximately 341 mL. Effluent condensate was collected directly in 40 mL VOA vials submerged in ice bath to minimize losses of volatiles. During about 134 minutes of steam injection, about 341 grams of steam were injected and 336 grams of condensate were collected which is equivalent to about 2.63 pore volumes of the sand pack. Altogether 10 aliquots of condensates were sequentially collected and chemically analyzed for volatile and semi-volatile constituents. This limited laboratory scale treatability experiment showed that the steam flow through the contaminated sand pack extracted several hydrocarbons most likely through vaporization of the more volatile constituents. However, the data also indicated that the high volatility compounds still remained in the sand matrix after the steam extraction experiment ended. The low volatility compounds remained in the soil matrix without much removal occurring by the applied steam. It is concluded that steam enhanced extraction alone is not likely to be sufficient to remove the majority of the coal-tar mass. Presumably much higher temperatures could be more effective in removing the low volatility fractions of the coal-tar as well as the readily volatilizable constituents.
[404] Characterization of a Ca-Alginate Based Ion Exchange Resin and its Applications in Lead, Copper and Zinc Removal

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Characterization of a novel Ca-alginate based ion exchange resin and its application in the metal removal were investigated in this study. The metal removal percentages increased from almost 0 to a higher value (almost 100% for the metal concentrations < 0.1 mM) from pH 1.2 to 4 and a plateau was established at pH > 4. The removal percentages were in the following descending order: Pb²⁺ > Cu²⁺ > Zn²⁺ at pH < 4. Lower initial concentration and ionic strength slightly enhanced the removal percentage. The maximum metal removal capacities (q_max) were 2.01 and 2.04 mmol/g for lead and copper, respectively, much higher than activated carbons and other reported biosorbents. Competitive effects were important for the zinc removal, but less significant for lead and copper uptake. The organic leaching from the resin was negligible. The single- and multiple-species metal ions were removed completely within about 90 and 130 min, respectively. The lead removal became much faster when its concentration was decreased and in the absence of other metal ions. Presence of the competitive metal ions significantly reduced the metal uptake rate. The removal process kinetics were controlled by the mass transfer, while the local equilibrium followed an ion exchange relationship.

[406] Effect of Heavy Metal Ions on the Wastewater Treatment using Membrane Bio-Reactor (MBR)

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Bench scale experiments were conducted using a 9-L activated sludge bioreactor equipped with 0.06 m² submerged polysulfone hollow fiber membrane. Using medium strength synthetic wastewater, the system was operated without wasting sludge, and with a hydraulic retention time of 24 hours. The system showed a high resistance to fluctuation in environmental factors such as temperature changes, dissolved oxygen level, and the leakage of sludge. With a pressure drop of 0.96 bar applied as the trans-membrane pressure, a rapid decrease in flux occurred within 2 days; the flux dropped from 3.2 to 1 m³/m² day. The flux declined steadily over 10 days to a level of 0.5 m³/m² day, and maintained at this stable value over two months. The effects of introducing Cr (VI) to MBR system were investigated with different feeding concentrations (0 mg/L – 5 months, 0.4 mg/L – 1 month, 10 mg/L – 1 month and 50 mg/L – 1 month). High COD and BOD₅ removal could be maintained even feeding Cr (VI) concentration was 50 mg/L, which meant the carbonaceous removal was not obviously affected. However, nitrification was badly deteriorated when feeding Cr (VI) was 10 mg/L. These results were compared with data got from batch experiments. At the same time, a comparison was conducted on the sludge production in different MBRs as well as conventional activated sludge process.
**Abstracts 408, 409, 414**

**[408]**

*Modification of a Commercial Activated Carbon for Metal Adsorption by Several Approaches*

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It has been widely recognized that metal removal by activated carbon adsorption is due to the surface complex formation between the metal ions and the acidic surface functional groups. As the amount of the functional groups of the commercially available activated carbons, such as Filtrasorb 200 from Calgon is relatively low, improvement of the carbon by using several novel modification approaches is investigated in this study. Filtrasorb 200 was first modified by hydrogen peroxide in an acid medium or by nitric acid. The carbon then was dried in a 100 °C oven for 24 hours. The porosity of the modified activated carbon was then analysed by N₂ and CO₂ adsorption isotherm experiments. It was found that both agents slightly altered the surface area of the activated carbon. The surface functional groups were quantified by means of the titrimetric techniques. Both agents with the optimum concentrations can significantly enhance the amount of the acidic functional groups in the carbon. Adsorption of metal ions, such as copper and lead onto the activated carbon modified above was conducted under the varied pH, ionic strength, and initial metal concentrations. Kinetic study showed that the modifications greatly decreased the adsorption equilibrium time. In addition, the metal uptake was dramatically increased. The removal was found to be dependent on the solution ionic strength and the initial concentrations. Maximum adsorption capacities (qₘₐₓ) determined by the Langmuir isotherm equation were 1.5, 4.5, and 9.0 mg/gram for unmodified, modified by hydrogen peroxide and nitric acid, respectively. The relationship between copper ion adsorption capacity and different surface functional groups of modified activated carbon was discussed. Finally the adsorption process for single- and multiple-species metal ions was described by using the surface complex formation model (SCFM).

**[409]**

*Phytosorption Method of Decontamination of Soils Polluted with Heavy Metals and Radionuclides*

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After Chernobyl accident the major territories were contaminated with radionuclides of cesium, strontium, plutonium, and also with some heavy metals (Pb, Cd). Thus the clearing of the major contaminated territories by usual engineering methods seems to be improbable or impossible. In this communication the results of study a possibility of application phytosorption method for remediation of the contaminated soils are presented. A number of soil additives including activated carbon, mineral adsorbents, its modified forms and composite materials were tested on their influence of ¹³⁷Cs transition in plants (sunflower, rape, lupine, amaranthus, mustard, Jerusalem artichoke). The influence of sorbent type, its amount and degree of soil activity on the process of soil decontamination was studied. The field experiments were carried out on ¹³⁷Cs - contaminated soil, which has level radioactivity in the interval from 24 to 0.9 kBq/kg. The field investigations showed not ordinary role of sorbents in migration of radionuclides in complicated system soil-plant. It was shown that in the presence of mineral sorbent the accumulation of ¹³⁷Cs by plant only a little bit exceeds the natural process of phytoextraction, while the use of composite carbonmineral sorbents essentially increase cesium concentration in plant green mass. Such effect was observed at the different activity of the soils. It was established that the additions of carbonmineral sorbents into the soil increases the growth of the shoots and the harvest as a hole. It is probably caused by presence in the sorbent matrix of some microelements, and also by the ability of the sorbents to remove from the soil the contamination of the herbicides and pesticides, which depress the growth and development of the plants. At the same time we can observed effect of decreasing migration of radionuclides in the plants and essential decreasing of vegetative mass in comparison with the control. This effect is observed at addition in the soils some sorbents and complexons which can strong fix radionuclides. It means, that using linking function of sorbents or complexons towards radionuclides makes possible the producing of environmentally clean agricultural produce on the polluted soils. During the test of a number of radioaccumulating plants it was determined, that amaranthus is a plant with the highest potential for extraction Cs-137 from the contaminated soils, at first, due to the natural high specific radioaccumulative ability (k₁=1.5-2.5), secondly because of high productivity (k₂=2.5-3.5). The introduction of sorbent increase both these properties (k₃=6-8) of amaranthus, that makes possible the use of it for removal of cesium from the soil.

**[414]**

*In Situ Thermal Desorption of Soils, Completed Project Results, and New Application for Treating MGP Waste*

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*In Situ* Thermal Desorption (ISTD) is a soil remediation process in which heat and vacuum are applied simultaneously to subsurface soils. Heat flows into the soil primarily by conduction from heaters typically operated at 700-800°C. The heaters are installed in wells at regular intervals within the soil. As soil is heated, contaminants in the soil are vaporized or destroyed by several mechanisms, including evaporation, steam distillation, boiling, oxidation, and pyrolysis. The vaporized constituents are drawn toward extraction wells. Compared to fluid injection processes, the conductive heating process during ISTD is very uniform in its vertical and horizontal sweep. The combined
Iron filings as a reactive media have proven their ability to dehalogenate VOCs to less dangerous compounds. An above ground iron filings treatment system has been developed to overcome the deployment, removal and unpredictable hydraulic and chemical characteristics of in situ iron filings permeable barriers. During operation, contaminated groundwater is extracted from three artesian wells and distributed to multiple containers holding the reactive media. Hydrogen produced during dehalogenation is allowed to vent to the atmosphere. Iron that has gone into solution during the reduction process is precipitated out as iron oxide as the water cascades through “aeration” trays. This forces the precipitation of iron oxides, which are filtered out of solution by sand filters. The combination of artesian pressure and elevation drop allows the entire system to function without the need for pumps. Typical VOC destruction efficiency for the iron filings system is about 90%. This above ground iron filings treatment systems combines the benefits of a conventional in situ reactive barrier with an ex situ facility which allows for tight control of process flow, accurate monitoring and easy decommissioning.

**[415]**

**Passive Above Ground Iron Filings Treatment of Contaminated Groundwater**  
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Iron filings as a reactive media have proven their ability to dehalogenate VOCs to less dangerous compounds. An above ground iron filings treatment system has been developed to overcome the deployment, removal and unpredictable hydraulic and chemical characteristics of in situ iron filings permeable barriers. During operation, contaminated groundwater is extracted from three artesian wells and distributed to multiple containers holding the reactive media. Hydrogen produced during dehalogenation is allowed to vent to the atmosphere. Iron that has gone into solution during the reduction process is precipitated out as iron oxide as the water cascades through “aeration” trays. This forces the precipitation of iron oxides, which are filtered out of solution by sand filters. The combination of artesian pressure and elevation drop allows the entire system to function without the need for pumps. Typical VOC destruction efficiency for the iron filings system is about 90%. This above ground iron filings treatment systems combines the benefits of a conventional in situ reactive barrier with an ex situ facility which allows for tight control of process flow, accurate monitoring and easy decommissioning.

**[416]**

**Use of Engineered Wetlands to Phytoremediate Explosives Contaminated Surface Water at the Iowa Army Ammunition Plant, Middletown, Iowa**  
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Sediments impacted by organic compounds, heavy metals, and other potentially toxic contaminants can be effectively managed in various ways. They can be removed by dredging and treated ex situ, as appropriate, prior to disposal. The sediments can also be managed in place, or in situ. In situ management approaches can include natural recovery, encapsulation, or treatment by biological or chemical means. Choosing the most appropriate and environmentally protective approach is often a complicated process and may, for some projects, best involve an integration of several different technologies, e.g. dredging plus subsequent encapsulation. Installation of in situ sediment caps, or barriers, can be an attractive management approach, implemented alone or in concert with other management technologies. Appropriately designed sediment barriers can: physically isolate contaminated sediments from benthic macroinvertebrate communities; stabilize the contaminated sediment mass; significantly reduce the movement of dissolved contaminants into the overlying water column; and provide a replacement substrate for flora and fauna. AquaBlok™ is a clay based capping technology displaying performance attributes equivalent or superior to granular-based capping materials. Summarized in this presentation are results of AquaBlok™ installations in deepwater and wetland environments as well as a discussion addressing the conceptual integration of clay based barriers with in situ treatment technologies.

**[417]**

**Use of a Clay Based Barrier Technology for In Situ Management of Impacted Sediments**  
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Sediments impacted by organic compounds, heavy metals, and other potentially toxic contaminants can be effectively managed in various ways. They can be removed by dredging and treated ex situ, as appropriate, prior to disposal. The sediments can also be managed in place, or in situ. In situ management approaches can include natural recovery, encapsulation, or treatment by biological or chemical means. Choosing the most appropriate and environmentally protective approach is often a complicated process and may, for some projects, best involve an integration of several different technologies, e.g. dredging plus subsequent encapsulation. Installation of in situ sediment caps, or barriers, can be an attractive management approach, implemented alone or in concert with other management technologies. Appropriately designed sediment barriers can: physically isolate contaminated sediments from benthic macroinvertebrate communities; stabilize the contaminated sediment mass; significantly reduce the movement of dissolved contaminants into the overlying water column; and provide a replacement substrate for flora and fauna. AquaBlok™ is a clay based capping technology displaying performance attributes equivalent or superior to granular-based capping materials. Summarized in this presentation are results of AquaBlok™ installations in deepwater and wetland environments as well as a discussion addressing the conceptual integration of clay based barriers with in situ treatment technologies.
Low cost, robust sensors are needed for remote, in situ monitoring of contaminants, verification of cleanup remedies, or other indicators of potential stewardship failures in a variety of media. Sensing targets include contaminants (organics, metals, radionuclides), diagnostic parameters (dissolved oxygen, etc.), water quality indicators (salinity, pH, Eh, oxidation-reduction potential, etc.), soil characteristics (dielectric constant, matric potential, moisture content, erosion, etc.), meteorology and climatic variables, and radiation levels. Some commercially available sensors can meet the general functional requirements for sensing these parameters in soil or groundwater. However, site-specific constraints, such as the size of a borehole or depth to the water table, are the chief obstacles to the deployment of existing sensors. Harsh operating conditions, variable contaminant levels, mixtures, and distributions present challenges for the deployment and operation of sensors for long-term monitoring applications. This paper discusses deployment issues, such as methods to emplace sensors, integration of a suite of sensors, electronics and communications interfaces, construction of modular monitoring networks, and telemetry of sensor output to a centrally located processing station.

The zero-valent iron (ZVI) used in permeable reactive barrier (PRB) installations comprises a kiln-fired, milled mixture of cast iron cuttings and borings arising from a variety of primary manufacturing processes. Confounding differences in commercial ZVI reactivity for both VOC degradation and trace metal removal have been documented by several research groups. The purpose of this study is to examine in detail the chemical, metallurgic and surface properties of commonly used ZVI end products, as well as the individual feedstocks used in these mixtures to determine if differences in reactivity can be traced to feedstock composition and/or milling procedures. Analyses including physical and chemical characterization (specific surface area, bulk density, chemical leaching, SEM, XRF and XRD) and reactivity column tests will be completed on commonly used end products and 12 feedstocks. Reactivity testing will focus on the ability of these materials to degrade common chlorinated ethenes. Results from these tests will be presented in terms of any correlations arising between reactivity and metallurgic/chemical characteristics of these materials.

Chemical reduction by in situ gaseous treatment has been shown to be a promising innovative approach for treatment and immobilization of metals and selected radionuclides in the vadose zone. In particular, laboratory investigations indicate that reduction and immobilization of hexavalent chromium, Cr(VI), in contaminated soils can be readily achieved through treatment with diluted hydrogen sulfide gas. A field test has been undertaken at a waste site that involved the injection of a mixture of 200 ppmv hydrogen sulfide diluted in air. The gas mixture was drawn through the site soil by a vacuum applied to extraction boreholes located at the site boundary, and residual hydrogen sulfide was removed prior to release of the air back to the atmosphere. Monitoring of hydrogen sulfide in the extracted stream was used as a basis for assessing treatment progress during the injection test, which lasted 76 days. No detectable releases of hydrogen sulfide to the site atmosphere occurred during the test. Comparison of Cr(VI) analyses of soil samples taken before and after the test indicated that 70% of the Cr(VI) originally present at the site was reduced and thereby immobilized by in situ gaseous reduction. Treatment was generally better in zones of higher permeability sands containing less silt and clay, but the concentration of Cr(VI) in all post-test samples was well below regulatory cleanup criteria.
Assuring the Performance of Subsurface Monitoring Systems for Long-Term Stewardship: Challenges
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This paper identifies the challenges and innovations needed to provide effective long-term groundwater monitoring for most large-scale stewardship programs. Issues related to monitoring structure longevity include: the long-term performance of materials used in the construction of wells (e.g., corrosion resistance and chemical/electrochemical interactions between contaminants or sensors and well materials); security and concealment from vandalism while providing signage, ease of access, and locating; and maintenance and rehabilitation requirements for periods of 100 years or more. Sampling systems (in situ sensors, automated sampling or other) using automated analysis systems, and remote transmission to a central data management system will not only require the development and testing of new technologies, but also need to accommodate changes in a dynamic real world groundwater flow system. A comprehensive subsurface science and technology agenda for long-term stewardship should consist of activities that will increase knowledge and capabilities in four areas: 1) understanding basic subsurface processes; 2) better capabilities for monitoring and data collection and storage; 3) new computer models, predictive capabilities, and data visualization methods; and 4) implementing a process that continually upgrades the quality of monitoring structures being installed. The agenda will need to address the integration of existing knowledge from different technical disciplines and sources, identification of data gaps and unknowns, and the necessary laboratory and field experiments to fill those gaps. These efforts will involve scaling the results from small-scale experiments to field-scale problems.

Challenges in Monitoring the Short-Term and Long-Term Performance of DNAPL Remediation Technologies
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Preliminary site characterization at Launch Complex 34 (LC34), Cape Canaveral Air Station, Florida showed the presence of chlorinated volatile organic compounds (CVOCs), primarily trichloroethylene (TCE), associated with the soil and groundwater. The high CVOC concentrations indicated the presence of dense non-aqueous phase liquid (DNAPL) and detailed characterization of the DNAPL source zone was subsequently conducted. Three remedial technologies – oxidation, resistive heating, and steam injection were applied to adjacent treatment plots within the source zone. There are four challenges in monitoring the performance of remedial actions at DNAPL sites that had to be addressed at LC34: (1) characterizing the hydrology and chemistry of the aquifer adequately to enable effective and economical application of remedial actions; (2) monitoring the progress of the remedial technology and potential for DNAPL migration from the treatment zone; (3) characterizing the chemistry of the aquifer following the remedial action to evaluate short-term soil and groundwater quality improvements; and (4) monitoring the long-term effectiveness of the remedial action in terms of potential for contaminant rebound and plume generation. At LC34, soil coring and well clusters were used to identify and define the DNAPL source zone for remediation. The number and locations of the soil cores were determined on a statistical basis using TCE concentration variances obtained from the preliminary site characterization. Soil coring was repeated following the remedial actions and the results were evaluated statistically. Groundwater and surface emissions monitoring was conducted periodically during the remedial actions to determine remediation progress and potential for contaminant migration. Additional monitoring of soil and groundwater was conducted selectively for the next one year to determine long-term effectiveness. This project was conducted as part of a demonstration of DNAPL remediation technologies organized by the Interagency DNAPL Consortium (IDC), a group consisting of the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), U.S. Department of Defense (DoD) and National Aeronautic and Space Administration (NASA).
The road to deployment and sector commercialization for the Well Injection Depth Extraction (WIDE TM) Technology is presented and discussed pacing the technology from the academic R&D initiative through to demonstrations at DOE and DoD field sites. Discussions of four different private / government partnerships with information pertaining to the contractual relationships of the organizations, project management and planning issues, regulatory compliance interfacing, public participation, partnership approach, and lessons learned will be presented and discussed. The WIDE technology began through research funding through a University Cooperative Agreement administered by the National Energy Technology Laboratory (NETL) to West Virginia University in early 1992. With laboratory and pilot testing successes field demonstrations were initiated. The first site was a former gas station facility and the project team assembled for this 1996 demonstration included the DOE-NETL, West Virginia University, the Nilex Corporation, and the Ashland Petroleum Corporation, the site owners. In early 1997 the NETL partnered with the DOE Ohio Field Office for demonstration of the WIDE TM technology at the Ashtabula Environmental Management Project. Here the demonstration team included the DOE-NETL (EM-50), Ohio Field Office (EM-40), West Virginia University, North Carolina State University, 3M Corporation, Nilex Corporation, the SpinTek Corporation, and Earthline Technologies. The efforts of this project proved beneficial with results indicating the WIDE TM technology could support the DOE-OHIO for site remediation. Two deployments of the WIDE TM technology scheduled for 2000 and 2001 included the Former Lockbourne Air Force Base pilot demonstration and the DOE Accelerated Site Deployment project planned for the Battelle – West Jefferson Site, both sites are located in Columbus, Ohio. The Former Lockbourne AFB project began in September 2000 with the project team consisting of the following seven organizations: US DOE – National Energy Technology Laboratory, US Army Corps of Engineers – Louisville, KY, Nashville, TN, and Huntington, WV District Offices, Informatics and Nilex Corporations, the North Carolina State University, and the Rickenbacker Port Authority. For the DOE Accelerated Site Technology Deployment project at the Battelle – West Jefferson Site, both sites are located in Columbus, OH the project team includes: DOE-NETL, DOE-Ohio Field Office and DOE Columbus Environmental Management Project, the Informatics and Nilex Corporations, the North Carolina State University, Battelle, and the 3M Corporation. The Ohio EPA was the regulatory organization involved for work performed at the three Ohio sites.

[426]
Private Sector, University, DOE, and DoD Partnerships for Deployment and Commercialization of the Well Injection Depth Extraction (WIDE TM) Technology Case Study
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A conference on containment requires a paper on current concepts with regard to permeability. Traditionally permeability has been regarded as a fixed property such as strength, which can be varied only by a change in the effective stress or chemical damage. In fact permeability is a dynamic property and zones of varying permeability may move through the material as reaction fronts move through it. It follows that permeability of a barrier in the ground can be varied by orders of magnitude, upwards or downwards, if reactive chemicals are introduced adjacent to it. This offers the potential for repair of barriers by chemical manipulation. The challenge is then to identify the best repair chemicals – these will be specific to the barrier chemistry and the damaging species. Examples will be given showing how the same species can either damage or help depending on the chemical history of the barrier and the enormous range of permeability control that can be achieved. Recognition of the dynamic nature of permeability raises two other important issues: (1) permeability may change as a function of time and chemical reaction. Permeability will exert a strong influence on the rate at which reactions move through the material. Reactions may occur much faster in young samples so that it may be useful to protect a young barrier from aggressive species; and (2) a sample cored from a barrier may show a quite different permeability to a sample from the edge of the wall where reaction is occurring with the surroundings. This can mean that samples cored from a wall are poor indicators of the overall barrier permeability – and give markedly high values as in fact in-ground reactions often slowly reduce the permeability of a barrier.

[427]
Permeability: A Dynamic Property of Barrier Materials
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[430]
A New Hysteresis Coefficient Based on a Differential Approach for Characterizing the Adsorptive-Desorptive Behavior of Contaminants in Soils
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Mexico D.F., Mexico
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ESIQIE del IPN
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TESE
Ecatepec, Edo. de M xico M xico

In this work, a new hysteresis coefficient is proposed and its usefulness for determining the adsorption-desorption behavior of pollutants on soils is examined. In soil pollution and remediation, the adsorption and desorption play a key role on pollutants availability and transport. In other processes of environmental interest, such as the removal of toxicants and persistent organic compounds from wastewaters using activated carbon packed bed
columns, the adsorption and desorption also are the basis of process sizing, design and operation. Most of the research has been focused on adsorption, and relatively less attention has been devoted to desorption. For several pollutants and solid matrices, the desorption pathway is different from that of the adsorption. This phenomenon is known as hysteresis. Here, we define a hysteresis coefficient $C_H$ as the ratio of the slope (derivative) of the adsorption curve and the slope of the desorption curve in a given point $(C_q, q)$ of interest. We demonstrate that: i) $C_H$ is dimensionless; ii) when hysteresis is not important, $C_H = 1$, i.e., the adsorption is reversible; iii) when hysteresis is important, $C_H > 1$, i.e., the adsorption is irreversible; iv) the larger the hysteresis, the larger the $C_H$; v) the $C_H$ can be determined at any convenient point $(C_q, q)$ of interest of the adsorption curve, performing a few consecutive desorption steps, and there is no need to determine the full adsorption-desorption cycle; vi) the $C_H$ is consistent (i.e. $C_H \geq 1$) with the most common isotherm models (linear, Freundlich and Langmuir); vii) there exist also analytical, particular, simple equations for finding $C_H$ for the linear, Freundlich and Langmuir isotherm models; and viii) the $C_H$ shows several advantages over the well known hysteresis indices defined by Huang and Weber (1997) and Ma et al. (1993). Using experimental data from refereed literature, we also show that the $C_H$ provides a quantitative basis for i) comparing the irreversibility of the adsorption of different individual pollutants on a given soil; ii) comparing the irreversibility of the adsorption of a given pollutant on different soils; iii) determining the effect of aging and weathering on adsorption irreversibility; and iv) evaluating the effect of in vitro addition of surfactants and solvents. Overall, the $C_H$ allows for the quantitative determination of pollutant availability and this, in turn, could be a valuable tool for estimating the remediation potential of polluted soils.

[431] Geochemical Investigation of Three Permeable Reactive Barriers to Assess Impact of Precipitation on Performance and Longevity
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A geochemical assessment is underway at three permeable reactive barrier sites to evaluate performance and longevity issues. The assessment is being carried out at former NAS Moffett Field (California), Dover AFB (Delaware), and former Lowry AFB (Colorado). These sites were selected because they differ in barrier design, contaminant types, hydrology, and geochemistry, and therefore represent a number of factors that could have bearing on long-term performance. Analysis of groundwater and iron cores were the primary means used to evaluate the potential for precipitate formation, which could affect both the surface reactivity of the iron as well as the hydraulic conductivity of the reactive cell. In addition, geochemical modeling with PHREEQC and Geochemist’s Workbench was used to simulate iron reactivity in each of the three groundwater types and assist in understanding precipitation sequences. The study focused on behavior of native inorganic constituents of the groundwaters, such as dissolved oxygen, calcium, magnesium, alkalinity, and sulfate, as potentially able to influence precipitation within the reactive cells. In addition, long-term accelerated column tests are currently underway using two different iron-groundwater systems, which model the Moffett Field and Lowry barriers. Results of the column tests will assist in understanding precipitation kinetics and physicochemical characteristics.

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One of estimation ways of consequences as a result of explosive emergencies is the physicochemical analysis of objects of an environment. Morphological and microelement analysis of samples of objects of an environment are most informative for a feature detection of aerosol fragments of an explosive origin and form the basis development of models of prediction of aerosol impurity of terrain as a result of emergencies. It was selected in the report the three-level scheme of the analysis for detection of impurity of terrain at explosive emergencies: • The analysis of an environmental factors; • Isotope, element and morphological analysis of samples of objects of an environment; and • The analysis of structure and morphology of fragments of model explosive experiment. It was shown, that the form, morphology and element structure of aerosol fragments characterized its explosive origin. The report of the research analysis demonstrates that the offered technique is most real for detection of aerosol fragments in objects of an environment and detection of explosive experiments. Refinement and development of separate aspects will allow to improve the scheme of monitoring and models of prediction of aerosol impurity of terrain as a result of emergencies.
Clark Island, located in the St. Lawrence River near Valleyfield, Québec, was a site of a manufacturing facility that produced alum, hydrofluoric acid, and sulfuric acid. Past operating practices resulted in the losses of pyrite cinder wastes, which are high in metals, to local waters. An initial sediment quality survey was conducted to determine the general range of metals concentrations and to explore potential metals bioavailability based on an analysis of simultaneously extracted metals (SEM) and acid-volatile sulfides (AVS). Metals concentrations in all samples were found to exceed typical screening/advisory sediment quality guideline values. However, results of the SEM/AVS analysis indicated that the metals present in the sediment were not biologically available. Based in these initial findings, a detailed ecotoxicological evaluation was designed to verify that the metals present in the sediment were not impacting the aquatic community. The results of the sediment quality study indicated that risks to the benthic community were limited to a clearly defined area associated with a high occurrence of the pyrite cinder, possibly due to substrate issues. Adjacent areas with elevated metals showed a low concordance among metals concentrations, sediment toxicity, and altered benthic community structure. Fish tissue residue analyses showed metals concentrations that were not significantly different from the regional average for this section of the St. Lawrence River.

Phytoremediation is being evaluated at a manufacturing facility in southern New Jersey to address contaminated soil, sludge and lagoon sediment and provide a site-wide remedy that includes a landfill “phyto-capping” system. This approach, which has received preliminary regulatory support under the NJDEP Site Remediation Program, combines the major elements of a conventional landfill cap into a single unit, while simultaneously providing an on-site treatment remedy for impacted media. This paper discusses the results of a four-month laboratory study, in which 35 plant species native to the site were tested for the treatment of soil and sludge impacted by petroleum hydrocarbons and metals. In this extensive study, more than 300 samples of soil/sludge mixtures, plant roots and leaves were analyzed. This paper also describes a phytoremediation field pilot study, which is currently being conducted to examine the “phytoretreatability” of 18 plant species including grasses, shrubs and trees. The 10-month field study will evaluate the magnitude and rate of organic degradation and metals uptake and accumulation under field conditions. The results of the study will determine the applicability of the phytoremediation capping system for the entire eight-acre landfill as a means to optimize land use through the use of an innovative technology.

For many years, a common misconception has propagated through the environmental community concerning “regulatory acceptance” of technologies used for environmental problem-solving. Decision makers and technology users want to use the right tool for the job, but are often unwilling to try something innovative or new because it may be considered to be “untested” or “unproven.” Few people want to be the first to try something new, particularly if it doesn’t work for their application or is misapplied and results in a failure. This presentation attempts to put this technology acceptance problem in perspective and describes an approach used by the U.S. Environmental Protection Agency to accelerate the recognition and use of environmental technologies.

Characterization typically requires a large number of discrete measurements to define the precise lateral and vertical distribution of source contaminants and the trajectory of the resulting plume. Discrete information (“point” monitoring from soil borings, monitoring wells and the like) is the basis for developing a detailed conceptual understanding of the site, for developing an efficient and effective remediation system, and for monitoring the performance of active remediation systems. Development of a useful conceptual model from the data relies on methods to “upscale” the point measurements to represent the heterogeneous subsurface. The most successful approaches incorporate large-scale boundary conditions and geologic considerations such as depositional environment. The importance of understanding plume geometry and the subsurface processes that control migration is exemplified by the tritium plume at the Brookhaven National Laboratory High Flux Beam Reactor, by the behavior of dense organic solvents at the Savannah River Site, and by the behavior of radionuclides beneath the waste tanks at Hanford.
Themes embodied in the listed examples include: 1) the varied and creative methods that are possible to improve interpretation, 2) the importance of understanding the horizontal and vertical position of subsurface contamination to optimize remediation, and 3) the need to develop a flux based monitoring paradigm to assess the progress of long term clean up.

[448]
**Geophysical Applications in Vadose Zone Characterization**

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Cold War production legacy waste includes man-made gamma-emitting radionuclides that are known to be present in the vadose zone circumscribing the single-shell tank farms of the Hanford’s Central Plateau. A spectral gamma geophysical logging tool was developed and deployed in cased boreholes in the vicinity of the single-shell tank farms to identify man-made gamma-emitting radionuclides. The success of the baseline characterization program completed in 2000 resulted in identification and quantification of man-made primary radionuclide target analytes including $^{137}$Cs, $^{60}$Co, and $^{134/137}$Eu, as well as, naturally occurring radionuclides associated with $^{40}$K, $^{238}$U and $^{232}$Th. These baseline data indicate that some contaminant plumes have migrated to significant depths within the vadose zone and may have reached groundwater. Extension of the baseline characterization project will include related liquid waste effluent disposal sites in use throughout nuclear material production and process history. Discussion presented includes development and implementation of the high-resolution spectral gamma logging system, technical issues related to spectral gamma logging for man-made radionuclides in cased boreholes, and considerations for future planning relevant to geophysical applications in vadose zone characterization and monitoring programs.

[449]
**Method DYVELOP - the Instrument for not only Industrial Environmental Management**

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A description, analysis and evaluation of every ones process system requires a model. This one, as component model of a reality, must contain all substantial functions, relation fields, agents, elements, subsystems and attributes. It must, as structural model of process system, also include of substantial connections, relations, behaviour, incidences and influences, including their modalities. And this model must express an integration on the environment – ENV [1]. In addition, the process system must display a sensibility at two independent parameters - space and time. This all is possible to be modelled by the help of set mathematics [1]. However, for factual representation isn’t sufficient pure mathematical expression. It seems that the linguistic representation (native language) has perfect apparatus, which is susceptible to implement accurate plus sensitive representation of complex and environmental differentiated process approach. A method, which is able to fulfil above demands was named DYVELOP® - the Dynamic Vector Logistics of Processes. It is special method of Industrial and Environmental Engineering suitable for environmental management of containment processes. It gives the instruments for P&W (Product and Waste) logistical monitoring and control during whole Product Life Cycle of the P&W. The DYVELOP®as a ToP® [1] product is able to catch the dynamics and productivity of processes in time-space-information (t-s-i) dependence. Here the DYVELOP® is introduced as a new scientific implement of an investigation and regulation of the processes.

[452]
**Theory of Processes - New Language of Human Sustainable Development**

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The waste becomes from all products always and/or the product could arise from all waste, if we try one’s utmost. The waste can not be taken separately, but it is native product (P&W) [2] of processes technologies. Without-waste technology don’t exists, only bad discriminative level of process evaluation can characterize the technology like without-waste. Discriminative level relates with process environs definition. If anthroposophy approach is applied to process system and its environs (include e.g. market subjects), a complex image - an environment (ENV) is obtained. Above named constituents are the cornerstones of the Theory of Processes - ToP®. Specific process approach creates a quite new discipline from the ToP®. Its apparatus will be introduced by means of fundamental mathematical definitions of new entities in process context – hierarchical functions of five classes, blazons, attributes, modality etc. Here preferred Set Theory is very friendly and well-arranged graphic apparatus. It is susceptible to express very complex, multi-levels relations, influences and connections of production process systems. Cognition sources of process systems and their environment are – technology (TSF), anthroposophy (ASF), logistics, production and informatics. They are represented by means of their spheres – BSF(biosphere); ESF (eco-sphere); NAT (Nature) on next set model.
Two major containment/stabilization projects have been conducted at the former refinery in Casper, Wyoming. The projects are installation of a state-of-the-art subsurface barrier wall, and removal of subsurface piping and hydrocarbon source areas. These projects are complementary to RCRA reforms and have accelerated meeting this NPRAs facility’s corrective action goals for ground water. The State of Wyoming, WDEQ is the lead regulatory agency regarding RCRA corrective action. USEPA’s role has been to provide oversight and technical assistance. Recently a partnership was formed by Texaco, WDEQ, and EPA to explore innovative technologies to address residual hydrocarbon contamination. This effort is part of a broader RTDF partnership with industry. Numerous other refineries are part of RTDF. Texaco’s ambitious four-year program to decommission the refinery included removal of all buildings, tanks, processing units and other above-ground structures. Texaco also included a creative process for removal of all subsurface refinery components, including over 200 miles of subsurface refinery piping, thousands of tons of concrete, and thousands of cubic yards of petroleum contaminated soils. Texaco’s efforts to stabilize, contain, and remove residual groundwater contaminants were centered on installation of a state-of-the-art Waterloo Barrier steel sheet piling barrier wall. Secondly, the wall protects water quality in the North Platte River which forms the northern, down-gradient border. The river is a regional source for municipal, agricultural, and industrial water; and is critical as for fishery and wildlife resources and recreational use. The patented sheet piling is designed to allow each panel joint to be grouted and sealed. With a length of 3,400 feet and surface area of about 87,000 square feet, the Texaco barrier is recognized as one of the largest and best of its type. Common sense lessons learned are: (1) emphasize containment, stabilization and source reduction and (2) interim goals must achieve ERI’s. Phased long-term remedies must employ public comment and future land use. Texaco’s facility has been nominated to receive the IOGCC Environmental Stewardship Award. Texaco received the EPA Region 8 Regional Administrator’s 2000 External Award.
designed to forge links between R&D and site operations: The Vadose Zone Science and Technology Roadmap, the Subsurface Geoscience Laboratory (SGL), and the Subsurface Science Initiative (SSI). The Roadmap is a strategic planning effort to develop a national response to vadose zone science and technology issues. It provides a structure for understanding the context of remedial and long-term stewardship decision-making by DOE. It addresses the components that contribute to an improved scientific input to these decisions and a discussion of the critical research necessary to realize the vision of a sound scientific basis for making public policy and regulatory decisions. It envisions decades of research and infrastructure development aimed at making quantum advances in underlying science understanding. The SGL will be a DOE facility located at the INEEL that will allow researchers to perform a full range of interdisciplinary, three-dimensional, meso-scale experimental campaigns that include work with radioactive components. It will be a critical element in support for experiments that bridge the gap between the laboratory and field scales. It will be a facility unique for its collection of equipment and instrumentation. The SSI is envisioned to enhance substantially the scientific and engineering underpinnings of the DOE environmental remediation programs at the INEEL and across the Complex. This will provide better opportunities to focus collaborative, interdisciplinary and multi-institutional efforts on the most vexing problems surrounding remediation, monitoring and long-term stewardship of contaminated sites. These research initiatives will support DOE’s complex-wide needs while simultaneously advancing the state-of-the-art of vadose zone characterization, monitoring and modeling science and technology. Interdisciplinary research focused on DOE problems and coordinated to integrate and communicate results is critical if the vadose zone research community is to move forward in pace with DOE’s need to understand the basic processes at work in the vadose zone. There is a need to possess the right data necessary for monitoring contaminant migration and building computer simulations, and to adequately model and predict contaminant behavior and fluid flow in the vadose zone. These, when combined, will provide an improved scientific basis for decision-making with respect to the vadose zone.

[456]
**Scale Characteristics of the Different Methods of Measuring Soil Permeability**

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The various air permeability and hydraulic conductivity field measurement techniques range from small scale probe methods to very large scale hydraulic drawdown measurements. Different methods are distinguished by their measurement scale and varying sensitivity to heterogeneity and anisotropy. Several case studies will be presented, in which varying scale methods have been compared. One is a cone penetrometer hydraulic conductivity measurement compared with a large scale drawdown test at the Savannah River Site. The other is a suite of three different scale measurements of air permeability: straddle packers, open borehole anemometry, and total well vapor extraction, performed at Los Alamos National Laboratory in Bandelier tuff. The utility of the different measurement methods is dependent on the application. Large scale measurements are needed to develop production characteristics for remedial design, whereas small scale, detailed profiles are needed to delineate discrete sources to optimize production.

[457]
**Tightening Up Vadose Zone Gas Phase Characterization and Monitoring**

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Sampling and analysis of soil gas collected from wells has had a perilous history as a technique for characterizing vadose zone contamination. Although ostensibly simple to collect, measurements of gas phase contamination are rarely relied upon because of common troubles with concentration variability in wells. The variability is justifiably, not well-understood in light of a common but incorrect conceptual model of homogeneous, diffusion of volatile compounds from well defined sources in the vadose zone and accurate sampling of ambient concentrations using vadose zone wells. Much of the inconsistency can be resolved and often eliminated, however, if a correct conceptual model of contamination and gas transport in the vadose zone is employed in collecting and evaluating gas phase data. A conceptual model of vadose zone contamination and transport factors will be discussed including the relation of advection and diffusion in heterogeneous geology, and surface/subsurface interactions (e.g., barometric pumping effects through sampling wells). Tools for accurately collecting and interpreting gas phase data will also be presented in examples of actual field characterization activities and experiments. The examples will include sites contaminated with volatile organic contaminants and tritium.
Concentration and Immobilization of Spent Radioactive Lubricating-Cooling Liquids
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The problem of radioactive wastes (RAW) causes a great interest of scientific circles in Europe, United States, Japan and other countries. More and more wide using of emulsions, lubricating-cooling liquids (LCL), washing solutions in the atomic industry causes increasing negative effect on the environment. It is necessary to contain the listed above solutions including toxic and ionizing sources of raw material in capacities - storehouses that increases a cost of the process of the appropriate production and does not exclude a possibility of migration or dispersion of radionuclides in the environment. At present the development of untraditional methods of immobilization – the priority direction in the field of handling with accumulated in a large volume medium- and low-active RAW, in particular spent LCL. The results of two stage method based on treatment by cheap chemical inorganic reagents (oxides and acids) are introduced in report. The first stage - is the concentration of radionuclides in oil phase, the second stage – is the immobilization of radionuclides in monolith solid phase. Some results of a lixiviation rate of radionuclides from a formed monolith are performed.

Demonstration of Geostatistical Methods for Long-Term Groundwater Monitoring Optimization
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The U.S. Environmental Protection Agency Technology Innovation Office is sponsoring a project to showcase the use of geostatistics as a tool to evaluate and optimize long-term groundwater monitoring activities. During this project geostatistics and other techniques will be used to evaluate spatial and temporal frequency of monitoring data with respect to data quality objectives. The objectives of this demonstration are to: (1) increase the awareness of geostatistical methods, and their specific application to long term monitoring optimization (LTMO); (2) determine the usefulness of geostatistical methods for LTMO problems; (3) determine the applicability of geostatistical methods for LTMO problems; and (4) promote the use of these techniques for LTMO problems. One of the benefits of geostatistics is they can provide both regulators and responsible parties a more quantitative analysis of when and where to collect groundwater samples. To this end, four sites with existing long-term groundwater monitoring networks will be included in the study. Assistance will be provided to each site to determine if suggested modifications to the monitoring networks are feasible and acceptable from a regulatory standpoint. Preliminary results from up to three of the sites will be discussed during the presentation. In addition to the geostatistical evaluation, a new software product for long term monitoring design and evaluation, MAROS - developed for the US Air Force Center for Environmental Excellence (AFCEE), will be used to perform parallel evaluations at the same four sites. Preliminary results from the MAROS evaluation may also be discussed.
[462]  
**Decision Support Software for Designing Monitoring Plans**  
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The need for both active (e.g., pump and treat systems) and passive (natural attenuation) remediation of affected groundwater sites often requires expensive monitoring systems. Although the annual cost of long-term monitoring at an individual site may be relatively small, groundwater monitoring at a large number of sites for long time periods creates the potential for a tremendous cost liability of billions of dollars (1997 Air Force Modeling and Monitoring Workshop). The Monitoring and Remediation Optimization System (MAROS) software has been developed by the Tech Transfer Division of the Air Force Center for Environmental Excellence (AFCEE) to provide site managers a strategy for formulating appropriate long-term groundwater monitoring programs that can be implemented at lower costs. The MAROS software optimizes a site-specific monitoring program that is currently tracking the occurrence of contaminant migration in groundwater. MAROS is a decision support tool based on statistical methods applied to site-specific data that account for relevant current and historical site data as well as hydrogeologic factors (e.g., seepage velocity) and the location of potential receptors (e.g., wells, discharge points, or property boundaries). Based on this site-specific information the software suggests an optimization plan for the current monitoring system in order to efficiently achieve the termination of the monitoring program. For example, plumes that appear to be decreasing in extent, based on adequate monitoring data over several years, are analyzed statistically to determine the strength and reliability of the trend. If it can be demonstrated statistically through primary lines of evidence (i.e. Mann-Kendall Analysis and/or Linear Regression Analysis) and/or secondary lines of evidence (modeling or empirical) that the plume is shrinking with a high degree of confidence, then future monitoring can either be suspended or reduced in scope. MAROS allows the option to apply heuristically-derived rules based on trend analysis results and site information or to utilize more rigorous statistical methods (i.e. Delaunay Triangulation and/or Cost Effective Sampling) in determining the minimum number of wells, sampling frequency, and well density suggested for future compliance monitoring at the site. These preliminary monitoring optimization results provide a basis for which to make more cost effective, scientifically based future long-term monitoring decisions. As the monitoring program proceeds, more recent sampling results can be added to historical data to assess the progress of the current monitoring strategy. The optimization process can be reviewed and updated periodically using the MAROS guidance recommendations. MAROS addresses a variety of groundwater contaminant plumes (e.g., fuels, solvents, metals) and is designed to be “evergreen” so that long-term monitoring plans can be modified as the plume changes over time (e.g., reducing monitoring efforts when a plume changes from stable to shrinking). The software and manual are now being distributed free over the internet (www.gsi-net.com).

[463]  
**Hyperspectral Remote Sensing of SRS Capping Systems**  
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Aerial remote sensing was conducted over the SRS Mixed Waste Management Facility and the Low Level Radioactive Waste Disposal Facility using the AVIRIS hyperspectral sensor system deployed by NASA. This sensor system provides data across a wide portion of the spectrum with very narrow band widths. Data were processed using a variety of traditional and innovative techniques to analyze the spectral signatures derived from the vegetative cover at these two facilities. Limited ground truth data were available for correlation with the remote sensing data, but substantial differences were evident across the caps. Numerous algorithms derived from the agricultural sciences proved useful in analyzing the data, as did several more novel approaches. Qualitatively, the analyses correlated with spatial differences in grass species composition, apparent vegetation density and other cap management attributes. Spectra derived from copper stressed bahia grass were also useful in analyzing the hyperspectral data, suggesting a more generic spectral response to stressors. Statistically significant correlations were obtained between certain spectral groupings and subsidence measurements on the two caps. These results indicate a significant potential for using aerial remote sensing data for monitoring the quality of the vegetative layer and possibly other parameters related to capping system functional performance.
CBA Environmental Services (CBA) has developed and patented an innovative environmental remediation technology known as the Mobile Injection Treatment Unit (MITU). The technology has been successfully utilized for remediation of over 50 contaminated sites since 1994. The MITU is available in several models and sizes; all of the models are highly mobile units that can be easily transported to almost any location. The technology utilizes the action of modified trenching machines to treat contaminated soil or sludge either in situ or ex situ. The units are designed for superior soil mixing and density breakdown and utilize a combination of mechanical mixing and reagent injection. The MITU is capable of injecting forced hot air at temperatures in excess of 800°F, various chemical reagents, or slurry mixtures for the desorption, oxidation, stabilization, or reduction of a variety of organic and inorganic contaminants. The MITU was originally designed to remove volatile organic contaminants (VOCs) through the use of hot air injection and soil mixing. CBA has improved the process of in situ enhanced thermal desorption and expanded the capabilities of the MITU to include chemical reagent mixing. The MITU has proved to be superior to other mechanical mixing applications with its ability to work in all soil types. The capacity of the MITU varies depending on the model and the site conditions. Straight reagent mixing applications can achieve a production rate of over 1000 cubic yards per day, while enhanced thermal desorption production rates have ranged from 50 to 500 cubic yards per day. The MITU has succeeded on sites where other in situ remediation or bioremediation technologies have failed either due to incompatible soil types and characteristics or ambient weather conditions. Single-pass treatment depths range from 0 to 12 feet with the most common MITU models, and up to 30 feet with the largest available model. Emissions of gases, vapors, or dusts created through the treatment process are captured and can be delivered to an on-board air stream treatment system or to a separate stand-alone treatment system. The MITU has been approved in several states in the Northeast (PA, NJ, NY, OH) and in the Midwest (IN, MI, IL, WI) and also by EPA Region 3 and Region 5. Air quality permits can either be easily obtained or are not required. CBA is continuing to improve the process through continued research and development and is also finding new innovative applications of the MITU technology.

Oil extraction and processing operations in Romania have resulted in the production of large volumes of oily sludge, which constitute a severe pollution problem for this industry. The oily sludge contains crude oil (10-60%), water (30-90%) and petroleum solid particles (5-40%) in various proportions depending on its origin. These oily sludges are emulsions of either oil-in-water or water-in-oil type, with relative stability determined by the presence of mineral particles along with the oil and reservoir water. Previous investigations of our research group have focused on microbial communities naturally occurring in these oily sludges, and have selected several bacterial strains and consortia with high efficiency for hydrocarbon degradation. This paper presents the results of the studies regarding the degradation of sludge hydrocarbons by selected bacterial strains and consortia. The bioremediation studies were conducted in field experiments designed to rehabilitate contaminated soils from the Potlogi Oil Field, Dambovita County (Southern Romania). The experiments were carried out in field plots with and without addition of a special selected bacterial inoculum. Before addition of the inoculum, the sludge-contaminated soil was mixed with coarse sand and chopped hay in all experimental parcels except controls. These bulking agents increase the permeability and porosity of oily sludge, improving bacterial accessibility to hydrocarbons. A nutrient solution was added to all parcels to stimulate naturally occurring microbiota. Hydrocarbon concentrations in soil samples as well as the status of soil microbial communities were evaluated routinely. At the end of the 2-year experimental period, good hydrocarbon degradation efficiencies (exceeding 50%) were observed, and were associated with rich microbial populations in the soils of all parcels. The best results were found in those plots to which the bacterial inoculum was added.
Vegetative Cover for Phosphogypsum Dumps: A Romanian Field Study

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Intensive mining and processing activities along the Romanian Black Sea Coast have resulted in the production of millions of tons of waste that has been disposed without any treatment in tailing dumps. At Navodari, 20 km north of Constanta harbor, over 3,000,000 m³ of phosphogypsum, deposited in three stacks, represents a permanent threat to the surrounding environment and human population. High levels of toxic metals and radionuclides, along with elevated sulfate concentrations, are examples of problems associated with these stacks, according to a complex environmental characterization and risk assessment study. Consequently, vegetative cover might substantially reduce the risk of contaminant migration, under the coastal climate of high rainfall and strong winds. In this paper, a field research effort to cover phosphogypsum residue with suitable vegetation is presented. Several remediation schemes, based on greenhouse experiments have been successfully deployed in the field. These schemes used different combinations of soil amendments and plant species. Periodic investigations on plant growth and metal uptake, as well as enzymatic activities in the substrates were carried out. On the basis of this 18-month experiment, an efficient rehabilitation scheme is proposed.

Interagency DNAPL Consortium: A Successful Commitment to Accomplish Three Complex Demonstrations of Innovative Technologies for DNAPL Remediation

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The U.S. Department of Energy, Office of Science and Technology (DOE-OST); U.S. Environmental Protection Agency, National Risk Management Research Laboratory (EPA-NRMRL); National Aeronautics and Space Administration, Kennedy Space Center (NASA-KSC); and the U.S. Air Force 45th Space Wing (45th Space Wing) have combined resources to form the Interagency Dense Non Aqueous Phase Liquids (DNAPL) Consortium (IDC). Each of these member offices signed a Memorandum of Agreement on April 6, 1999 to formalize their relationship and commitment to the IDC. In FY2000 the U.S. Navy, Naval Facilities Engineering Services Center (Navy-NFESC) realized the benefits of the IDC and have been actively participating since. Through 2002 the Interagency DNAPL Consortium will conduct demonstrations of DNAPL remediation and monitoring technologies. The objective of the demonstrations is to evaluate and compare the cost and performance of in situ DNAPL remediation processes through concurrent testing under realistic, field-scale conditions and in similar geologic environments. The demonstrations are being conducted at Launch Complex 34, Cape Canaveral Air Force Station, Florida. The technologies being demonstrated are Oxidation using Potassium Permanganate, Six Phase Heating, and Steam with Co-air Injection. In order to successfully accomplish the demonstrations, each of the IDC members has had to determine a joint set of goals and framework for accomplishment; provide resources and expertise to fund the demonstrations; manage the design and field efforts; monitor the technology installations and operations; and determine the cost and performance results. In order to disseminate the demonstration results, the IDC had to develop a publishing plan that accurately presents the results to the DNAPL research and site owner communities, while balancing the marketing strategies of each technology vendor. All of these accomplishments have required from each IDC member a commitment to success and profound willingness to learn and jointly confront design, logistical, and performance issues in a clear, documented, defensible manner. The intent of the presentation is to provide a background on the IDC and highlight their accomplishments and commitments, provide a brief summary of the demonstration results to date, and present the proposed future efforts of the IDC.
Abstracts 469, 470

[469] Characterization of DNAPL-Contaminated Sites - Past, Present and Future
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In natural subsurface systems, the delineation and even the detection of relatively insoluble, dense nonaqueous phase liquids (DNAPL) has proven to be extremely difficult. Over the last several years, a significant research effort in the federal complex has been focused on developing improved technologies and strategies for characterization and performance assessment at DNAPL-contaminated sites. As a result, innovative approaches and technologies for DNAPL characterization have been developed and applied at numerous federal and private sites. The innovative technologies include high resolution and hybrid geophysical techniques, tracer tests, and direct sampling and sensing methods. The field results show that each technology has inherent advantages and disadvantages and must be applied to appropriate problems. For example, partitioning or solubilizing tracer tests also probe a large subsurface volume and can detect small pockets of separate phase contaminants but the contaminants must be in the flowpath of the tracers. Direct sampling or sensing, particularly when applied with direct penetration tools, can offer positive identification of DNAPL at very high vertical resolution but low lateral resolution because the methods do not probe beyond the radius of the borehole. Although it has been documented that many of these innovative methods provide a significant advance in performance over conventional approaches, a single technology has not emerged that can be applied with confidence to characterize most sites. The unique features of a specific site will dictate and narrow the list of appropriate tools and the cost of the technologies will further constrain the selection. At most sites, the results from all characterization activities are used to develop to an evolving conceptual model of the site. The selection of technology and results from each application must contribute to the evolution of this conceptual model. This presentation will focus on the current status and appropriate application of state of the art DNAPL characterization tools and systems.

[470] Performance Evaluation and Long-Term Environmental Monitoring Optimization: Methods for Long-Term Stewardship
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Long term environmental monitoring is a critical component of stewardship for three reasons: (1) data provide ongoing evidence of environmental compliance and protection of the public and the environment; (2) the monitoring program, in part, determines the life cycle cost and extent of stewardship; and (3) the monitoring program provides a framework to develop trust and agreement between the site steward, stakeholders, and public. Quantitative performance evaluation of the restoration or waste site system over a given compliance period (for example, 30 to 100 years) provides a mechanism for (1) estimating parameter and model uncertainties and sensitivities, (2) establishing long term monitoring objectives and metrics, (3) eliminating or reducing uncertainties in the system model, and (4) knowing when to cease monitoring. Often, the site performance evaluation is risk- and probability-based—a powerful quantitative tool to assess predictions, remedies, and institutional control approaches. For the reasons mentioned, this paper includes a discussion of performance evaluation as a precursor to long term monitoring program design, and later, as an iterative tool to optimize and validate system management. Federal, State, and local laws and regulations, as well as DOE Order 5400.1, provide the requirements and guidance for environmental monitoring programs. DOE draft stewardship implementation plans offer guidance, and identify the need for technically defensible monitoring programs. Long-term environmental monitoring under stewardship will provide new challenges and opportunities. The National Research Council’s most recent report on long-term stewardship emphasizes that planning for the “long-term” must entail considerations of continual change and system failure. State-of-the-art methods for evaluating long-term monitoring effectiveness, cost, and improvement are also discussed in this paper. Optimization methods include: (1) spatial and temporal interpolation and extrapolation (i.e., models, trend analysis, geostatistical, and Bayesian methods); (2) decision analysis (i.e., engineering/heuristic methods, trees, and probability of failure); (3) expert elicitation; and (4) case study examples of success.
Clean Technologies International Corporation has developed a patented Chemical Reduction Waste Treatment Process, which utilizes a proprietary liquid reactant metal alloy bath composed primarily of mixtures of natural highly chemically reactive aluminum, magnesium, and lithium, along with specific alloys of other alkaline metals. These chemically reactive reducing alkaline metal alloys molecularly decompose complex organic chemicals, and all halogenated hydrocarbons, including PCBs, while capturing in the liquid bath all metals. This includes all radioactive isotopes contained within the waste materials introduced into this chemical reduction medium. Clean Technologies International Corporation’s patented chemical reduction waste treatment process will be utilized to meet the objectives of the DOD and the DOE in the treatment of all types of waste. Chemical reduction, as a method of processing waste, does not produce any EPA or RCRA listed effluents or by-products in off-gas emissions. This non-incineration thermal chemical waste treatment off-gas air emissions analysis has earned an exemption from Title Five of the Clean Air Act. The Air Quality Bureau of the New Mexico Environmental Department granted this exemption. This exemption is a lifetime exemption. By design, dioxins and furans are not produced in the off-gas air emissions. This is realized by the formation chemistry necessary to produce both of the toxic compounds. To reform, both toxic compounds require oxygen and chlorine atoms in high temperature off-gases. Clean Technologies’ chemical reduction waste treatment process operates in an anaerobic environment, at water-cooled lower temperatures, and with less than 5% oxygen. All chlorine atoms are chemically converted into aluminum chloride salts by chemical synthesis. This chemical reduction waste treatment process will be utilized for the decontamination/destruction technology demonstration for the removal of organics in transuranic waste. These treatment concepts meet the stated objectives for the treatment of all mixed waste. All organic materials, including all halogenated hydrocarbon compounds, will be chemically processed, removed, and separated from the transuranic metals. The alloyed transuranic metals will be placed into metal ingots, which are good for long-term storage. The chemically reduced pure metals can be reclaimed from the ingots if needed. The removal of organics from radioactive metals eliminates the production of hydrogen gas during shipment and storage. Radiolysis cannot occur without organic materials.

[471]

CIIC, Chemical Reduction Technology
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This describes the progressive remediation of a PCE contaminant plume using two separate chemical oxidizers in a fractured saprolite bedrock aquifer in Rockville, Maryland. The geology consists of fine-grained soils overlying weathered-fractured schist and phyllitic bedrock (saprolite). The state of Maryland required that the onsite source be remediated to a risk-based PCE cleanup goal of 253 micrograms per liter (ug/L) and allowed natural attenuation as the offsite remedial action. The source area remediation was initially performed using a Fenton’s Reagent-based chemical oxidation process. A successful bench test and a field scale pilot test were conducted prior to implementing a full-scale program using ten stainless steel treatment wells. The initial post-treatment results looked promising, but the contaminant concentrations increased (rebounded) significantly following the treatment process. The October 2000 (rebound) PCE contaminant concentrations in the aquifer ranged from 7.8 ug/L to 26 milligrams per liter (mg/L), averaging 8.5 mg/L, as determined from 17 sample points. In response to these concentrations, 11,000 pounds of liquid sodium permanganate were injected into the aquifer at 50 locations in late January 2001. This successful treatment program resulted in an 89.3 percent average PCE reduction in the aquifer with an average concentration of 909 ug/L by late February 2001.

[472]
[474]
Networked Emplantable Sensors and Web-Based Data Acquisition for Long-Term Environmental Monitoring
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The authors describe emplantable sensor packages that can be permanently emplaced in the subsurface using direct push technology. A microcontroller embedded in each emplantable package digitizes sensor output and communicates with a field computer via an RS-485 connection. Sensor identification and calibration information also are stored on EEPROM in the embedded system. Sensors deployed to date include pH, ORP, and temperature for water quality monitoring, and volumetric soil moisture, soil electrical conductivity, and temperature for vadose zone soil monitoring. Additional sensors are under development. The field communications protocol will accommodate over 3000 sensors per network, and wireless linking, between field components and from the field network to the Internet, is also possible. The field computer can either store acquired data locally or transmit them via any TCP/IP connection to an Internet-accessible host computer running WebDACS™. WebDACS™ is Applied Research Associates’ web-based data acquisition and control system. This system makes monitoring data available to users through the familiar interface or any standard web browser. Users can access their data from virtually anywhere they can connect to the Internet. WebDACS™ generates on-screen plots and tabular output as well as downloadable ASCII files, and provides data security features that include password protection and visibility control.

[475]
Heavy Metal Removal from Municipal Sewage Sludge by Phytoextraction
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In European Union countries up to 80% of sewage sludge is used in agriculture and forestry, whereas in Poland only 11% is used as fertilizer. The principal environmental concern is due to the inevitable presence of heavy metals when using sewage sludge as fertilizer. The main objective of this study is to assess the effectiveness of the phytoextraction process in removing heavy metals from sludges. A method of whole plant (with roots) harvesting was developed since plants initially accumulate heavy metals in roots. EDTA (ethylenediaminetetraacetic acid) was used as a chelating agent in the experiment. Results of the control treatment (without EDTA) showed that the concentration of heavy metals (Pb, Cd and Zn) in corn and white mustard roots was 2–6 fold higher than in shoots. In treatments with EDTA this effect was not observed. The method of whole plant harvesting was most effective in removing Cd from sewage sludge in experiments with corn and with EDTA; however, this effect was not detected with white mustard. It was shown that the new harvesting method could be effective in removing heavy metals from municipal sewage sludge.

[483]
Installation of Permeable Reactive Barriers using Pneumatic Injection
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Several methods of installing permeable reactive barriers (PRBs) have been developed over recent years. These techniques have evolved in order to address deeper contaminant plumes. One method that was developed to address this issue uses the patented pneumatic fracturing to emplace dry media such as iron filings. The technology, pneumatic injection, was patented by the New Jersey Institute of Technology (NJIT) in 1999. This technology offers several advantages, especially with iron PRBs. It allows the installation of media much deeper than conventional methods and over a greater lateral distance. The second advantage eliminates the concerns associated with solid iron walls (i.e., biofouling, precipitation, and unachievable reductions). The third advantage is the installation of the media at targeted depths, which, in turn, reduces the amount of iron and hence, the cost. A column study was conducted for the preliminary design of an iron PRB in Gardena, CA. The site has the highest VOC contamination in three transmissive zones between 20 to 100 feet bgs. Pneumatic injection can target the transmissive zones, while achieving reduction, and eliminate 60% of the iron required for treatment, if a solid or continuous iron wall were installed.
Abstracts 486, 487

[486] Bioremediation Advances: Discovery, Development and Deployment of Biocatalysts

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Sludge samples obtained from a 100 year old waste site at the Czechowice Oil Refinery near Czechowice-Dziedzice, Poland were analyzed for high-potential microorganisms for bioremediation applications. The aged sludge was acidic (pH 2) and contained high concentrations of asphaltics and polycyclic aromatic hydrocarbons (PAHs). Additionally, the waste lagoon contained spent catalysts, diatomaceous earth, silica gel, and coal fly ash. Approximately 120,000 tons of this petrogenic waste was deposited in unlined lagoons 3 meters deep covering a total of 3.8 hectares. A total of 60 bacteria, 50 fungi, and several yeast spp. Have been isolated from the sludge on acidic minimum salts medium exposed to naphthalene vapor. The isolates were characterized by classical taxonomic criteria, BIOLOG®, and analysis of the SSU rRNA genes. A number of the bacterial isolates were commonly encountered group possessed high nucleotide sequence similarity (99-100%) to *Ralstonia* sp. KN1 (eight isolates). In addition, isolates belonging to the Actinobacteria (high G+C gram positives), and Firmicutes (low G+C gram positives) were found. Several of the *Ralstonia* isolates and a *Bacillus* isolate grew with catechol, naphthalene, or fluorene as the sole carbon source indicating a high bioremediation potential. In addition three of the *Ralstonia* spp. Appear to produce biosurfactants in exceptional quantities. The fungal isolates that grew on naphthalene vapor appear to represent taxa that have not been previously reported to degrade PAHs. The bacteria are being screened for scale-up and potential application in a bioreactor at the Institute for Ecology of Industrial Areas (IETU), our Polish international partner. A similar bioreactor at SRS will be deployed for bioremediation of mixed waste. This international project is part of the joint ongoing effort between the U.S. Department of Energy, SRS, Florida State University and the IETU to develop efficient bioremediation strategies for Central and Eastern Europe and domestic U.S. Department of Energy applications.

[487] Application of Bioremediation to Petroleum-Contaminated soils

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Due to environmental stressors and evolution, microbes are able to inhabit and prosper in harsh and seemingly inhospitable environments. One such environment is the Czechowice Oil Refinery sludge lagoon, which contains decades of materials from crude oil waste remaining. These waste materials consist of both aliphatic and aromatic (PAHs) hydrocarbons at extremely low pH (2.5). Microorganisms living in this unique environment have developed the ability to degrade petroleum hydrocarbons. These microbial strains could be extremely useful in remediating petroleum contaminated soils. The key to bioremediation is accelerating the naturally occurring biodegradation process. First, the limiting factors (i.e., oxygen, nutrients, etc.) must be identified and provided to the system. Then, the site must be monitored to ensure that optimal conditions for biodegradation are maintained under a variety of conditions. This presentation will summarize work conducted at the Czechowice Oil Refinery biopile as well as the design, construction, start-up and operation of a small, mobile bioreactor intended for use in remediating limited volumes of contains soils or investigatively derived wastes.
Coordinating Committee for Environmental Systems (JCCES) established between DOE and the Institute for Ecology of Industrial Areas (IETU) deals with environmental remediation technologies throughout the Central and Eastern European region. As part of the JCCES program the Institute for International Cooperative Environmental Research (ICER) of Florida State University collaborated with the IETU in development of phytoremediation technology. The phytoremediation project targeted two key aspects of heavy metals remediation: optimization of large scale Pb and Cd phytoextraction, and using plants to reduce the environmental and human health risk associated with mercury-contaminated soils.

[490]
Application of Phytoremediation to Lead-Contaminated Soils
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Some plants have the natural ability to remove heavy metals from soil. In the case of lead phytoremediation amendments are applied to the soil and to the plant itself in order to mobilize the metal and to translocate it to the above-ground portion of the plant where it can be removed by harvesting. The contaminated plant material is then treated by recycling, composting or direct disposal in a secure landfill. Lead is a widespread soil contaminant all over the world due to industrial activities such as the combustion of leaded fuel, the manufacture and recycling of batteries, paint and firing range activities. Plants are able to remediate large areas of moderate to low concentrations of lead contamination. The Institute for Ecology of Industrial Areas, Katowice, Poland has been working with the U.S. Department of Energy and Florida State University to identify the most promising plants and amendment combinations for removing enough lead from soil to reach regulatory limits. Current technology and cost-effective methods of lead phytoremediation will be presented.

Employment of plants for removing hazardous substances from soil and aqueous streams continues to intrigue the public, scientists, and environmental engineers. Phytoremediation is a family of extensively developed novel plant-based remediation technologies that can provide inexpensive alternatives to conventional soil remediation technologies. Scientific and technological aspects of phytoremediation are being developed in academia and industrial settings all over the world. The Joint

[491]
Optimization of Phytoremediation Process by Monitoring Plant Fluorescence
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Phytoremediation is based on the ability of particular plants to extract contaminants in large quantity from soil or groundwater.
Heavy metal removal is accomplished by concentrating the contaminant in above-ground plant parts, such as leaves, that can be harvested and removed from the site. To enhance metal accumulation and increase the rate of phytoextraction, a chelator (e.g., EDTA) is added to the soil. This mobilizes bound metals, thus making them more available for uptake by plants and dramatically increasing the rate of uptake. Monitoring the temporal variation of plant fluorescence provides a measure of the plants’ health status, before any stress-related damage to the plants appears. A computerised, portable chlorophyll fluorometer, CFM-636973, was used for optimization of the phytoremediation process. At high EDTA concentrations the uptake is rapid but is quickly saturated and plants die as they reach their tolerance threshold. By reducing the concentration of EDTA, the uptake will be slower but plants will be able to invoke tolerance mechanisms that allow them to adapt to stressful environments. This mechanism can be exploited by increasing the tolerance threshold. In this way, the final accumulation can be increased by a factor of 3-5, significantly reducing total clean up time and cost. Studies of a similar optimization for the phyto removal of chlorinated solvents e.g., TCE and PCE, is under way.

[492]
Building on Success IV: Achieving Results
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Beginning in FY 2000, and following our “Breakthrough 2000” meeting with management, end users and other team members, the Subsurface Contaminants Focus Area (SCFA) have utilized an integrated performance measurement process to evaluate and guide our program. These program performance metrics were developed as a result of the input from the Breakthrough meetings. These high level “stretch” program metrics focus on strategic planning, transition of basic science to applied research, deploying real solutions, and achieving documented life cycle cost savings. These sessions also identified a need to expand the services of the Focus Area to include technical assistance to the sites. We have been able to accomplish these challenging goals by utilizing the best available expertise throughout the DOE, universities and national laboratories. The SCFA also placed emphasis on improving areas of need as identified in reports received from review groups, including, the National Academy of Sciences and the Environmental Management Advisory Board (EMAB). SCFA increased the use of technical expertise of the national laboratories to help with program strategic planning and identification of major end user problems in addition to facilitating deployment of cutting edge technologies. The bottom line is, to be successful you must first focus on the customers needs, then you must utilize the best available expertise to bring to your customers the most acceptable solutions at the lowest possible costs. You must establish goals that exceed your present capabilities. This will result in the need to identify innovative solutions and utilize all available resources to make the Stretch Goals a reality. Finally you must have systems in place to provide verification to the end users, regulators and stakeholders on the performance and costs of the solutions as compared to the baselines being used.

[493]
Building on Success I: Raising the Standards of Performance
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As Deputy Assistant Secretary for the Department of Energy’s Office of Science and Technology (OST), I have a very diverse customer base across the DOE Complex. I must assure that all the resources of the OST are utilized to the maximum benefit of the end users of the technologies being funded by my office. The Subsurface Contaminants Focus Area is one of the five focus areas assigned responsibility as a national research and development program to solve problems throughout the DOE Complex. The SCFA was established in 1995 to address the problems in the subsurface, and is managed out of the EM organization at the Savannah River Operations Office. The program has had many successes during the years from 1995-1998 and had established a very good customer base in the DOE. However, there was a perception that the SCFA program was not doing enough to solve the biggest problems of the end users. I wanted to see the program more focused, increased advocacy by the problem holders, more projects moved into deployment, and a corporate perspective in addressing our subsurface problems. Given the diversity of needs and problem sets identified by DOE environmental remediation managers across the complex and the magnitude of the problem, a more integrated and focused approach to providing solutions was needed. To better focus the SCFA efforts, I was pleased to kick off a streamlined approach, called “Breakthrough 2000”, to improve program planning and institutionalize value added. This approach resulted in the integration of a number of new initiatives in an effort to stretch beyond predictable outcomes. “Breakthrough 2000” involved the integration of new capabilities representing a full spectrum of potential solutions; establishment of a lead laboratory to harness the technical resources of the nation; and active customer involvement through the User Steering Committee. The SCFA has greatly exceeded my expectations and has made significant contributions to the Department of Energy.
[494] Building on Success III: Stretching to Reach Our Goals
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As a result of the Breakthrough process, the Subsurface Contaminants Focus Area (SCFA), in conjunction with DOE–Headquarters and environmental restoration end users identified four challenging performance goals to be accomplished within two years (i.e., by the end of fiscal year 2001). These goals were: 1) deploy 100 technologies; 2) provide 100 technical assistance solutions; 3) transition 10 basic research projects into the applied phase; and 4) achieve $0.5B cost savings as a result of technologies deployed. We focused on making “step change” improvements or those with the biggest benefits. These goals represented a stretch beyond what we thought was truly possible or attainable based on our planning at that time. This drove SCFA to enhance its program planning, end user interfaces, and technical expertise in order to achieve these results. Now it appears the program is on track to meet most of these stretch goals. The process of establishing challenging measures and tracking our performance against them resulted in a shift in thinking and increased ownership in our processes and their results. The Technology Assistance function was a relatively new concept. With the emphasis on deployments and other readily quantifiable measures, the elevation of technical assistance for the program resulted in an expansion of the way in which SCFA could address and help solve problems. It also provided an additional resource for end users whose problems could not merely be solved by the deployment of an innovative technology. An integrated lead laboratory was successfully established and has been the model for the rest of the Focus Areas.

[495] Building on Success V: Forging our Future
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After the progress that the Subsurface Contaminants Focus Area has made as a result of “Breakthrough 2000”, the standard for successful performance has been raised. We are challenged to continue to build upon the successes of the program, while taking the next steps in the evolution of the SCFA program. One of the fundamental components of “Beyond Breakthrough” is a strategic plan that clearly lays out the main problem areas the SCFA will strive to solve. Expanding technical assistance to address surface water contamination problems will also help avert groundwater contamination issues of the future. This will be done through a multi-pronged approach using technical assistance, enhanced research, and continued use of innovative technologies to solve near-term problems and develop the necessary knowledge base to solve our out-year challenges.

[496] Building on Success II: Strengthening the Foundation
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In order to achieve a “Breakthrough” in thinking and program implementation, JMJ Consulting worked with the Subsurface Contaminants Focus Area (SCFA) to facilitate a process by which the group could jump start the program to achieve a level of performance previously not thought possible. Beginning in December of 1998, the group first addressed status, in both real terms and perceived – the perceptions of their customers and HQ. Recognizing where improvement was needed, yet building on their strengths, SCFA chose to set a new path, with a clear mission and breakthrough targets, not just tougher goals in established areas. The program re-organized in support of the mission and targets, regularly monitored and managed progress and promoted current successes and new successes on the way to achieving the breakthrough targets. The consistent follow through and emphasis on recognition built momentum and credibility with their customers, and just as importantly improved morale within the area. Periodic workshops over a two-year period updated the mission and breakthrough targets, as well as firmly established a renewed commitment to customer service. These sessions also addressed difficult issues in work process, reporting and working interfaces. The group was continuously challenged in the process to be candid about issues, go beyond their historic approaches, to recognize success yet be willing to set new standards.

[498] Natural and Accelerated Bioremediation Research Program Field Research Center in Oak Ridge, Tennessee

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The Natural and Accelerated Bioremediation Research Program (NABIR) has established a Field Research Center (FRC) on the Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee. NABIR is funded through the Environmental Sciences Division of the Office of Biological and Environmental Research in the U.S. Department of Energy’s (DOE) Office of Science. The FRC provides a site for investigators in the NABIR program to conduct research and obtain samples related to in situ bioremediation of metals and radionuclides. The NABIR program is a ten-year fundamental research program designed to increase the understanding of biogeochemical processes that would allow the use of bioremediation approaches for cleaning up DOE’s contaminated legacy waste sites. Oak Ridge National Laboratories (ORNL) Environmental Sciences Division (ESD) manages the FRC.
The objective of this project is to understand key factors that control the bioavailability and biostabilization of high molecular weight organic contaminants (e.g., PAHs and PCBs) sequestered within multi-component dense non-aqueous phase liquids (DNAPLs) entrapped in heterogeneous soil systems. The main hypothesis of this project is that slow dissolution of contaminants released from DNAPL pools entrapped in the subsurface, when combined with low-level microbial activity in the vicinity of the DNAPL source region, can result in stabilization of contamination with diminished plume formation and associated risk reduction. Bench-scale biostabilization screening tests are developed to examine the potential for biostabilization of various DNAPLs. Screening test results consistently showed favorable potential for in situ biostabilization of coal tar; screening indicators were not consistently favorable for Aroclor biostabilization. Bench-scale biometer tests were conducted to measure and model the biodegradation kinetics and associated microbial growth kinetics due to the degradation of a mixture of PAHs released from DNAPL coal tar. The impact of long-term PAH dissolution and degradation from multi-component coal tar, is coupled with changes in porous media properties (porosity and dispersivity), to demonstrate the potential for bio-isolation of coal tar pools in the subsurface. Factors that control DNAPL bio-isolation are explored through an integrated computational model developed for this project. Ongoing tank-scale dissolution and biostabilization experiments are being conducted to validate the integrated modeling framework.

**[500]**

**Biostabilization of Multicomponent Dense Non-Aqueous Phase Liquids (DNAPLs)**

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Effects of Anaerobic Sorbent Degradation on the Sorption of Toluene and o-Xylene on Municipal Solid Waste Components

**[501]**

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The overall objective of this research is to develop an understanding of factors controlling the bioavailability and fate of organic contaminants sorbed to components of municipal solid waste (MSW). As part of this effort, fresh and anaerobically degraded model MSW components (office paper, newsprint, and rabbit food) were characterized by chemolytic techniques, infrared spectroscopy (IR), and solid-state $^{13}$C nuclear magnetic resonance (NMR) spectroscopy. For all compounds, anaerobic degradation processes led to a loss of cellulose and hemicellulose and enrichment in lignin. As a result, the degraded materials exhibited a more aromatic character. For the rabbit food, fat and protein contents were similar after anaerobic degradation. Sorption isotherm data showed that partition coefficients normalized by organic carbon content ($K_{OC}$) increased with increasing hydrophobicity of the sorbate ($K_{OW}$) as well as with increasing hydrophobicity of the sorbent organic matter. Anaerobic degradation increased toluene and o-xylene sorption on office paper and newsprint but not on rabbit food. This result suggests that fat and perhaps protein determined the toluene and o-xylene sorption capacities of rabbit food. Isotherms conducted in acidogenic and methanogenic leachates yielded partition coefficients that were similar to those obtained in single-solute systems. Similarly, binding of toluene and o-xylene by leachate organic matter was not observed. Current tests are evaluating the effects of aging on toluene and o-xylene desorption rates. Additional tests are being conducted with *Pseudomonas putida* to evaluate the effects of aging on toluene bioavailability.

**[502]**

Enhanced Biodegradation of Petroleum: Contaminants in Rhizosphere Soil

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Bioremediation of petroleum contaminants in soil using indigenous microorganisms has proven effective in many field settings; however, the biodegradation rate of the more recalcitrant and potentially toxic petroleum contaminants is rapid at first but declines quickly. Biodegradation of such compounds is limited by their strong adsorption potential and low solubility. Research has indicated that plant roots may play an important role in the enhancement of contaminant biodegradation in soil. For petroleum compounds, the presence of rhizosphere microorganisms may accelerate biodegradation of the contaminants. The establishment of plants on hazardous waste sites is potentially an economic and effective approach for waste remediation and stabilization. Over the last six years, field trials have shown that phytoremediation is a viable treatment alternative for moderately impacted petroleum contaminated soil. Total petroleum hydrocarbon concentration was found to be lower in planted plots than in unplanted controls. However, there are limitations of this technology. Considerable time is needed to achieve regulated levels, depending upon the initial concentrations and desired end-points. Phytoremediation using grasses and legumes is a reasonable alternative for surface contamination but will have minimal impact below a depth of 1 meter. Also, more information is needed concerning plant species that are best adapted to phytoremediation.
Relations of Heavy Metal Sequestration and Production of Metal Ion Ligands in Plants under Different Environmental Conditions

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Root exudation of metal ion ligands (MIL) is vital to nutritional acquisition of Fe and Zn, and may also be important to mobilization of metal contaminants by plants. We have developed a multidimensional NMR and GC-MS approach for broad profiling of exudate and tissue components including MIL. Amino and organic acids plus mugineic acid (MA) phytosiderophores were identified and quantified. SH-rich peptides were also analyzed using fluorescent tag and SDS-PAGE. The MIL profile differed among plants and genotypes. MA exudation by wheat and barley roots was induced by Fe deficiency, which is consistent with MA’s role in Fe acquisition. Cd treatments of wheat greatly reduced the exudation of MA and other MIL; yet transition metal sequestration into roots increased substantially. This suggests that metal uptake may be mediated by a different mechanism in Cd-contaminated rhizosphere. SH-rich peptides (i.e., phytochelatins) and other MIL accumulated greatly in Cd-treated wheat tissues, possibly related to the intracellular immobilization of Cd and transition metals. Moreover, co-treatment with soil humic substance (HS, an important extant rhizosphere ligand) alleviated Cd-induced loss of wheat biomass and root exudation, while causing a higher sequestration of Cd and transition metals into roots. This is contrary to HS role as a competitive chelator.

EPA Star Grants for Environmental Biotechnology Research

M.M. Lasat
U.S. Environmental Protection Agency
Washington, DC, USA

The cost of using conventional technologies to clean up nation’s contaminated soil and water has been estimated as high as $900 billion. Clearly, there is a need for cost-effective alternatives to convert hazardous waste into harmless compounds. The EPA is actively supporting research aimed at developing innovative, cost-effective remediation technologies. Such an innovative approach is bioremediation, the use of plants and microorganisms for environmental cleanup. Bioremediation is emerging as an energy-efficient, cost-effective alternative. In addition, bioremediation is potentially less harsh to the environment than other treatment options such as chemical treatment. The EPA/ORD (Office of Research and Development)/NCER (National Center for Environmental Research) has used several funding mechanisms to support extramural research in Bioremediation. Thus, in collaboration with the National Science Foundation, Office of Naval Research, Department of Energy, and Department of Agriculture, EPA has initiated a research program in Environmental Bioremediation. Under the auspices of Bioremediation Initiative, through STAR (Science to Achieve Results) grants program, EPA has awarded more than $15 million for research in this area. Significant results from this program will be detailed, and current EPA research priorities in Bioremediation and Environmental Biotechnology will be presented and opened for suggestions and discussion.

Strip Test as a Method for Optimizing Land Characterization for Phytoremediation of Heavy Metals

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Site characterization and treatability studies currently are conducted sequentially, prior to the initiation of soil phytoextraction processes. The purpose of these activities is to describe the nature and extent of contamination at the target site (site characterization), and to determine if, and under what conditions, proposed plant species will extract the target contaminants (treatability study). This approach is time consuming, expensive and may not lead to success at field scale phytoextraction. A new approach, “Strip Test”, integrates site characterization and treatability studies into a single effort. The concept of the “Strip Test” is based on a geostatistical assumption that an adequately distributed number of soil samples can describe the distribution of metals across an investigated site. Furthermore, it is supposed that planting with the same pattern would provide information on whether the soil would support plant growth, and an estimate of phytoextraction efficiency for the site. The general expectations are: 1) reduction in the total cost of this initial step of phytoextraction process; and 2) early decisions regarding the applicability of phytoextraction as a remedial technology for a given site. Our results show that the “Strip Test” can be used as a method for optimizing phytoextraction.
Abstracts 508, 509, 510

[508]
**Mercury Content in Soils Around a Chlor-Alkali Production Facility, Tarnow, Poland**

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Environmental pollution by mercury is a very serious and wide spread problem for industrialized as well as developing countries. Numerous industrial activities, ranging from gold mining to chlor-alkali production, have introduced mercury into terrestrial and aquatic ecosystems. The Tarnów AZOTY chemical works in southern Poland is an example of such a site. This facility is over 70 years old and used metallic mercury extensively for chlorine and sodium hydroxide production (over 60 years) and as a catalyst for PCV production (over 40 years). As a result, there are several locations on the site which have high levels of mercury in soil. A number of remediation technologies are under evaluation for application to this site. This presentation will summarize the results of the characterization effort for this site and will outline plans for evaluating remediation technologies.

[509]
**NATO/CCMS Pilot Study on Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean-up of Contaminated Land and Groundwater**

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This Pilot Study has met annually since 1992 to discuss state-of-the-art developments in environmental clean-up technologies. Representatives from the NATO countries as well as invited non-NATO countries (e.g., Austria, Switzerland, Armenia, Romania) participate in the Pilot Study. The NATO Program under which this activity is conducted is the Committee on Challenges of Modern Society (CCMS) which addresses a range of non-defense related social issues, including the environment. Building a knowledge base so that innovative and emerging technologies can be identified and deployed is the impetus for this NATO/CCMS Pilot Study. Under this Pilot Study, new technologies that are being developed, demonstrated, and evaluated in the field are discussed in the context of possible application to the clean-up of contaminated land and groundwater. This Pilot study draws from a broad representation of international environmental experts and has examined over fifty environmental projects. A number of widely distributed publications and reports concerning these technologies have resulted from this Pilot Study and are available upon request through its Directors (Dr. Walter W. Kovalick, Jr. and Mr. Stephen C. James, both of the U.S. Environmental Protection Agency).

[510]
**Full Scale Clean-Up of PCE and Turpentine under Buildings by Steam Stripping**

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A contamination with PCE and turpentine at a former dry cleaning facility was thoroughly characterized from 1997-1999. The contamination is located in a sand layer from 0-5 m.b.g. This sand layer is underlain by uncontaminated alluvial clay. The upper unconfined aquifer is located in the sand above the alluvial clay and has an unconfined water table 2 m.b.g. The source zone is located partly beneath residential buildings and has an approximately circular shape and a diameter of approx. 20 m. In the center of the source zone separate phase PCE and a floating layer of turpentine was detected. Based on a risk assessment in 1999, the County of Northern Jutland decided to conduct a source zone remediation at the site to secure the indoor air quality in an apartment building at the site. Among a wide variety of remediation technologies, steam stripping was chosen as the most cost efficient technique for the clean-up. In total, 800 kg of turpentine and 100 kg of PCE were removed and the contaminant concentration in the extracted groundwater and soil vapor was reduced to well below the acceptable level. The post-steam clean-up documentation by soil and groundwater sampling is conducted in June 2001, when the site is expected to have cooled to ambient temperatures. The presentation will discuss the strategy, implementation and performance of the Steam stripping system. In addition, the identified mechanisms of removal will be discussed and recommendations for field implementation at shallow sites will be offered.
Steam Enhanced Extraction is an aggressive in-situ technique for removal of contaminants from the subsurface. A pilot scale demonstration was performed for the US Navy at the former NAS Alameda, currently Alameda Point. An underground waste oil/solvent tank had leaked for decades. Highly TCE-rich stoddard solvents as well as diesel and motor oil had seeped into the subsurface, creating an 18 m diameter LNAPL area, concentrated between 2 and 3 m below grade. The NAPL contained as much as 10% TCE by mass, both floated. Detailed site investigations were carried out using traditional soil, groundwater and soil vapor sampling as well as advanced Cone-Penetrometer tools such as Laser-Induced Fluorescence (LIF), Membrane Interface Probe (MIP), and a downhole camera obtaining real-time images of the sediments and fluids at the pore-scale. Total Petroleum Hydrocarbon concentrations exceeded 20,000 mg/kg at places, and TCE was as high as 3,800 mg/kg in the soils. GeoVis images identified NAPL pools, droplets, ganglia and films in the pore skeleton of the sediment. The NAPL was smeared across the water table, and a substantial mass trapped below. Natural attenuation time requirements were in the 1,000-3,000 year range, based on current dissolution and degradation rates. The site contained an estimated mass of 400-800 kg of contaminants within the source zone, based on an integration of all available data. The poster presents data on the site characterization, and the implementation, performance and efficiency of the Steam Enhanced Extraction system.

An overview of the CAREC will be presented: it’s origin, purpose, organizational structure, main functions and examples of projects and activities. The CAREC is one of the regional environmental centers (RECs) established under the United Nations Economic Commission for Europe (UN-ECE). These centers are to be set-up as independent, not for profit, non-political sub-regional organizations of international character to address regional environmental issues and concerns. These centers are also designed to provide a framework for regional cooperation among governments, NGOs and businesses on such regional issues as sustainable development, public participation, information exchange and for conducting research and training. Other RECs have been established by UN-ECE in Central Europe, the Caucasus and Russia. The CAREC was established in Almaty, Kazakhstan during 2000.

Vadose zone processes play a pivotal role in the behavior of subsurface contaminants and often determine the options and opportunities for environmental cleanup. Unfortunately, the significance and control exerted by this subsurface interval—the soil, sediment and rock between the ground surface and the water table—is often overlooked. The influence of the vadose zone is not routinely incorporated into conceptual models of contaminant behavior at waste sites and industrial facilities. Throughout the 20th century, the vadose zone was often assumed to simply “hold up contaminants and protect the groundwater.” This official policy was assumed to be “true” until conclusively disproven—typically without direct vadose zone monitoring. Monitoring at such sites consists of upgradient and downgradient wells that indicate environmental impacts only after groundwater is already contaminated. In 1998 and 1999, the U.S. Department of Energy (DOE) sponsored an international effort to identify technical and scientific challenges associated with the vadose zone. The effort resulted in the publication of a comprehensive book — Vadose Zone Science and Technology Solutions. A sampling of case studies provides a clear understanding of the importance and pervasiveness of the influence of vadose zone processes on environmental characterization and clean-up. “Simple” case studies such as tritium migration at the Brookhaven National Laboratory, “complex” case studies such as Hanford waste tanks, “arid” site case studies such as Yucca Mountain, and “humid” site case studies such as Savannah River Site, all document that a new emphasis and awareness of vadose zone science is needed. Based on the input of all of the participants and contributors, a listing of science and technology needs was developed for the book. As expected, the identified needs centered on issues such as heterogeneity, upscaling, complex transport processes, setting remediation goals, and the like. The book, including its case studies and recommendations, has been a primary resource in DOE’s current effort to develop a roadmap for future subsurface science research.
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- W1, W2  Workshop I, II
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