

Proceedings of

Environmental Science and Technology

(2005)
Volume 2

Edited by

William G. Lyon

Jihua Hong

Ramesh K. Reddy

Proceedings of
**Environmental Science
and Technology**
(2005)

Volume 2

Edited by

William G. Lyon
Jihua Hong
Ramesh K. Reddy

American Science Press, New Orleans, USA

Library of Congress Cataloging-in-Publication Data

Proceedings of Environmental Science and Technology 2005 (II)

Proceedings from the First International Conference on Environmental Science and Technology, held January 23-26, 2005 in New Orleans, Louisiana, USA

Includes bibliographical references
ISBN 0-9768853-5-2

I. Lyon, William G., II. Hong, Jihua.

III. Reddy, Ramesh K.

IV. International Conference on Environmental Science and Technology
(1st : 2005 : New Orleans : Louisiana)

Printed in the United States of America

Copyright © 2005 American Science Press. All rights reserved. This document, or parts thereof, may not be reproduced in any form without the written permission of the American Science Press. Requests for permission or further information should be addressed to the American Science Press, 6464 Avenue B, New Orleans, LA 70124, USA

Email: press@AASci.org

Website: www.AASci.org/press

ISBN 0-9768853-5-2
© 2005 American Science Press

SCIENTIFIC/TECHNICAL COMMITTEE
ICEST2005

Wasim Ali, Ph.D.
Karlsruhe University
Karlsruhe, Germany

Malcolm S. Cresser, Ph.D.
University of York
Heslington, York, UK

Ed Alperin, Ph.D.
Shaw Environmental, Inc.
Knoxville, TN, USA

Zhi-Qiang Deng, Ph.D.
Louisiana State University
Baton Rouge, LA, USA

Kim A. Anderson, Ph.D.
Oregon State University
Corvallis, OR, USA

Mark S. Dortch, Ph.D.
U.S. Army Engineer R & D Center
Vicksburg, MS, USA

Brad Autrey, Ph.D.
U.S. Environmental Protection
Agency
Cincinnati, OH, USA

James D. Englehardt, Ph.D.
University of Miami
Coral Gables, FL, USA

Rupert Bäumler, Ph.D.
Technische Universität München
Freising, Germany

Lorne G. Everett, Ph.D.
Shaw Environmental, Inc.
Shaw Group
Santa Barbara, CA, USA

Elly P.H. Best, Ph.D.
U.S. Army Engineer R & D Center
Vicksburg, MS, USA

Joseph R.V. Flora, Ph.D.
University of South Carolina
Columbia, SC, USA

Olivier Briand, Ph.D.
Ecole Nationale de la Santé Publique
National School of Public Health
Rennes Cedex, France

Mark E. Fuller, Ph.D.
Shaw Environmental, Inc.
Lawrenceville, NJ, USA

Xinde (Rocky) Cao, Ph.D.
Stevens Institute of Technology
Hoboken, NJ, USA

Betsy Grim
USEPA
Washington D.C., USA

Ni-Bin Chang, Ph.D.
Texas A&M University at Kingsville
Kingsville, TX, USA

Paul B. Hatzinger, Ph.D.
Shaw Environmental, Inc.
Lawrenceville, NJ, USA

Gianna M. Cothren, Ph.D.
University of New Orleans
New Orleans, LA, USA

Gary R. Hecox, Ph.D.
Shaw Environmental &
Infrastructure
Knoxville, TN, USA

Cliff Ho, Ph.D.
Sandia National Laboratories
Albuquerque, NM, USA

Robert Holmberg, Ph.D.
Athabasca University
Athabasca, Alberta
Canada

Jihua (Jim) Hong, Ph.D.
American Academy of Sciences
New Orleans, LA, USA

Keld A. Jensen, Ph.D.
National Institute of Occupational
Health
Copenhagen, Denmark

Haifeng Ji, Ph.D.
Louisiana Tech University
Ruston, LA, USA

John Katers, Ph.D.
University of Wisconsin at Green
Bay
Green Bay, WI, USA

Mary E. Kentula, Ph.D.
U.S. EPA
National Health and Environmental
Effects Research Laboratory
Corvallis, OR, USA

Scott F. Korom, Ph.D.
University of North Dakota
Grand Forks, ND, USA

Paul R. Lear, Ph.D.
Shaw Environmental, Inc.
Knoxville, TN, USA

Qilin Li, Ph.D.
Oregon State University
Corvallis, OR, USA

Liyuan Liang, Ph.D.
Cardiff University
Cardiff, Wales, UK

William G. Lyon, Ph.D.
American Academy of Sciences
New Orleans, LA, USA

Chris McGrath
U.S. Army Engineer R&D Center
Vicksburg, MS, USA

Denise MacMillon, Ph.D.
Environmental Laboratory
Omaha, NE, USA

Mariam Mathew
Ngee Ann Polytechnic
Singapore

Victor F. Medina, Ph.D.
U.S. Army Engineer R&D Center
Waterways Experiment Station
Vicksburg, MS, USA

Susann Müller, Ph.D.
Centre for Environmental Research
Leipzig, Germany

Eric A. Nelson, , Ph.D.
Savannah River National Laboratory
Westinghouse Savannah River Co.
Aiken, SC, USA

Gon Ok, Ph.D.
Pukyong National University
Busan, Korea

Arijit Pakrasi, Ph.D.
Shaw Environmental &
Infrastructure, Inc.
Monroeville, PA, USA

Robert W. Peters, Ph.D.
University of Alabama at
Birmingham
Birmingham, AL, USA

Spencer A. Peterson, , Ph.D.
U.S. EPA Environmental Research
Laboratory
Corvallis, OR, USA

Ramesh K. Reddy, Ph.D.
University of Florida
Gainesville, FL, USA

Clint Richardson, Ph.D.
New Mexico Tech
Socorro, New Mexico, USA

Yutaka Sakakibara, Ph.D.
Waseda University
Ohkubo, Shinjuku-ku
Tokyo, Japan

John J. Sansalone, Ph.D.
Louisiana State University
Baton Rouge, LA, USA

Charles E. Schaefer, Ph.D.
Shaw Environmental, Inc.
Lawrenceville, NJ, USA

Jens Ejbye Schmidt, Ph.D.
The Technical University of
Denmark
Lyngby, Denmark

Karl-Werner Schramm, Ph.D.
GSF-National Research Center for
Environment and Health
Neuherberg, Germany

George A. Sorial, Ph.D.
University of Cincinnati
Cincinnati, OH, USA

Steve Starrett, Ph.D.
Kansas State University
Manhattan, Kansas, USA

Robert J. Steffan, Ph.D.
Shaw Environmental, Inc.
Lawrenceville, NJ, USA

Jeffrey W. Talley, Ph.D.
University of Notre Dame
Notre Dame, IN, USA

John P. Tharakan, Ph.D.
Howard University
Washington, DC, USA

A. Paul Togna, Ph.D.
Shaw Environmental, Inc.
Lawrenceville, NJ, USA

Gurudeo Anand Tularam, Ph.D.
Griffith University
Graceville, Queensland, Australia

Yuu Ubukata, Ph.D.
Tokyo Metropolitan University
Minami-ohsawa, Hachiohji
Tokyo, Japan

Todd Webster, Ph.D.
Shaw Environmental, Inc.
San Diego, CA, USA

John T. Wilson, Ph.D.
National Risk Management Research
Laboratory
Ada, OK, USA

Yonghua Yang, Ph.D.
Shaw Environmental, Inc.
Lawrenceville, NJ, USA

Kimberly K. Yates, Ph.D.
U.S. Geological Survey
St. Petersburg, FL, USA

TABLE OF CONTENTS

INTRODUCTION	1
LAND (SOIL, WASTE SOLID) POLLUTION AND REMEDIATION	
<i>Contaminant Transport in the Subsurface</i>	
Advection and Diffusion in Unsaturated Soils Influenced by Adsorption, Capillarity and Suction. Peter Schick	4
Fate of <i>Escherichia coli</i> O157:H7 in Irrigation Water on Soils and Plants. A. Mark Ibekwe, Pamela M. Watt, Peter J. Shouse, and Catherine M. Grieve	11
Innovative Characterization of Multi-Component DNAPL in a Heterogeneous Aquifer. Ed Meyers. Lewis Davies, Nicole Scroggins, Jason Perdicaris, and Brad Goeb	17
Lead Contamination and Immobilization in Shooting Range Soils. Xinde Cao, Dimitris Dermatas, and Lena Ma	18
<i>Natural Attenuation of Contaminants</i>	
Weathering of Ethanol-Blended Gasoline in Aquifers – A Field Experiment. Henry X. Corseuil, Márcio R. Schneider, and Mário do Rosário	26
<i>In Situ</i> Denitrification in the Elk Valley Aquifer, Larimore, North Dakota. Scott F. Korom	32
Activity-Dependent Enzyme Probes for Confirmation of Intrinsic Aerobic TCE Biodegradation. Ryan A. Wymore and Kent S. Sorenson, Jr.	37
Effect of Long Term Lawn Management on Soil Carbon Sequestration. Mamta H. Singh, Parwinder S. Grewal, and Warren A. Dick.	39
Microbial Activity Assessment using ¹³ C-BTEX Amended <i>In Situ</i> Microcosms. A.D. Peacock, D.C. White, K.L Sublette, A. Miltner, R. Geyer, H.-H. Richnow, and M. Kästner	40
<i>In-Situ Remediation</i>	
Remediation of Organoarsenic-Contaminated Soil by a Washing Process. Shuzo Tokunaga, and Seiji Kunishige	41
Manufacture and Testing of Macroencapsulated Buffers for pH Control. Joseph R.V. Flora, C. Marjorie Aelion, Benjamin Baker, Lubo Liu, and Daniel Wybenga.	45
Development of Consortium of Hydrocarbon Utilizing Microorganisms for Seeding Oil Polluted Sites. George E. Nkeng, Gerard Nkwelang, Roland N. Ndip, Marie N. Limla	51
Lactic Acid Recovery from Fermentation Broth of Kitchen Garbage by Reactive Distillation. Xiaohong SUN, Qunhui WANG, Rui Ma, and Wenjun ZHAO.	58
Bioremediation of Diesel-contaminated Mainland Soil in Singapore.	

<i>Mathew M., L.R. Tan, Q. Su and X. Yang, M. Baxter, E. Senior.</i>	64
Improvement of the Performance of a Biological Solubilization Process for Food Waste Treatment. Gonzales, Hazel B.; Gondo, Takehiko; Sakashita, Hideki; Nakano, Yoichi; Nishijima, Wataru; And Okada, Mitsumasa.	70
Relationship between Dehalococoides DNA and Geochemical Parameters in Chloroethylene-Contaminated Aquifers. Xiaoxia Lu, Donald H Kampbell, and John T Wilson.	76
The Evaluation of Water Treatment Sludge as Ameliorant for Acid Mine Waste. L. van Rensburg, P.J. Jansen van Rensburg and T.L. Morgenthal	77
Extraction and Recovery of Heavy Metals from MSWI Fly Ash. Li-Choung Chiang, Pai-Haung Shih, Yi-Kuo Chang, Juu-En Chang, Hsing-Cheng Lu, Yuan-Hao Chen, and Chieh-Chih Lin.	78
 Solid Waste Management	
Solid Waste Organic Matter Stability in Landfill Sites – A Case Study, S-Germany. Rupert Bäumlner and Ingrid Kögel-Knabner.	79
Long Term Stewardship Criteria for Radioactive and Hazardous Waste Sites - A National and International Perspective. Lorne G. Everett	86
Studies of Solid Waste Management Scenarios of Urban Area. Chungching Wang and Min-Der Lin	87
Pretreated MSWI Bottom Ash Utilized as Cement Raw Material. Pai-Haung Shih, Tz-Hau Guo, Juu-En Chang, and Li-Choung Chiang.	93
A High Temperature Ferrite Process for Hazardous Heavy Metal-Containing Sludge. Hung-Ta Chen, Juu-En Chang, Hsing-Cheng Lu, Chia-Yu Ko, Pai-Haung Shih.	100
Catalytic Production of Liquid Fuels from Organic Residues of Rendering Plants. S. Bojanowski, A. Fiedler, A. Frank, J. Rossmannith, G. Schilling, E. A. Stadlbauer.	106
 On-site and Off-site Remediation	
The Effect of Woodchip Waste on Vegetation Establishment during Platinum Tailings Rehabilitation. Leon van Rensburg and Theunis Morgentha.	108
Principles of Solidification/Stabilization Treatment, and Examples of Use in Remediation. Charles M. Wilk	122
Evaluation of the Efficiency of Various Commercial Products for the Bioremediation of Hydrocarbon Contaminated Soil. L. van Rensburg, K.J. Riedel, P.J. Jansen van Rensburg, J.J. Bezuidenhout and S. Claassens.	123
An In Situ Chemical Remediation of PCB-Contaminated Soils. Sung-Chul Kim and Dong-Keun Lee.	125
Mitigation of Energetic Compound Leaching into Soil Using Peat and Soybean Oil. Charles E. Schaefer, Mark E. Fuller, Jean M. Lowey, and Robert J. Steffan.	131

Strategies for Remediation Using Bioaugmentation under Performance Based Contracts. D. Scott Pittenger and Mark A. Rasberry	132
Destruction of Gas-Phase VOCs by a Coupled Adsorption/Fenton's Reaction Process. Carla L. De Las Casas , Kurt G. Bishop , Wendell P. Ela , A. Eduardo Sáez , Robert G. Arnold , and Scott G. Huling	133
Role of CO ₂ Exsolution in Acid Drainage Neutralization within Anoxic Limestone Systems. Silvana Santomartino and John A. Webb	134
EHC TM – A Novel Material for In-Situ Reductive Dechlorination of Chlorinated Solvents. Eva Dmitrovic , Alan Seech , Kerry Bolanos-Shaw , David Hill , Mike Gibson , James Mueller , and Jack Trevors	135
Investigation of Chlorinated Methane Treatability Using Activated Sodium Persulfate. Duane K. Root , Philip A. Block , and William G. Cutler	136
Evaluation of Electron Donors for Use during Biostimulation of Residual Source Areas. Tamzen W. Macbeth , Ryan A. Wymore , and Kent S. Sorenson, Jr.	136

Landfill

Hydrogeological Fundamentals of Landfill Flushing. Gernot Doeberl , Johann Fellner and Paul H. Brunner	138
An Experimental Rhizosphere Fumigation System for Landfill Revegetation Research. Douglas H. Trotter , John A. Cooke and Norman M. Pammenter	145
Numerical Modeling of the Long-term Behavior of Waste in Landfills. Yasumasa Tojo , Nobutoshi Tanaka , Toshihiko Matsuto , and Masahiro Osako	152
Combined Cellular Automata with Multi-criteria Decision-making for Siting New Landfill in an Urban Region. Gomathishankar Parvathinathan , Javier Guerrero and Ni-Bin Chang	159
Analysis of Wisconsin Municipal Solid Waste Landfilling Trends and the Impact of Recycling Fee Increases on the Amount of Imported Waste. John F. Katers and Dawn M. Walczak	166
Tree Response to Simulated Landfill Soil Conditions of High CO ₂ and Low O ₂ . Douglas H. Trotter , John A. Cooke and Norman M. Pammenter	172
Phytocapping of Landfill Sites: the Importance of Selecting Suitable Plant Species. Nanjappa Ashwath and Nina Pangahas	173

Biotransformation of Pollutants

Phytoremediation of TNT Contaminated Soils Using Crude Nitroreductase Enzyme Extracted from <i>Spinacia oleracea</i> . Clinton P. Richardson and Enric Bonmati	175
Optimization of Anaerobic Degradation of Xenobiotic Compounds in CSTR Reactors Treating Sewage Sludge. N. Christensen , D.J. Batstone and J.E. Schmidt	182
Biotransformation of PCBs in Contaminated Sludge: Use of Novel Biological Technologies. John Tharakan , Dave Tomlinson , Anuradha Addagada and Abdul Shafagati	183

Biodegradation of Sheep Dip Wastes as an Environmentally Safe Method of Disposal. Cannon, Mairin, Clipson, Nicholas, Grant, Russell and Doyle, Evelyn.	190
---	-----

Permeable Reactive Barriers

Long-term Performance of Fe(0) Permeable Reactive Barriers: Integrating Field and Laboratory Studies. Liyuan Liang	192
Iron Oxide Coatings on Fe ⁰ Grains Used for Nitrate Removal. Yong H. Huang and Tian C. Zhang	210
Removal of Dissolved Metals by Zero-Valent Iron (ZVI) under Storm Water Conditions. Ropru Rangsviek, Martin Jekel, and Gary Amy	216
Perchlorate Reduction by Bacteria Supported on Zero-Valent Iron. Xueyuan Yu, Christopher Amrhein, Marc A. Deshusses and Mark R. Matsumoto	223
Over 10 Years of Field Performance of Permeable Reactive Barrier (PRB) Systems. Michael Duchene and John Vogan	229
Use of Reactive Permeable Barrier for Groundwater pH Adjustment. M.T. Balba, D. Coons, S. Dore, D. Pope, Jr., J. Singer, M. Tomka and A.F. Westo	230

ECOSYSTEM RESTORATION

Restoration of Ecosystems

Are We Failing at Stream Restoration? Raymond P. Morgan II	237
Utilization of Grass Establishment and Amelioration in Co-disposed Diamond Tailings Rehabilitation. M.S. Maboeta and L. van Rensburg	243
Quantifying the Physical and Chemical Properties of Co-disposed Diamond Tailings - Rehabilitation Perspectives. M.S. Maboeta and L. van Rensburg	243

Nutrients and Functions of Ecosystems

Integrated Assessment of BMPs, Nutrient Transport, and Water Quality in an Agriculturally-dominated Stream. Indrajeet Chaubey, D. Sahoo, B.E. Haggard, K.L. White, and T.A. Costello	244
Effects of Lawn Management Practices on Soil Nematode Community and Nutrient Pools. Zhiqiang Cheng, Parwinder S. Grewal, and Benjamin R. Stinner	244
Distribution of Matrix-Bound Phosphine and its Relationship with Sedimentary Environment in Jiaozhou Bay, China. Xiuxian Song, Qinglin Mu and Zhiming Yu	245
Soil Nutrient and Sediment Dynamics on the Kent Stour Floodplain, England. Hadrian F. Cook	247
Nutrient Uptake by Young Poplar and Alder Trees Treated with Hog Manure. Polona Kalan and Daniel Žlindra and John H. Carson, Jr.	254

Ecosystem Assessment

Evaluation of Coal Discard Site Rehabilitation Based on Soil Microbial Community Function and Structure. S. Claassens, K.J. Riedel, L. van Rensburg, & P.J. Jansen van Rensburg	260
Acid Sulfate Soils: Their Drainage, Oxidation, and Best Management. Mike Melville, David Waite, Ros Desmier, Andrew Kinsela, Jason Reynolds, Annabelle Keene, Jodie Smith, Ben Macdonald, Ian, Erica Donner, and Robert Quirk	261
The Effect of Different Salinity Levels of Root Zone on Water Consumption, Yield of Kallar Grass (<i>Diplanthe Fusca</i>). Zeynep Zaimoğlu, M. Yavuz Sucu	262

WETLANDS

Conservation and Geochemical Processes of Wetlands

Factors Controlling the Dynamics of As, Cd, Zn, and Pb in Alluvial Soils of the Elbe River Germany). Jörg Rinklebe, Anja Stubbe, Hans-Joachim Staerk, Rainer Wennrich, and Heinz-Ulrich Neue	265
Metal Distribution in the Flooding Zones from the Xianghai Wetlands, Northeast China. Wang Guo-ping Wang Jin-da Zhai Zheng-li	271
Water Chemistry Depth Profile in a Bog Restoration Site. Rofiq Iqbal, Koichi Tokutake, Atsuko Ishige, and Harukuni Tachibana	277

Wetlands for Wastewater Treatment

Metal Removal from Process and Stormwater Discharges by Constructed Treatment Wetlands. Rofiq Iqbal, Koichi Tokutake, Atsuko Ishige, and Harukuni Tachibana	283
Metals Retention in Constructed Wetland Sediment. Anna Sophia Knox, Dave Dunn, Eric Nelson, Winona Specht, Michael Paller, and John Seaman	289
A Pilot Study on Agricultural Wastewater Treatment in Tidal Flow Constructed Wetlands. Guangzhi Sun, Stephen Allen, Yaqian Zhao, and David Cooper	295
Aerated Wetlands for the Treatment of Municipal Wastewater. Sung-Chul Kim, Dong-Keun Lee and Ku-Hyun Park	302
Neutral Mine Drainage Treatment with Constructed Wetlands. Mark W. Fitch, Joel G. Burken, Chang Ye, and Cem Selman	307
Plant-Covered Retention Soil Filters (RSF) – The Mechanical and Biological Combined Water Treatment Plant. Franz-Bernd Frechen, Wernfried Schier and Jörg Felmeden	308
Design of a Three-dimensional Water Sampling Array in a Constructed Wetland. C.F. Williams, F.J. Adamsen and N. Silvestry Rodriguez	309

SEDIMENTS

Contaminated Sediments

Biokinetic Parameter Estimation for Polycyclic Aromatic Hydrocarbon	
---	--

Remediation. <i>Prasanna. K. Mohan, George Nakhla and Ernest.K.Yanful</i>	311
Assessing the Availability of 2,4,6-Trinitrotoluene from Sand and Clay Minerals Using TPD-MS. <i>Kara M. Young and Jeffrey W. Talley, Steven L. Larson</i>	319
Managing Risks of Sediment Contaminants. <i>Danny Reible</i>	325
Non-extractable DDT-related Compounds in Aquatic Sediments Revealed by Thermochemolysis-GC-MS. <i>Alexander Kronimus, Jan Schwarzbauer, and Sabine Heim</i>	326
Diurnal and Seasonal Changes in Redox and pH of Sediments. <i>F.J. Adamsen, C.F. Williams, and N. Silvestry Rodriguez</i>	327

Assessment and Remediation

The Risk Assessment of Heavy Metals and Organic Matter in Prague. <i>Libuše Benešová, Jaroslav Tonika, Petra Hnatuková</i>	328
Chromium Contaminated Sediments in the Czorsztyn Reservoir Watershed. <i>Ewa Szalińska</i>	335
Importance of Water& Sediment Quality for Lagoons. A Case: Küçükçekmece Lake in Turkey. <i>Zehra Sapci Zengin and Beyza Ustun</i>	341
Spatial Distribution of Total Mercury in Surficial Sediment of Songkhla Lake, Thailand. <i>Sompongchaiyakul, P. and Sirinawin, W.</i>	347
Water Quality Assessment and Heavy Metal Accumulation in the Sediments of a Drainage Channel, Cukurova Plain, Turkey. <i>A. Yuceer, Z. Zaimoglu, O. I. Davutluoglu, I. Hazir, and M. Y. Sucu</i>	354

GLOBAL CHANGE

On The Concept of Gradient Biome and its Feasibility. <i>Hiroshi Kagemoto, Hiroo Ohmori, Junya Yano and Tsuguki Kinoshita</i>	362
N ₂ O Emission Factor as Affected by Precipitation. <i>Yao Huang and Xunhua Zheng, and Yanyu Lu</i>	366
Recent Sea Level Variations at the North Sea and Baltic Coastlines. <i>Jürgen Jensen and Christoph Mudersbach</i>	367
The Characteristics of Energy Consumption of SOHO Architecture in Central Tokyo. <i>Junqiao Han, Hironori Fujiki and Toshio Ojima</i>	373
Quantitative Dependence of Crop Dark Respiration on Tissue Nitrogen Concentration. <i>Wenjuan Sun, Shutao Chen, Yao Huang and Xunhua Zheng</i>	380

METALS

Metal Distribution

The Transformation and Concentration of Environmentally Hazardous Trace Elements during Coal Combustion. <i>Yao Duoxi, Zhi Xia-chen</i>	382
Distribution Characters of Heavy-Metal Elements in Deposits of Huainan Section, Huaihe River. <i>Yan Jiaping, Zhou Fulai, and Xu Guangquan</i>	389

Testing the Use of Multi-Element Soil Contamination Data in Environmental Archaeology. <i>Clare Wilson, Donald Davidson, and Malcolm Cresser</i> ..395	
Trace Elements in Honey and Royal Jelly from Diverse Geographical Origins. <i>Stocker A., Schramel P., Grill P., Kettrup A., Schramm K.-W., and Bengsch E.</i>	401
Acid and Metal Discharges from Acid Sulfate Soils, Eastern Australia and Finland. <i>Macdonald, B.C.T., White, I., Åström, M.E., Reynolds J.K., and Österholm, P.</i>	402
Environmental Factors Affecting the Uptake of Metal Contaminants by Hydroponically Cultured Celery. <i>Yang Miaofeng, Liu Haibo, Chen Chengxiang, Zhuang Zhixia, Huang Zhiyong, Chen Yanhong, Hong Yanli, and Wang Xiaoru</i>	410

Metal Behavior and Remediation

Effectiveness and Mechanisms of Permanganate Enhancing Arsenite Co-Precipitation with Ferric Chloride. <i>Liu Ruiping, Li Guibai, Yuan Baoling, and Wu Rongcheng</i>	411
The Residual Effects of Heavy Metals in Recultivated Deposols. <i>Licina Vlado, Svetlana Antic-Mladenovic, Mirjana Kresovic</i>	417
Risk Assessment and Environmental Fate of Arsenic and Heavy Metals from Mine Soil – X-Ray Diffraction, REM- and Mobility Investigations. <i>Hamer, M. and Brümmner, G.W.</i>	423
Removal of Uranium from Solution with Bacterially-Produced Iron Sulphide Using HGMS. <i>Daisuke Ito, Kuniaki Miura, Osuke Miura, Yoshiaki Takahashi and Yukio Wada</i>	424
Role and Properties of Calcium Aluminum Oxide Hydrates in Chromium Waste Stabilization. <i>M. Chrysochoou, D. Dermatas and D. Moon</i>	429

Speciation and Bioavailability

Do Microbes Affect Groundwater Arsenic Concentrations? A Study on an Arsenate-Reducing Bacterium. <i>Jennifer M. Weldon and Jean D. MacRae</i>	430
Arsenic Speciation and Identification of Active Iron Adsorbent Sites by XAFS Technology. <i>Dilshad Masih, Ken-ichi Aika and Yasuo Izumi</i>	435
Role of Colloids in Transport and Potential Bioavailability of Chromium in Streams Contaminated with Tannery Effluents. <i>J. Dominik, B. Koukal, B. Ferrari, J.-L. Loizeau, M.-H. Pereira de Abreu, D. Vignati, and A. Bobrowski</i>	441

ORGANIC POLLUTANTS

Behavior of Organic Pollutants

TCE Sorption Characteristics of Soil Amendments Suitable for Permeable Biological Barrier. <i>Yelena Katsenovich, Zuhail Ozturk, Lawrence Moos, Marshall Allen, Berrin Tansel</i>	450
Investigation of Characteristics and Release Amounts of PCDDS/DFS and DLPCBS from Sewage Disposal Facilities. <i>Gon Ok, Ji-Hoon Park</i>	

<i>and Dong-Hwan Kim</i>	457
Risk Assessment of Pesticide Impact in Groundwater and Surface System in the Lower Rio Grande Valley, Texas. <i>Srilakshmi Kanth., R., Parvathinathan, G., Chang, N. B and Mani Skaria</i>	461
Crop Residue and Benazolin Turnover in Undisturbed Soil Columns. <i>Anne Berns, Frauke Schnitzler, Nadine Haupt and Peter Burauel</i>	467
Density-Dependent Transport and Sequential Biotransformation of Trichloroethylene in the Variably Saturated Zone. <i>Wonyong Jang and M. M. Aral</i>	468
Minimization of Hazardous Emissions in Coal Solid Waste Co-Combustion by Primary Measures. <i>Marchela Pandelova, Dieter Lenoir, Antonius Kettrup, Karl-Werner Schramm</i>	474
 <i>Degradation of Organic Pollutants</i>	
Thermodynamic Assessment of Anaerobic Degradation of Xenobiotic Compounds. <i>D.J. Batstone, E. Trably, N. Christensen, I. Angelidaki, and J.E. Schmidt</i>	475
Cometabolic Degradation of MTBE by Different Species of Bacteria. <i>Kathleen Haase, Karin-Dagmar Wendlandt, and Ulrich Stottmeister</i> ...	481
Sorption of Complex Systems of Nonylphenol and Small Nonylphenol Polyethoxylates onto SPM. <i>Hong-wen Sun and Shao-gang Hou</i>	487
Effect of Nutrient Amendments on Oil Biodegradation in Seawater. <i>Xia Wen-xiang, Zheng Xi-lai, Li Jin-cheng, Song Zhi-wen, and Zhou Li</i> ...	493
Biodegradation of an Emerging Contaminant: 1,4-Dioxane. <i>Robert J. Steffan and Simon Vainberg</i>	499
Biotransformation of Dichloro- to Tetrachlorodibenzo-p-Dioxin by White-Rot Fungi. <i>Ichiro Kamei and Ryuichiro Kondo</i>	500
Evaluation of MTBE Destruction and Byproducts Formation by Using Advanced Oxidation Processes. <i>Rajib Sinha, Radha Krishnan, Balaji Ramakrishnan, George Sorial, Craig L. Patterson, and Roy C. Haught</i>	501
 <i>Transport and Remediation of Organic Pollutant</i>	
Bioremediation of Polychlorinated Biphenyl and Petroleum Contaminated Soil. <i>Hamid Borazjani, Don Wiltcher, and Susan Diehl</i>	502
Automated Spray Irrigation Control for Groundwater Remediation. <i>Arun Varadhan, Stephanie Salazar, Lawrence Moos, Marshall Allen</i>	508
Stabilization of Organic Contaminants – A Cost-Effective and Practical Remedial Alternative. <i>Paul R. Lear and Greg Bennett</i>	514
Remediation of MTBE Contaminated Groundwater: An Historical Perspective. <i>Robert J. Steffan</i>	520
Field Comparison of Biostimulation and Bioaugmentation for in situ Bioremediation of Chlorinated Ethenes. <i>Daniel P. Leigh, Tarek Ladaa, Robert Steffan, and Scott Anderson</i>	521

MODELING

Environmental Process Simulation

Numerical Study of Heavy Axisymmetric and Line Particle Clouds using LES. **Singh Jaswant, Akiyama Juichiro and Shegeeda Mirei**523

Application of High Performance Computing Techniques (Parallel Processing) to the Modeling of Complex Coupled Geo-Processes using a Finite Element Approach (GEOSYS/ROCKFLOW). **Dany Kemmler, Olaf Kolditz, Panagiotis Adamidis and Rolf Rabenseifner**...530

Numerical Simulation of Saltwater Intrusion Employing Finite Element Solvers. **Gurudeo Anand Tularam, Nick Surawski and Roger Braddock**538

Water Quality Modeling

A Mathematical Model For Difference-Type Tail-Water Measuring And Controlling System. **Bangyi Yu, and Zhiqiang Deng**547

Water Quality Modelling from Sewer Network to Coastal Water: A Case Study. **Frédéric Gogien, and Mathieu Zug**553

Wall Boundary Conditioning of Turbulent Particle-Laden Flows. **Rodion Groll**560

Quantitative Analysis of the Dystrophication from Rainfall. **Jizhen Wang, Meiyi Zhang and Lei Ge**566

Development of Modelling for Environmental Processes. **Miklós Bulla, Péter Keresztes, László T. Kóczy and Éva V. P. Rácz**567

GIS, STATISTICS, AND REMOTE SENSING

GIS for Environmental Assessment

Incorporating Historical Data into a GIS for Environmental Planning. **James Bond and Judy Reagan**578

GIS-Based Zoning of Illegal Dumping Potentials for Efficient Surveillance. **Tomohiro Tasaki, Takatsune Kawahata, Masahiro Osako, Yasuhiro Matsui, Susumu Takagishi, and Akihiro Morita**584

A GIS-Based Decision Support System for Watershed Management. **Indrajeet Chaubey, Sudhanshu S. Panda, Marty D. Matlock and Kati L. White**590

A GIS Web Mapping Approach for Identifying Species and Locations for Ecological Risk Assessments. **Thomas Pfleeger, Connie Burdick, David Olszyk, John Gabriel, Lew Ladd, Rachel Schwindt, George King, Jeffery Kern, and John Fletcher**591

GIS Integration for Groundwater Evaluations—Illustrated with Case Study of Ogallala Aquifer, Northwestern Kansas. **Gary R. Hecox**.....592

Data Management and Statistics

An Adaptive Management Approach for Mitigating Mercury Sources under Total Maximum Daily Load Guidelines. **Alexander W. Wood, Richard Bernknopf, James Rytuba, Donald A. Singer, Richard**

<i>Champion, William B. Labiosa</i>	593
Multivariate Comparison to Background. John H. Carson Jr. and Arjun K. Gupta	600
Statistical Evaluation Plans for Compliance Monitoring Programs. Robert A. Ellgas and Julian C. Isham	606
Multivariate Estimation of the Efficiency of Soil Sampling Designs. Polona Kalan, Katarina Košmelj, Charles Taillie, Anton Cedilnik, and John H. Carson, Jr.	612
Multi-faceted Sustainability Assessment for Resources Conservation and Recycling in the Lower Rio Grande River Basin, Texas. Eric Davila and Ni-Bin Chang	613

Environmental Remote Sensing Applications

Ship Based Radar Mapping Of Sea Surfaces Covered By Substances. Nicole Braun, Marius Cysewski, Gottfried Schymura, and Friedwart Ziemer	614
Combined Remote Sensing with Water Quality Modeling for Storm Water Management. Jeng-Chung Chen and Pei-Shan Tsou, and Ni-Bin Chang	619

SOCIETY AND THE ENVIRONMENT

The Changing Role of Science in Environmental Policy Making. Adriaan Slob and Gerald Jan Ellen	627
Discovering REACH – Lessons from the EU’s Regulatory Framework for Chemicals. Heinrich Tschochohei	634
The Role of the Financial Sector in Sustainable Development: A Case Study of TVEs Development in China. Guo Peiyuan and Yu Yongda	641
A Study on Environmentally Conscious Behavior in a Recycling-Oriented Society. Shoichi Taniguchi and Taka Morikawa, and Hitomi Sato	647

ENVIRONMENTAL ANALYSIS AND MEASUREMENTS

EPA Method 1664, SPE, and GC-MS for Analysis of Organics in Runoff. Rebecca R. James, Albert E. Ogden and John P. DiVincenzo	654
Application of Semipermeable Membrane Devices to Monitoring Typical Toxic and Organic Pollutants. Shugui Dai, Xia Zhong, Jian Xu, Ping Wang, Qinghua Nie, and Junxing Dong	660
Using Ionic Liquid–filled Semipermeable Membranes to Extract Polycyclic Aromatic Hydrocarbons from Water. Shu-gui Dai, Wen-yan Zhao, Meng Han, Jian Xu, and Xia Zhong	667
Detection of CH ₃ Hg ⁺ Using Microcantilever Sensors Modified with 1,6-hexanedithiol Monolayers. Hai-Feng Ji, Vemana Purathomam, Yifei Zhang, and Don Haynie	677
A Microbial Biosensor of BOD for Sea Water. Cui Jiansheng, Ma Li, Wang Xiaohui and Chen Xi	673

Development of Analytical Methods for Organic Polymer Determination Used in Water Treatment. S. Majam , S.B. Jonnalagadda , and P. Thompson	678
Rapid Identification of Environmental Petroleum Contaminants by Near-Infrared Spectroscopy (NIR). Li Wang , Xiaoru Wang , Frank. Lee and Ying He	685
Real time and in situ measurement of dissolved oxygen in seawater. Yuefen Yin , Frank S C Lee , Xiaoru Wang , and Yubin Yu	690
The Ionizer as a Sampling Method for Airborne MCWA: A Comparison Study. Maja Jamedzija , Ragnar Rylander , and Lena Elfman	691
Solid Phase Extraction Determination of Trace Elements in Fish Otoliths by ICP-MS. Zikri Arslan	692
Analysis of Cations in Estuary Water Samples by Ion Chromatography with Conductivity Detection. SHEN Yang , YIN Yue-fen , WANG Xiao-ru , Frank Sen-Chun Lee	692
Guided Surface Vehicles as Mobile Instrument Platforms. Mike L. Hall and Eric T. Steimle	693

INTRODUCTION

The First International Conference on Environmental Science and Technology 2005 was held in New Orleans, Louisiana, January 23-26, 2005. The Program included 14 sections, containing 59 sessions with approximately 600 platform and poster presentations.

Authors of the presentations accepted for the program were invited to submit their papers to the Conference Organizing Committee. More than 200 papers were received and then reviewed by the editors, session chairs, and the members of the Scientific/Technical Committee of the conference. Those papers and abstracts accepted for publication were assembled into two volumes.

Sections are arranged basically according to their order listed in the original program except the session entitled *Bio-Assessment and Toxicology*. This exception was made to balance the length of the two volumes.

Proceedings of Environmental Science and Technology 2005 (I) contains the following sections:

- Water Pollution and Water Quality Control
- Air Pollution and Air Quality Control
- Bio-Assessment and Toxicology

Papers of more sections are included in *Proceedings of Environmental Science and Technology 2005 (II)*:

- Land (Soil, Waste Solid) Pollution and Remediation
- Ecosystem Restoration
- Wetlands
- Sediments
- Global Change
- Metals
- Organic Pollutants
- Modeling
- GIS, Statistics, and Remote Sensing
- Society and the Environment
- Environmental Analysis and Measurements

We would like to thank the session chairs, who not only presided over their sessions during the conference, but also contributed their time to review papers, suggesting corrections or directly correcting the papers submitted by the presenters in their sessions.

The Conference was sponsored and organized by the American Academy of Sciences and the Shaw Environmental Group, with financial contributions from the following co-sponsors and supporting organizations:

- CIBA Special Chemicals
- Elsevier
- ENVIRO-Klean Remediation Group, Inc.
- Environmental Record Search
- EnviroMetal Technologies, Inc.
- ESRI, Inc.

The papers in these proceedings represent the authors' results and opinions. No sponsors, co-sponsors, participating organizations or editors should be construed as endorsing any specific contents or conclusions in the proceedings.

William G. Lyon, Ph.D.
American Academy of Sciences

Jihua Hong, Ph.D.
American Academy of Sciences

Ramesh K. Reddy, Ph.D.
University of Florida

**LAND (SOIL, SOLID WASTE)
POLLUTION
AND REMEDIATION**

ADVECTION AND DIFFUSION IN UNSATURATED SOILS INFLUENCED BY ADSORPTION, CAPILLARITY AND SUCTION

Peter Schick (Technical University of Berlin, Germany)

ABSTRACT: A Two-Component Model for the saturation-suction relationship (pF-curve) of fine-grained soils is proposed that uses the physical water-binding mechanisms capillarity and adsorption. Standardized soil-mechanics index values are sufficient for its application. Accuracy of class-A predictions of pF-curves, a key property for emission and transport calculations in unsaturated soils, is improved considerably. Results are e.g., capillary pore distribution, characteristic inner surface, and amount of adsorbed water. Coefficient of permeability of partially saturated soils, as well as diffusion coefficients may be predicted using the same set of parameters used for the pF-curve. Thus, the effect of capillary and adsorptive forces is obvious. If the structure that has formed as a result of sufficient drying is incorporated into the next step, this results in models with aggregates and fissure planes. The advective and diffusive transportation properties of the latter have to be superimposed on the properties of the aggregates.

INTRODUCTION

Transport phenomena in porous media may be explained by advection and diffusion. The physical reason for advection (whereby dissolved matter is passively transported by convective flow of pore fluid) is a pressure or temperature gradient; however, substances spread by diffusion even in resting pore fluids because of the extremely small probability of an unequal matter distribution in comparison to the huge number of uniformly distributed states (2nd fundamental theorem of thermodynamics). Transport phenomena are influenced by interactions between pore water and grain surfaces (adsorption and desorption of water and substances) as well as between pore water and pore gas (evaporation, condensation). Often pollutants will spread only in water or gas, depending on their water solubility and vapor pressure.

MATERIALS AND METHODS

pF-Tests with Cohesive and Granular Soils: The Two-Component Model may be applied to all mineral soils that are not dominated by their organic content. Its biggest advantages are for cohesive soils because of their remarkable inner grain surfaces and, therefore, of their pronounced adsorption effects. Experimental determination of the pF-curve is conducted pointwise by several different tests with different accuracy and testing principles: Pulling mercury column, tensiometer, pressure plate test, filter paper and salt solution. Data collected over 7 orders of magnitude by these methods show noticeable scatter (Fredlund, Rahardjo, 1993; Barbour 1998).

RESULTS AND DISCUSSION

Inner Grain Surface and Adsorption Water. The volume of adsorbed water may be calculated from the thickness of adsorbed water layer d_{wA} and corresponding specific surface O , the latter from the grain size number (fraction A_k of gravel/sand/silt/clay: $A_G/A_S/A_U/A_T$ with medium grain diameter $d_k = 11.0/0.35/0.011/0.001$ mm), three different constant grain shape factors $\alpha_{k,i}$ and two index values for the mineralogical composition (Schick, 2002) (eq. 1). Distinction of three grain shapes is sufficient: $i=1$ for cubical and spherical shaped grains ($\alpha_{k,1} = 6$), $i=2$ for platelets of thickness $e = 0.1 d$ ($\alpha_{k,2} = 24$), $i=3$ for platelets of thickness $e = 0.01 d$ ($\alpha_{k,3} = 204$). For the coarse grained part only $i = 1$ was taken, clay content may be represented by only $i = 2$ and 3 , so 7 addends remain (eq. 2). The index values for mineralogical composition are:

- fraction of clay minerals in total silt $A_{TU} = A_{\text{Clay minerals in silt fraction}}/A_U$
 - fraction of montmorillonite in total clay minerals $A_{MT} = A_{\text{Mont.}}/A_{\text{Clay min. total}}$
- Grain fractions may be calculated by: $A_{Gr,1} = A_{Gr}$, $A_{S,1} = A_S$, $A_{Si,1} = 100 - A_{TU}$, $A_{Si,2} = A_{TU} \cdot (100 - A_{MT})$, $A_{Si,3} = A_{TU} \cdot A_{MT}$, $A_{Cl,2} = 100 - A_{MT}$, $A_{Cl,3} = A_{MT}$. The empirical equations (3) and (4) may be useful (Schick, 2003):

$$O \left[\frac{\text{cm}^2}{\text{g}} \right] = O_{Gr} + O_{Sa} + O_{Si} + O_{Cl} = \sum \frac{\alpha_{k,i}[1] \cdot A_{k,i}[\%] / 100}{\frac{d_k[\text{mm}]}{10} \cdot \rho_{S,k,i} \left[\frac{\text{g}}{\text{cm}^3} \right]} \quad (1)$$

$$O = O_{Gr,1} + O_{Sa,1} + O_{Si,1} + O_{Si,2} + O_{Si,3} + O_{Cl,2} + O_{Cl,3} \quad (2)$$

$$A_{TU} = 0.127 \cdot \ln(P(A < 0.4\text{mm})) + 0.729 \quad (3)$$

$$A_{MT} = 0.136 \cdot \ln(P(A < 0.4\text{mm})) + 0.393 \quad (4)$$

Adsorbed water is made up of a few molecules thick hydration water ($d = d_{hyd}$) and water bound ever more loosely as the distance increases ($d = 1/\kappa$) (Mitchell, 1993). A unified value of $d_{wA}(\psi \rightarrow 0) = d_{hyd} + 1/\kappa \approx 4$ nm allows fitting of all test results. Pore spaces are filled with adsorbed water in the saturated state as follows from (5). Usually $\psi_{0A} = pF 7 (= 1,000,000 \text{ kN/m}^2)$ is set for maximum suction (Barbour, 1998). Back-calculated values are about $600,000 \text{ kN/m}^2$ (Schick, 2003). The Two-Component Model contains a correction function (eq. 6) quite similar to (Fredlund, Xing, 1994) - where it has been used for the whole pF-curve - to force the $S_A(\psi)$ -curve (eq. 7) through the point ($S_A = 0; \psi_{0A}$).

$$n_{wA}(\psi = 0) = d_{wA}(\psi = 0) \cdot O \cdot \rho_d \quad (5)$$

$$C_{pA} = 1 - \frac{\ln\left(1 + \frac{\psi}{\psi_{kap}}\right)}{\ln\left(1 + \frac{\psi_{0A}}{\psi_{kap}}\right)} \quad (6)$$

$$S_A(\psi) = C_{pA} \cdot \frac{n_{wA}(\psi = 0)}{n} \quad (7)$$

Capillary Pore Size Distribution and Capillary Water. The capillary water fraction $S_C(\psi) = S - S_A$ is being forced through ($S_C = 0$; ψ_{kap}) by a correction function C_{pC} (eq. 8) and follows from eq. (9). The resulting pF-curves $S(\psi)$ show a sharp bend at $\psi = \psi_{kap} \approx 50,000 \text{ kN/m}^2$, where capillary water vanishes (Fig. 1, right). Therefore, pF-curves of coarse grained soils end in ($S_C = 0$; ψ_{kap}). Eq. (9) still contains the three free parameters a , m , and q . Parameter a may be calculated using geotechnical index values (Schick, 2003) because it is strictly correlated to the Air-Entry Value AEV (Fig. 1). AEV in turn is dependent on a characteristic maximum pore radius of coarse-grained soils and on liquid and shrinkage limits of fine-grained soils, respectively (eq. 10 and 11).

$$C_{pC} = 1 - \frac{\ln\left(1 + \frac{\psi}{\psi_{kap}}\right)}{\ln(2)} \quad (8)$$

$$S_C(\psi) = (1 - S_A(\psi = 0)) \cdot C_{pC} \cdot \left(\frac{1}{\ln\left(2.718.. + \left(\frac{\psi}{a}\right)^q\right)} \right)^m \quad (9)$$

$$a = 2 \cdot h_{k,p} \cdot \gamma_w = \frac{0,30}{f_{kp} \cdot d_{50}[\text{mm}]} \quad \left[\frac{\text{kN}}{\text{m}^2} \right] \quad (\text{coarse grained}) \quad (10)$$

$$a = (a_1 - a_2 \cdot w_L) \cdot \exp\left(\frac{(w_L - w_S) \cdot \frac{\rho_S}{\rho_W}}{a_3 \cdot w_L - a_4} \right) \quad \left[\frac{\text{kN}}{\text{m}^2} \right] \quad (\text{fine-grained}) \quad (11)$$

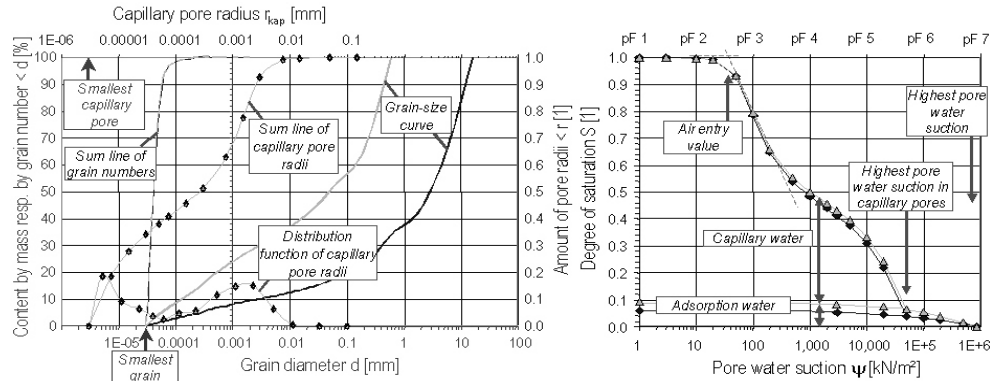


FIGURE 1: Left: Grain-size curves, sum lines and distribution functions of capillary pore radii for two soils, which are only differing in the amount of content $< 0,4$ mm. Right: pF-curves of both soils according to the Two-Component Model with limit values and water components [Schick, 2003]

Application of Two-Component Model and Required Inputs. Knowing some experimental points of the pF-curve (Fig. 1, right) and the standardized index values of the soil, parameter a follows from (10) or (11), and the pF-curve is already well described after postulating some reliable physical values (Tab. 1). Total porosity or dry density is needed as a state parameter. The nearly inversely proportional parameters m and q are found starting from $m [1] = 1$ and $q [1] = 1$; they control the form of the capillary pore radius distribution (Fig. 1, left side). Indeed, if one has to model drying-wetting cycles, a second state parameter S_0 has to be set, and a , m , and q will change during the first cycle.

TABLE 1: Necessary values for application of the Two-Component Model

Name	Needed for calculation of ...	Example				
Physical values and constants			For all soils			
Surface tension of water	Maximum capillary water suction	$T_w = 7.5E-08$ kN/mm				
Density of water	Water content and degree of saturation	$\rho_w = 1.000$ g/cm ³				
Smallest radius of capillary pores	Maximum capillary water suction	$\min r_{kap} = 3E-06$ mm				
Wetting angle water - mineral	Capillary water suction	$\alpha = 0^\circ$				
Thickness of adsorption water layer	Adsorptive bound water fraction	$d_{wa} = 4$ nm (up to $10...20$ nm at high montmorillonite content and high porosity)				
Maximum water suction at $S \rightarrow 0$	Correction function C_{pA}	$\psi_{0A} = 700,000$ kN/m ² (600,000 .. 1,000,000)				
Classification values			Soil i		Soil i+1	
Grain size index (or grain size curves)	Specific surface O resp. grain-number line	$A_G/A_S/A_U/A_T$ [%]				
Density of grains	Specific surface O resp. grain-number line	ρ_S [g/cm ³]				
Cohesive soils: liquid limit, shrinkage limit, grain density; Non-cohesive soils: Average grain size	Parameter a resp. AEV value	w_L [%] w_S [%], ρ_S [g/cm ³], d_{50} [mm]				
Mass fractions: clay minerals / silt grains; montmorillonite / total clay minerals	Specific surface O resp. grain-number line	A_{TU} [%], A_{MT} [%].				
Plasticity index	Estimation of A_{TU} and A_{MT} if no tests available	I_p [%]				
State parameters			State i_j	State i_k
Porosity	Influences adsorptive bound water fraction	n [%]				
Maximum degree of saturation after rewetting	Starting point of hysteresis loops for drying-wetting cycles	S_0 [%]				

Water Permeability and Advective Transport in Unsaturated Soils. The permeability of many soil types may be calculated by (12), e.g. for the $<0,4$ mm-content of “Bentokies” (mixed-grained sealing material, mixed-in-plant, sandy

gravel with clay powders). Reference values ($n^*=n_{100}$; $k^*=k_{100}$ with $\sigma'_v=100\text{kN/m}^2$) depend on plasticity. Often parameters $m_k = 1.5\text{...}2.5$, are influenced by many factors. Eq. (12) holds for mechanical one-dimensional compression. Dewatering has similar effects, so (12) may be used for unsaturated soils in the case of $S \gg S_A$. If only capillary water participates in the water flow, eq. (13) follows, and $k \rightarrow 0$ for $S \rightarrow S_A$, $k_{100}=k(S=1)$. A pF-curve and eq. (13) is shown in Fig. 2. As water saturation decreases, air saturation increases. Advection of gas may be calculated as Darcy-like pore air flow, accounting for gas concentration, specific weight and viscosity of the pore air.

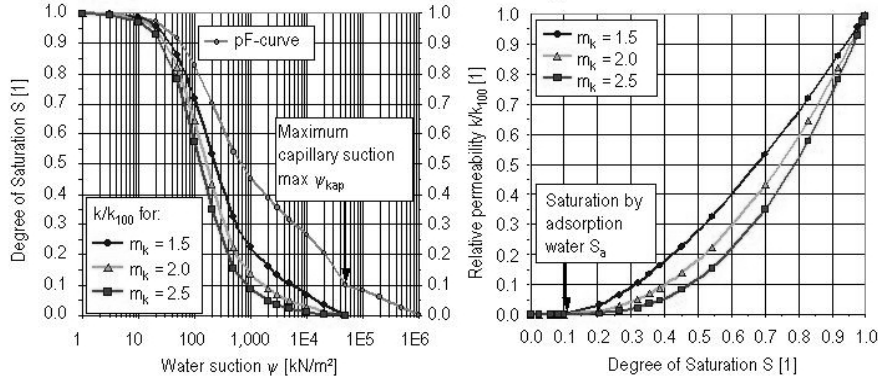


FIGURE 2: Left: pF-curve and relative permeability of unsaturated soil; Right: Relative permeability and degree of saturation acc. to eq. (13) [Schick, 2003]

$$\log\left(\frac{k}{k^*}\right) = m_k \cdot \log\left(\frac{n}{n^*}\right) \quad (12)$$

$$\frac{k}{k_{100}} = \left(\frac{S^*}{S_C}\right)^{m_k} = \left(\frac{S_C}{\max S_C}\right)^{m_k} \quad (13)$$

Diffusion in Unsaturated Soils. In low permeable soils, an effective diffusion coefficient D_{eff} accounts for the winding pathway of substances by means of a tortuosity factor, τ . A retardation factor $1/R$ handles ad- and de-sorption on characteristic grain surface areas. Transport equations should account for advective and diffusive transport, degradation, ad- and de-sorption. Neglecting hydraulic gradient and degradation and setting $n \neq f(x,t)$, $R \neq f(t)$, $d_0 \neq f(x)$, $\tau \neq f(x)$ leads to (14). For all cases with low sorption ($1/R=1$), e.g. chloride in water or tetrachloroethene in gas, the tortuosity factor is the ratio D_{eff}/d_0 , which decreases with porosity (Schick, Wunsch, 1994) (Fig. 3). As in Fig. 2 right, a decreasing diffusion coefficient has been observed with lower saturation (Barbour, 1998). There is diffusion in the adsorbed water layer up to $S = 0$, but the free diffusion coefficient d_0 becomes very small since it is inversely proportional to viscosity η_w of water according to the Stokes-Einstein equation (Atkins, 1993). Replacing the viscosity of water by the equivalent term from Rate Process Theory (Schick, 2003) gives eq. (15) (where r_h [L]: equivalent radius of particle; λ [L]: length of energy barrier, h : Plancks constant; $\Delta F/R_G T$ [1]: relative activation

energy barrier, R_G : Gas constant, T : Absolute temperature, N_A : Avogadro's No.). Free diffusion in adsorption water gets smaller due to increasing activation energy approaching the clay-mineral grain surface. Eq. (16) results if total diffusion coefficient $D_{\text{eff}}(S)$ for water-solved substances is summable from the capillary water part and the adsorbed water part.

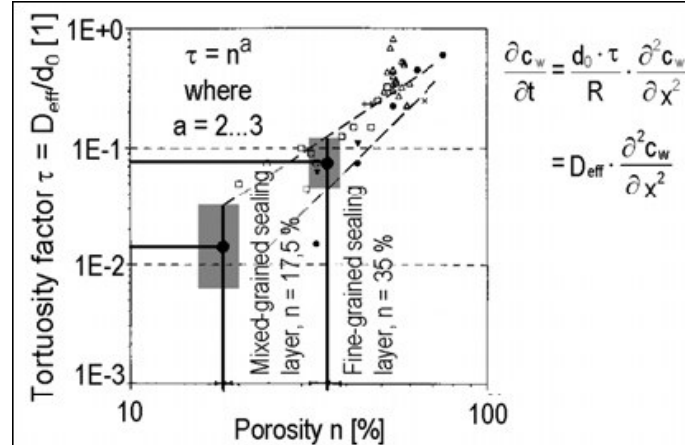


FIGURE 3: Tortuosity factor of chloride ions in soils (Schick, Wunsch, 1994)

$$\frac{\partial c_w}{\partial t} = \frac{d_0 \cdot \tau}{R} \cdot \frac{\partial^2 c_w}{\partial x^2} = D_{\text{eff}} \cdot \frac{\partial^2 c_w}{\partial x^2} \quad (14)$$

$$d_0 = \frac{R_G \cdot T}{f \cdot \eta_w} = \frac{R_G \cdot T}{6 \cdot \pi \cdot r_h \cdot \eta_w} = \frac{R_G \cdot T \cdot \lambda^3}{6 \cdot \pi \cdot r_h \cdot h \cdot \exp\left(\frac{\Delta F}{R \cdot T}\right) \cdot N_A} \quad (15)$$

$$\frac{D_{\text{eff}}(S)}{D_{\text{eff}}(S=1)} = S_C \cdot \frac{d_{0,C} \cdot \tau_C(S)}{R \cdot D_{\text{eff}}(S=1)} + S_A \cdot \frac{d_{0,A} \cdot \tau_A(S)}{R \cdot D_{\text{eff}}(S=1)} \quad (16)$$

CONCLUSIONS.

The Two-Component Model enables evaluation of the pF-curve with common, meaningful geotechnical and physical parameters. It gives information about the amount of adsorbed water, the characteristic inner grain surface and capillary pore-size distribution, which may be used for improved investigation of transport parameters in partially saturated soils. The distinction between water bound by capillary and adsorptive forces in the Two-Component Model is adequate and sufficient in this respect. Saturation-dependent concentration profiles were calculated for the homogenous and steady cases. Using the Peclet Number it can be shown, that ion transportation becomes more diffusion-controlled as water saturation vanishes.

Current research deals with application of the Two-Component Model on structuring of fine-grained soils (e.g. Schick, Schmitz, 2004), a wide-spread near-

surface phenomenon with impacts on environmental soil problems and on safety of geotechnical constructions. During drying-wetting cycles, structuring in soils will always appear and will change the transport mechanisms and strength dramatically. Nevertheless, the corresponding shrunken and cracked state is still difficult to predict. By using the Two-Component Model, some improvements are expected in this field of unsaturated soil mechanics.

ACKNOWLEDGEMENTS

This research was supported by the Federal Republic of Germany and is continued presently granted by the German DFG.

REFERENCES

- Atkins, P.W. 1993. *Kurzlehrbuch physikalische Chemie* (Textbook physical chemistry). Spektrum Verlag, Heidelberg.
- Barbour 1998. The soil-water characteristic curve: a historical perspective. 19th Canadian Geotechnical Colloquium, *Can. Geotech. J.* 35, 873-894.
- Fredlund, Rahardjo 1993. *Soil Mech. for Unsaturated Soils*. Wiley, New York.
- Fredlund, Xing 1994. Equations for the soil-water characteristic curve. *Can. Geotech. J* 31: 521-532 (1994).
- Mitchell, J.K. 1993. *Fundamentals of Soil Behaviour*. 2nd Ed., Wiley, N.Y.
- Schick, P. 1997: Bodenmechanische und bautechnische Eigenschaften von Bentokiesdichtungen (Properties of Bentokies liners for waste deposits – proof of security and serviceability). *Bautechnik* 74, H.5, S.320-330.
- Schick, P. 2002. Anwendung eines Zwei-Komponenten-Modells der pF-Kurve auf Strukturänderungen in Böden (Application of a Two-Component Model of the pF-curve to structure changes in soils). *Bautechnik* 79 (2002), Heft 2.
- Schick, P. 2003. Ein quantitatives Zwei-Komponenten-Modell der Porenwasser-Bindekräfte in teilgesättigten Böden. Mitt. Inst. Bodenmech. u. Grundbau, UniBwM, H. 17, 2003, im Druck (A quantitative Two-Component Model of the water-binding forces in partially saturated soils, in print).
- Schick, P. 2003. The pF-curve of fine-grained soils at high pore water suction. Int. Conf. "From exp. evidence towards num. modelling unsaturated soils", ISSMGE, Sept.18-19,2003, Bauhaus-Univ. Weimar, Germany, Springer.
- Schick, P., Schmitz, S.M. 2004. X-Ray Tomography of Structures in Clay Geosynthetic Barriers (CBR-C). In: Floss et al (eds.): EuroGeo3 Geosynthetics Conf., March 01-03 2004, Munich, Germany.
- Schick, P., Wunsch, R. 1994. Diffusion chlorierter Kohlenwasserstoffe durch Bentokiesdichtungen (Diffusion of chlorinated hydrocarbons through Bentokies liners). *Geotechnik* 18, S.197-204.

FATE OF *ESCHERICHIA COLI* O157:H7 IN IRRIGATION WATER ON SOILS AND PLANTS

A. *Mark Ibekwe*, Pamela M. Watt, Peter J. Shouse, and Catherine M. Grieve
USDA-ARS, George E. Brown Jr. Salinity Lab Riverside, CA 92507

ABSTRACT: A real-time PCR method was developed to detect and quantify *Escherichia coli* O157:H7/pGFP (*E. coli*). A probe was designed to hybridize with the *eae* gene of *E. coli* O157:H7. The probe was incorporated into real-time PCR containing DNA extracted from the phyllosphere, rhizosphere, and non-rhizosphere soils irrigated with water artificially contaminated with *E. coli* O157:H7. The detection limit for *E. coli* O157:H7 from quantification by real-time PCR was 1.4×10^3 in rhizosphere and phyllosphere samples. *E. coli* O157:H7 concentrations were higher in the rhizosphere than in the non-rhizosphere soils and leaf surfaces, and persisted longer in clay soil. The concentrations of *E. coli* O157:H7 obtained by real-time PCR were comparable to the concentrations obtained by traditional culture methods during the first three days of inoculation, and thereafter, the concentrations by real-time PCR were higher. The persistence of *E. coli* O157:H7 in phyllosphere, rhizosphere, and non-rhizosphere soils over 45 days may play a significant part in the re-contamination cycle of produce in the environment. Therefore, the rapidity and the feasibility of the assay may be a useful tool for quantification and monitoring of *E. coli* O157:H7 in irrigation water and contaminated fresh produce.

INTRODUCTION

Contaminated irrigation water is one of the most common vehicles by which *E. coli* O157:H7 may be introduced into crops. *Escherichia coli* O157:H7 causes a wide spectrum of diseases in humans, ranging from mild to bloody diarrhea, hemorrhagic colitis, and complications, including hemolytic uremic syndrome (HUS) and seizures that are particularly severe in children (Franke et al., 1995). Recently, Solomon et al., 2002 demonstrated the transmission of *E. coli* O157:H7 from manure-contaminated soil and irrigation water to lettuce plants using laser scanning confocal microscopy, epifluorescence microscopy and recovery of viable cells from the inner tissues of plants. They attributed the presence of *E. coli* O157:H7 in the edible portion of the plant to the direct migration through the conducting tissues of the root system.

Little research has been done on the quantification of this pathogen in the rhizosphere and phyllosphere of plants. The recent availability of new technologies such as real-time PCR has greatly aided the study of pathogens such as *E. coli* O157:H7 in the environment (Oberst et al., 1998). Recently, Ibekwe et al., 2002 described quantification of *E. coli* O157:H7 in soil, cattle feces, manure, and waste water using multiplex real-time PCR for quantification of natural *E. coli* O157:H7 from these samples. The purpose of this study was to use real-time PCR to determine the persistence of *E. coli* O157:H7 from contaminated irrigation water in the rhizosphere and phyllosphere of lettuce grown under flood

irrigation system and to compare these results with culture method based on the enumeration of pGFP expressing *E. coli* O157:H7.

MATERIALS AND METHODS

Bacterial strains, growth conditions, and inoculum preparation. The *E. coli* O157:H7 strain 34 with green fluorescent protein (pGFP) was used for this study. Plasmid construction of the strain has previously been described (Fratamico *et al.*, 1997). *E. coli* O157:H7/pGFP was cultured at 37 °C overnight in modified Tryptic Soy broth (mTSB)(Difco Laboratories Inc., Cockeysville, MD) supplemented with 100 µg of ampicillin mL⁻¹ (Sigma, St Louis, MO). Cells were harvested by centrifugation at 3500 g for 10 min and resuspended in PBS (Fisher Scientific, Pittsburgh, PA) to a concentration of ~10⁸ CFU mL⁻¹.

Soil, preparation of irrigation water and plants, and recovery of *E. coli* O157:H7/pGFP. Clay soil and sandy soil were collected from Mystic Lake dry bed and the Santa Ana River bed, respectively for this study. The soils were processed as described by Ibekwe and Grieve, 2004. Soils were tested by culture and PCR methods to make sure that they are *E. coli* O157:H7 negative. Seeds of green romaine lettuce *Lactuca sativa* (L.) cv. Green Forest) were grown in two growth chambers at 20 °C with 70% relative humidity and a photoperiod consisting of 16 h of light and 8 h of darkness.

The experiment was a completely randomized design with three replications. There were ten plants in each tray at transplanting, and one plant was harvested from each tray during analysis as stated below. The first irrigation with contaminated water containing *E. coli* O157:H7(pGFP) occurred at transplanting (day 1) for both soils, and the second contamination event occurred 15 days later. Irrigation solutions were prepared in 1000 L reservoirs and pumped to provide irrigation to the clay and sandy soil in polypropylene trays. A one liter solution containing ~ 10⁷ *E. coli* O157:H7/pGFP with 100 µg of ampicillin ml⁻¹ was applied directly to the irrigation lines and delivered to each tray with four drip lines.

Plant phyllosphere and rhizosphere soil samples were aseptically sampled for analysis at 3, 5, 9, 12, 15, 18, 25, 29, and 45 days after transplantation. Phyllosphere and rhizosphere samples were separated by cutting the above ground part of the plant into different sterile Petri dishes or collection bags and treating the rhizosphere the same. Samples were processed immediately in the laboratory. Bacteria were recovered from the phyllosphere (leaf surface) by homogenization with 100 mL of PBS for 2 min at 260 rpm in a Seward Stomacher 400 Circulator (Seward Ltd., London, UK). The same procedure was used to recover bacteria from the rhizosphere (volume of soil adjacent to and tightly held by plant roots and influenced by the plant roots). The homogenate was centrifuged at 3000 g for 10 min, the pellet was resuspended in 2 mL of PBS, 100 µL plated on mTSA with ampicillin and incubated at 37 °C overnight. *E. coli* O157:H7/pGFP colonies were enumerated under a hand-held Spectroline ultra-violet lamp (Spectronics Corporation, Westbury, NY). Portions of the concentrated samples from

rhizosphere and phyllosphere samples were used for extraction of total bacterial DNA and the DNA was used for quantification of *E. coli* O157:H7 by real-time PCR.

DNA extraction and Primer and probe design for real-time PCR. For the constructions of standard curves for real-time PCR, genomic DNA was extracted from pure culture of *E. coli* O157:H7/pGFP, grown for 8 h at 37 °C and extracted with the Qiagen tissue kit (QIAamp DNA Mini Kit; Valencia, CA). The standard curves from O157:H7/pGFP was used for the determination of detection limits of the *E. coli* by real-time PCR. Total bacterial DNA was extracted from rhizosphere and phyllosphere samples with the Ultra Clean Soil DNA Kit (MoBio Laboratories, Solana Beach, CA) and stored at -20° C. Primers and probe used for the detection and quantification of the *eae* gene in *E. coli* O157:H7 was as described by Ibekwe *et al.*, (2002). Real-time, quantitative PCR was performed with the iCycler iQ Real-Time PCR as described by Ibekwe *et al.*, 2002.

Standard curves generated from plotting the threshold cycle (C_T) versus \log_{10} of starting DNA quantities (pg) were used for determining the detection limit of the assay. The standard curve was constructed from known quantities of genomic DNA extracted from *E. coli* O157: H7. The titers (CFU mL⁻¹) of *E. coli* O157:H7 present in unknown samples were determined from the standard curve. The slopes of the standard curves were calculated by performing linear regression analysis within the iCycler iQ software to compare the PCR amplification efficiency and detection sensitivity among different experiments. Amplification efficiency (E) was estimated by using the slope of the standard curve and the formula: $E = (10^{-1/\text{slope}}) - 1$. Reaction with 100% efficiency generated a slope of -3.32. Standardization of DNA quantities between known and unknown samples was accomplished by dividing total CFU mL⁻¹ of *E. coli* O157:H7/pGFP by the mean starting DNA concentration of that CFU mL⁻¹ from the instrument analysis as described previously (Ibekwe *et al.*, 2002). This resulted in a CFU mL⁻¹ index, which was used as a multiplier to calculate the CFU mL⁻¹ of all unknown samples. The CFU mL⁻¹ index was obtained from the highest DNA quantity to estimate CFU mL⁻¹ from lower DNA quantities.

RESULTS AND DISCUSSION

Sensitivity, standard curve, and amplification efficiency of real-time PCR assay. Previous work (Ibekwe *et al.*, 2002) showed the *eae* gene to be a much conserved marker for distinguishing *E. coli* O157:H7 from other serotypes of *E. coli* after analyzing 33 Shiga toxicogenic *E. coli* (STEC) and non-STEC *E. coli* strains. The sensitivity of the Texas Red-labeled probe to specifically detect and quantify the *eae* gene was determined by plotting the log DNA starting quantities of *E. coli* O157:H7/pGFP. The mean C_T values were between 21 and 23 when 5 to 10 pg DNA mL⁻¹ was used as a template. The dynamic range for cell detection of the quantitative real-time PCR was determined to be between 10³ to 10⁸ CFU mL⁻¹ of *E. coli* pGFP (data not shown). Concentrations of *E. coli* O157:H7 in plant and soil samples were calculated from this standard curve. Based on this

approach, a correlation was observed between the C_T and the CFU mL^{-1} of the starting quantity of *E. coli* O157:H7 DNA, with a detection limit of $1.4 \times 10^3 \text{ CFU mL}^{-1}$ with a correlation coefficient of about 0.99 for each curve.

Fate of *E. coli* O157:H7 in phyllosphere and rhizosphere as determined by plate count of pGFP colonies and real-time PCR. *E. coli* O157:H7 populations in the phyllosphere samples after the first contamination event decreased an average > 3 logs between day 3 and 12 in the clay soil and < 4 logs for the sandy soil (Fig. 1a). On the average, about 170 CFU of *E. coli* O157:H7 g^{-1} was recovered from lettuce phyllosphere

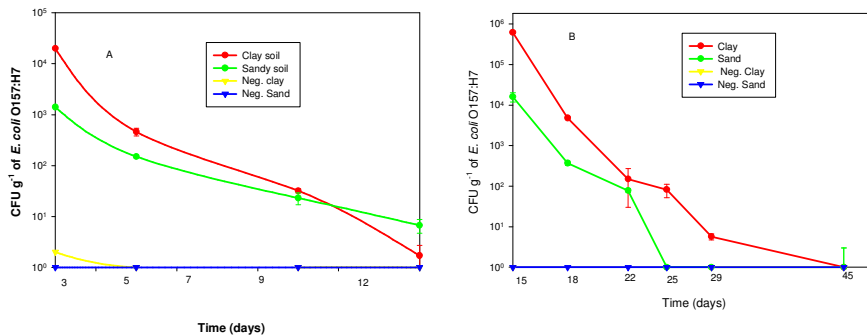


Fig. 1. Quantification of *E. coli* O157:H7 in the phyllosphere after (a) 12 d and (b) from day 15 to 45. *E. coli* O157:H7 enumerated from clay and sandy soils by plate count of pGFP.

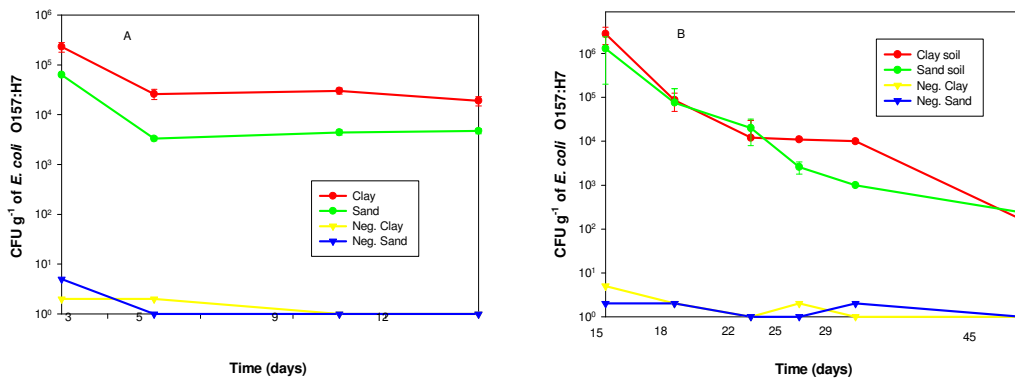


Fig. 2. Quantification of *E. coli* O157:H7 in the rhizosphere after (a) 12 d and (b) from day 15 to 45. *E. coli* O157:H7 enumerated from clay and sandy soils by plate count of pGFP.

grown on clay soil and about 67 CFU of *E. coli* O157:H7 g^{-1} was recovered from lettuce phyllosphere grown on sandy soil after the first 12 days. Following the

second contamination event, the concentration of the pathogen in the phyllosphere of both soils after 45 days dropped to ≤ 10 CFU g^{-1} (Fig. 1b). Throughout the 45 days study, the *E. coli* O157:H7 population decline was linear in the phyllosphere. The concentration of *E. coli* O157:H7/pGFP in rhizosphere soils was 10^5 CFU g^{-1} in both soils at day 12 (Fig. 2a), with the clay soil significantly higher than the sandy soil. However, the trend in survival after the second contamination event (from day 15 to 45) was significantly different from the first contamination event (Fig 2b). There were no differences in the concentrations between the two soils by the end of the study. The survival of *E. coli* O157:H7/pGFP in the rhizosphere was 2 logs higher in the rhizosphere than in the leaves of the plants. Furthermore, the *E. coli* O157:H7/pGFP population decline rate constant was significantly different on both the clay and sandy soils ($r^2 = 0.99$ and $P = 0.001$). Thus *E. coli* O157:H7/pGFP survived best and remained culturable for a longer period of time in the rhizosphere. This agreed with a recent report by Gagliardi and Karns (2000), that *E. coli* O157:H7 persistence was enhanced in the rhizosphere of rye and legumes grown in clay soil.

Table 1. Quantification of *E. coli* O157:H7 by real-time PCR during the first and the second inoculation events

Soil type	Day	Sample type	Real-time PCR of <i>eae</i> gene (CFU g^{-1})*	Soil type	Day	Sample type	Real-time PCR for <i>eae</i> gene (CFU g^{-1})*	
Clay	3	Phyllosphere	$1.1 \times 10^5 \pm 6.0 \times 10^5$	Clay	15	Phyllosphere	$7.0 \times 10^6 \pm 8.1 \times 10^6$	
		Rhizosphere	$2.5 \times 10^6 \pm 2.1 \times 10^5$			Rhizosphere	$1.7 \times 10^6 \pm 1.6 \times 10^6$	
	5	Phyllosphere	$4.9 \times 10^3 \pm 6.7 \times 10^3$		18	Phyllosphere	$3.2 \times 10^5 \pm 4.5 \times 10^5$	
		Rhizosphere	$1.5 \times 10^5 \pm 2.5 \times 10^4$			Rhizosphere	$2.5 \times 10^6 \pm 1.2 \times 10^5$	
	9	Phyllosphere	$1.4 \times 10^3 \pm 3.4 \times 10^3$		22	Phyllosphere	$3.6 \times 10^5 \pm 3.2 \times 10^5$	
		Rhizosphere	$1.7 \times 10^5 \pm 1.6 \times 10^5$			Rhizosphere	$1.1 \times 10^6 \pm 9.3 \times 10^5$	
12	Phyllosphere	$1.1 \times 10^3 \pm 6.9 \times 10^2$	25	Phyllosphere	$6.6 \times 10^4 \pm 3.2 \times 10^4$			
	Rhizosphere	$1.4 \times 10^5 \pm 2.1 \times 10^5$		Rhizosphere	$6.9 \times 10^5 \pm 4.0 \times 10^5$			
Sand	3	Phyllosphere	$5.9 \times 10^5 \pm 2.9 \times 10^5$	Sand	29	Phyllosphere	$3.6 \times 10^3 \pm 1.8 \times 10^3$	
		Rhizosphere	$2.5 \times 10^5 \pm 1.5 \times 10^5$			Rhizosphere	$2.0 \times 10^5 \pm 2.5 \times 10^5$	
	5	Phyllosphere	$3.2 \times 10^4 \pm 1.9 \times 10^4$		45	Phyllosphere	$1.7 \times 10^3 \pm 7.9 \times 10^2$	
		Rhizosphere	$7.1 \times 10^5 \pm 9.4 \times 10^5$			Rhizosphere	$9.8 \times 10^4 \pm 4.2 \times 10^4$	
	9	Phyllosphere	$1.3 \times 10^3 \pm 1.7 \times 10^3$		15	Phyllosphere	$2.1 \times 10^5 \pm 1.6 \times 10^5$	
		Rhizosphere	$3.8 \times 10^4 \pm 4.4 \times 10^4$			Rhizosphere	$3.0 \times 10^6 \pm 2.6 \times 10^6$	
	12	Phyllosphere	$2.4 \times 10^3 \pm 1.4 \times 10^3$		18	Phyllosphere	$6.1 \times 10^4 \pm 3.8 \times 10^4$	
		Rhizosphere	$3.6 \times 10^3 \pm 3.7 \times 10^3$			Rhizosphere	$4.1 \times 10^6 \pm 6.5 \times 10^6$	
						22	Phyllosphere	$2.3 \times 10^3 \pm 1.6 \times 10^3$
							Rhizosphere	$6.7 \times 10^5 \pm 5.9 \times 10^5$
						25	Phyllosphere	$4.5 \times 10^2 \pm 7.9 \times 10^1$
							Rhizosphere	$4.3 \times 10^4 \pm 3.7 \times 10^4$
				29	Phyllosphere	$2.4 \times 10^2 \pm 6.6 \times 10^2$		
					Rhizosphere	$1.8 \times 10^4 \pm 1.9 \times 10^3$		
				45	Phyllosphere	$5.2 \times 10^2 \pm 2.6 \times 10^2$		
					Rhizosphere	$1.4 \times 10^3 \pm 1.4 \times 10^3$		

*The numbers presented are means and standard deviation of triplicate samples.

Quantitative real-time PCR analysis of these samples revealed linearity between the C_T values and the starting quantities of DNA representing 10^3 to 10^8 CFU g^{-1} . Amplification efficiencies and the goodness of fit analysis for the standard curves were higher than 99%. Table 1 shows the quantification of *E. coli* O157:H7/pGFP detected over several weeks in the phyllosphere and rhizosphere soil samples by real-time PCR. The concentrations of *E. coli* O157:H7 in the rhizosphere soils obtained by real-time PCR were very close to the numbers of

pGFP colonies obtained by the traditional culture methods on mTSA during the first three to five days of the first contamination event, and days 15 to 18 of the second contamination event. After this point, except in a few instances, the concentration by real-time PCR was higher by 1 to 3 logs. This was observed in clay soil in day 9, sand rhizosphere day 9, and 15. Our study shows that pGFP is highly stable for a few days, but it may not be a good marker for monitoring long term survival of bacteria. The higher concentrations of bacteria determined by real-time PCR versus plate count, 9 days after inoculation in some instances, confirmed this observation.

The ability to quantify *E. coli* O157:H7 in fresh produce and other food matrices without using culture methods will be very helpful for developing risk assessment models. Currently, most data demonstrating the risk of *E. coli* O157:H7 in food depend on culture techniques (Duffy and Schaffner, 2001). Our study suggests that *E. coli* O157:H7 has the capability to exploit the nutrient resources on leaves under conditions in which the physical environment does not limit their activities, and therefore can survive in large numbers as part of the community. This observation was confirmed in a related study by Ibekwe and Grieve, 2004, which showed that microbial community development in lettuce, took about 7 to 12 days and that this may be the most likely period for maximum pathogen contamination in plants. The automated PCR amplification and detection of target gene amplicons described in this study is conducive for screening large numbers of samples in a single assay. The real-time PCR can be a useful method for processing plants to monitor the contamination of fresh produce for risk analysis before sending produce to the consumers.

REFERENCES

- Duffy, S. and Schaffner, D. W. 2001. Modeling the survival of *Escherichia coli* O157:H7 in apple cider using probability distribution functions for quantitative risk assessment. *J. Food Protect.* **64**:599–605.
- Franke, S., Harmsen, D., Caprioli, A., Pierard, D., Wieler, L. H. and Karch, H. 1995. Clonal relatedness of Shiga-like toxin-producing *Escherichia coli* O101 of human and porcine origin. *J. Clin. Microbiol.* **33**: 3174-3178.
- Fratamico, P.M., Deng, M.Y., Strobaugh, T.P., and Palumbo, S.A. 1997. Construction and characterization of *Escherichia coli* O157: H7 Strains expressing firefly luciferase and green fluorescent protein and their use in survival studies. *J Food Prot.* **60**: 1167-1173.
- Gagliardi, J. V. and Karns, J. S. 2000. Leaching of *Escherichia coli* O157:H7 in diverse soils under various agricultural management practices. *Appl. Environ. Microbiol.* **66**: 877-883.
- Ibekwe, A. M., Watt, P. M., Grieve, C. M., Sharma, V. K. and Lyons, S. R. 2002. Multiplex fluorogenic real-time PCR for detection and quantification of *Escherichia coli* O157:H7 in dairy wastewater wetlands. *Appl. Environ. Microbiol.* **68**: 4853-4862.

Ibekwe, A. M., and Grieve, C. M. 2004. Changes in developing plant microbial community structure as affected by contaminated water. *FEMS Microbiol. Ecol.* **48**: 239–248

Oberst, R. D., Hays, M. P., Bohra, L. K., Phebus, R. K., Yamashiro, C. T., Paszko-Kolva, C., Flood, S. J. A., Sargeant, J. M. and Gellespie, J. R. 1998. PCR-based DNA amplification and presumptive detection of *Escherichia coli* O157:H7 with internal fluorogenic probe and the 5' nuclease (TaqMan) assay. *Appl. Environ. Microbiol.* **64**: 3389-3396.

Solomon, E. B., Yaron, S. and Matthews K. R. 2002. Transmission of *Escherichia coli* O157:H7 from contaminated manure and irrigation water to lettuce plant tissue and its subsequent internalization. *Appl. Environ. Microbiol.* **68**, 397-400.

INNOVATIVE CHARACTERIZATION OF MULTI-COMPONENT DNAPL IN A HETEROGENEOUS AQUIFER

Ed Meyers. Lewis Davies, Nicole Scroggins, and Jason Perdicaris
(Earth Tech, Orlando, Florida)

Brad Goeb (Universal City Property Management, Orlando, Florida)

ABSTRACT: Recent groundwater assessment activities at a former unlined industrial landfill have delineated a 5-acre dissolved-phase groundwater plume, extending to a depth of 150 feet below land surface (bls). Dissolved-phase concentrations in excess of ten-percent solubility were detected for several contaminants, providing presumptive evidence that non-aqueous phase liquids (NAPLs) may be present at the site. NAPL distribution in the subsurface is typically localized; therefore, obtaining direct evidence of NAPL is often difficult. Conventional NAPL investigations typically involve time-consuming continuous soil borings and extensive soil and groundwater sampling to determine NAPL distribution. As an alternative to conventional methods, a Membrane Interface Probe (MIP) equipped with a soil conductivity detector was used to obtain real-time qualitative contaminant distribution and geophysical data, which assisted in determining the subsurface distribution of NAPL. Although preliminary groundwater analytical data indicated the potential for NAPL to exist throughout a large area of the plume, MIP investigation results and subsequent soil sampling indicate that the NAPL source area is smaller and more localized than groundwater solubility data suggests. The data obtained during the MIP investigation will reduce the time and cost of site remediation by focusing remedial actions on a smaller source area.