

*Association of Environmental Engineering and
Science Professors (AEESP)*

RESEARCH FRONTIERS

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AEESP ENVIRONMENTAL ENGINEERING AND SCIENCE RESEARCH FRONTIERS

Proceedings of the 1999 Association of
Environmental Engineering and Science Professors
(AEESP) Research Conference
University Park, Pennsylvania— July 31 - August 3

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Preface

Every profession must continually reflect upon itself, examining its needs and its societal role and goals. Since 1960, and for approximately every three years since then, environmental engineers and scientists from North America have gathered to discuss the research and education issues associated with their profession. The fifth such research conference (12th in total) was convened at the Pennsylvania State University in University Park from August 1-3 in 1999. This conference had two important distinctions from past gatherings. This was the first time that a meeting was held by the Association of Environmental Engineers and Science Professors (AEESP) under its new name (formerly, it was AEEP). Although AEESP remains committed to having as its core environmental engineering, the name change of AEEP to AEESP is symbolic of the greater rôle that environmental scientists play in engineering research and education. Many of the discussions at the 1999 conference reflected this increased emphasis on the interactions between scientists and engineers. The second difference from former meetings was that during the past year AEESP had opened up its membership to the global community. In the past, colleagues from parts of the world outside of North America were admitted as affiliate, and not full, members. This change in membership status was prompted by the recognition that we live in a global environment and that many challenges we will face are not limited to political borders.

The theme of the conference was "Research Frontiers for Environmental Engineers and Scientists." The conference was organized around the NSF/AEEP workshop "Research Frontiers in Environmental Engineering," held in January 1998 at the Asilomar Conference Center in Monterey, California. The research frontiers identified at that workshop included:

A Sustainable Environment: the study and design of sustainable water, soil, and air systems, and the response of these systems to continued environmental stress;

Complex Environmental Systems: understanding the components of natural systems at the microscale to understand functions at the macroscale;

Analytical Tools in Molecular Sciences: integrating molecular biological tools and atomic-level chemical tools into environmental analysis;

Process Technologies: developing new treatment processes for pollution prevention and control.

The conference consisted of a single set of meetings, each with a different emphasis. On Sunday, August 1, overview presentations were made on frontier topics from the Asilomar Workshop. On Monday, presentations were made by those individuals working at the "frontier" in a variety of disciplines. On Tuesday, the conference participants split into four groups and discussed the frontiers in an effort to reaffirm or deny the findings of the 1998 Asilomar Workshop, and to suggest new frontiers that emerged from conference presentations and discussions. The proceedings of the conference presented here document the thoughts and findings of the environmental engineers and scientists at this conference. The book is divided into three sections: summaries from the breakout sessions; summaries of pre-conference workshops (including a summary Table of Frontiers); and abstracts received from conference participants.

It is our hope that the materials contained in these proceedings will chart the important course that environmental engineers and scientists will follow in the coming years.

Bruce Logan and Fred Cannon (conference co-chairs)

TABLE OF CONTENTS

Page Number

AEESP Environmental Engineering and Science Research Frontiers	i
Preface	ii

Part 1

AEESP Environmental Engineering and Science Research Frontiers: Conference Summaries.

<i>A Sustainable Environment</i> ; William Ball, The Johns Hopkins University, Thomas Theis, Clarkson University, and John Novak, Virginia Polytechnic Institute	1
<i>Environmental Process Engineering</i> ; Steven Dentel, The University of Delaware, and Fred S. Cannon, The Pennsylvania State University	2
<i>Molecular and Other Research Tools</i> ; Edward Bouwer, The Johns Hopkins University, Jean-Francois Gaillard, Northwestern University, and Richard Unz, The Pennsylvania State University	4
<i>Complex Systems</i> ; Catherine A. Peters, Princeton University, James R. Hunt, University of California-Berkeley, Susan M. Larson, University of Illinois at Urbana-Champaign, and William Burgos, The Pennsylvania State University	6
<i>A Summary of Environmental Engineering and Science Frontiers</i> ; Robin Autenreith, Texas A&M	7

Part 2

AEESP Environmental Engineering and Science Research Frontiers: Summaries of Pre-Conference Workshops held July 31, 1999.

<i>Jumping Through Hoops: The Promotion and Tenure of Women and Minorities</i> ; Kimberly Gray, Northwestern University	10
<i>Vive la Différence</i> ; Nancy J. Hayden, University of Vermont.....	11
<i>Dual Career (Academic) Couples and Dealing with the Fork in the Career Path</i> ; Robin Autenreith, Texas A&M	12
<i>Imagining the Feminization of Environmental Engineering</i> ; Steven Dentel, University of Delaware	14

Part 3

List of Abstracts and Speakers for AEESP Frontiers Conference, Held at The Pennsylvania State University, August 1-3, 1999.

SUNDAY SESSION

A Sustainable Environment

Walter J. Weber Jr., University of Michigan-Ann Arbor, Chair

Roberts, Paul V., Stanford University; *Environmental Engineering/Science, Green Chemistry, and Pollution Prevention: Our Future Beyond the Green Door.*

Okun, Daniel A., University of North Carolina at Chapel Hill; <i>Problems in the Pursuit of Safe Water</i>	18
--	----

Process Technologies

O'Melia, Charles R., Chair

Arnold, Robert G.; <i>Integrated Above-Ground/Soil-Aquifer Treatment Systems for the Reclamation of Domestic Wastewater</i>	20
---	----

Analytical Tools in Molecular Sciences

Bouwer, Edward J., Chair

Gray, Kimberly A.; <i>Molecular Tools to Study Chemical Phenomena in Environmental Systems</i>	21
--	----

Smets, Bart F.; *Molecular Biology Tools for Study of Environmental Systems*.

Complex Environmental Systems

Hunt, James R., University of California-Berkeley, Chair; <i>Limiting Resource Degradation in Complex Environmental Systems</i>	22
---	----

Luthy, Richard and Upal Ghosh, Carnegie Mellon; <i>Analytical Tools to Assess Sequestration and Bioavailability of Organic Compounds</i>	23
--	----

Milford, Jana B. and Shelly L. Miller, University of Colorado Boulder; <i>From Source to Exposure: Completing the Chain in Analysis of Air Quality</i>	24
--	----

MONDAY SESSION (August 2, 1999)

A Sustainable Environment:

Novak, J. T., Chair

Small, Mitchell; Carnegie Mellon; <i>Human Dimensions of Sustainable Environmental Systems</i>	25
--	----

Theis, Thomas L. and Thomas P. Seager; Clarkson University; <i>Environmental Manufacturing Management: A New Paradigm for Sustainability</i>	26
--	----

Schnoor, J. L. University of Iowa; *Sustainability and Research in Environmental Engineering*.

Zehnder, A. J., EAWAG; *Environmental Science and Engineering: A European Perspective*.

Process Technologies

LeChevallier, Mark W., American Water Works Service Company, Inc.; <i>Drinking Water Research Needs: A Water Utility Perspective</i>	27
--	----

Speitel, Gerald E. Jr., Lynn E. Katz, and Desmond F. Lawler; *Treatment Process Engineering: Future Directions and Challenges*.

Cannon, Fred S., Robert C. Voigt, The Pennsylvania State University and Jim Furness, Furness-Newburge; <i>Foundry Air Pollution Prevention with Advanced Oxidation and Adsorption</i>	28
Pagilla, Krishna and D. Webster; Illinois Institute of Technology; <i>Improving Bacteria for Bioremediation</i>	29

Analytical Tools in Molecular Sciences

Gaillard, Jean-François, Northwestern University, Chair; <i>Microscopic and Molecular Methods to Elucidate the Speciation of Metals in Environmental Systems</i>	30
Head, Ian M., T. P. Curtis, and Mike R. Barer; University of Newcastle, UK; <i>Analytical Tools in Molecular Sciences: Characterizing Bacterial Populations in Activated Sludge-Composition, Quantification and Beyond</i>	31
Raskin, Lutgarde, University of Illinois; <i>Use of Molecular Tools to Quantify Microbial Populations and Specific Growth Rates in Mathematical Models of Biological Treatment Processes</i>	32
Hering, Janet G.; California Institute of Technology; <i>Applications of Mass Spectrometry (ICP-, Electrospray-, and Isotope-MS) in Environmental Chemistry</i>	33
Stone, Alan T., The Johns Hopkins University; <i>New Analytical Tools for Determining Metal Ion Speciation and Ligand Speciation in Aqueous Media</i>	34

Complex Environmental Systems

Larson, S. M., Chair

Love, Nancy G.; Virginia Institute of Technology; <i>Using the Molecular Stress Response as an Indicator of System Stress in Complex Environmental Systems</i>	35
Graham, David and C. Larive; University of Kansas; <i>Use of Molecular Tools in Understanding the Attenuation, Fate, and Ecotoxicity of Trace Organic Contaminants in Natural Systems</i>	36
Baker, Larry and C. Redman; Arizona State University; <i>Environmental Analysis of Urban Ecosystems</i>	37
Driscoll, Charles T., Syracuse University; <i>What is going on in the Real World?: Challenges and Opportunities for Research on Environmental Problems at Larger Scales</i>	38

POSTER SESSION ABSTRACTS

Adams, C.D., M.W. Fitch, and J.G. Burken, University of Missouri-Rolla; <i>Army Officers on Campus: A Joint UMR-Army Program Providing Master's Degrees</i>	39
Adin, A., P. Biswas, G.J. Dutari, and V. Sethi, University of Cincinnati; <i>Particle Measurements by In-Situ Laser Light Scattering</i>	40
Alagappan, Gunaseelan and Robert M. Cowan, The State University of New Jersey; <i>Benzene and Toluene Degrading Capabilities of a New Jersey Soil Microbial Population</i>	41

Brown, M.T. and W. J. Mitsch, University of Florida and Ohio State University; <i>Development of Ecological Engineering Programs at U.S.A. Universities</i>	42
Brown, M. T. and S. Ulgaiti, University of Florida and University Siena, Italy; <i>Emergy Evaluation of the Environment: Quantitative Perspectives on Sustainability and Environmental Carrying Capacity</i>	43
Butkus, M., J. Brockhaus, M. Kelley, and R. Klingseisen, U. S. Military Academy; <i>Monitoring Water Quality Parameters from Above: Use of Digital Aerial Photography</i>	44
Camesano, Terri and Bruce Logan, The Pennsylvania State University; <i>Measuring Bacterial Interaction Forces Using Atomic Force Microscopy and Implications for Bacterial Adhesion in Porous Media</i>	45
Cardenas, Mary, Harvey Mudd College; <i>Inverse and Forward Modeling of Fluid Flow at Waste Isolation Pilot Plant</i>	46
Cervenka, David, Student, The Pennsylvania State University; <i>Sustainability and "Waste"</i>	47
Cheng, Jason C.-M., and Harold W. Walker, Ohio State University; <i>Influence of Particle Surface Chemistry on the In-Situ Immobilization of Phenol by Horseradish Peroxidase</i>	48
Clark, Douglas, U.S. Military Academy; <i>A Senior Capstone Project: Teaching Environmental Engineering the Design Process on a Real World Project</i>	49
Costello, A.M. and M.E. Lindstrom, University of Washington; <i>Molecular Ecology Studies of Methanotrophs in a Freshwater Lake Sediment</i>	50
De Los, Reyes F. III, and L. Raskin, University of Illinois; <i>The Role of Filaments in Activated Sludge Foaming: Insights from Oligonucleotide Probe Hybridization Studies</i>	51
Dempsey, Brian and William Burgos, The Pennsylvania State University; <i>Beneficial Reuse of Wastewater at Penn State and the State College Area</i>	52
Deng, B. and S. Hu, New Mexico Institute of Mining and Technology; <i>Reductive Dechlorination of Trichloroethylene by Metallic Iron: Effects of Iron Corrosion and Corrosion Inhibition</i>	53
Escobar, I. and A. Randall, University of Central Florida; <i>The Influence of Membrane Treatment on Bacterial Regrowth Potential in Drinking Water</i>	54
Fuentes, H., G. DiCarlo, C. Hernandez, and R.S. Rodriquez, Florida International University; <i>Senior Environmental Design and Motivational Competition at Florida International University</i>	55
Gaillard, Jean-François, Samuel M. Webb, and Gary G. Leppard, Northwestern University; <i>Speciation of ZN in Contaminated Sediments: Microscopic and Spectroscopic Investigations</i>	56
Green, C.F., P.V. Scarpino, University of Cincinnati; <i>The Use of Ultraviolet Germicidal Irradiation (UVGI) in Disinfection of Airborne Bacteria</i>	57
Gurian, Patrick, John Lockwood, Dominic Boccelli, Mark Schervish, and Mitchell Small, Carnegie Mellon University; <i>Estimating the Cost of a Revised Arsenic Drinking Water Standard</i>	58

Hering, Janet G., California Institute of Technology; <i>Sustainable and Safe Supply of Potable Water from Wells in West Bengal, India and Bangladesh Completed in Arsenic-Bearing Aquifers</i>	59
Hill, Alex and Subhasis Ghoshal, McGill University; <i>Surfactant Solubilization of Polycyclic Aromatic Hydrocarbons from Multi-Component NAPLS</i>	60
Karthikeyan, K.G., Jon Chorover, and Patrick G. Hatcher, The Pennsylvania State University and Ohio State University; <i>Multi-Method Investigation of 1-Naphthol Sorption by Dissolved Humic Acid</i>	61
Keller, Arturo A. and P. Holden, University of California-Santa Barbara; <i>Effect of Climatic Variations on Pollutant Bioavailability</i>	62
Kelley, M., A. Elliott, A. Shetty, W. Kavanagh, and R. Lonardo, U.S. Military Academy; <i>Firing Range Lead Contamination of a West Point Wetland and Creek—A Project in Undergraduate Environmental Science Education</i>	63
Kelley, M., R. Getz and M. Butkus, U.S. Military Academy; <i>Visualizing Unit Processes and Natural Systems in Undergraduate Environmental Engineering Education</i>	64
Kim, Kijung and Bruce Logan, The Pennsylvania State University; <i>Microbial Treatment of Perchlorate Contaminated Water</i>	65
Kubicki, J., The Pennsylvania State University; <i>Molecular Modeling in Environmental Science</i>	66
Leeman, Whitney and Daniel P.Y. Chang, University of California-Davis; <i>Past and Present Contribution of Vehicular Sources to the Global Dioxin Budget</i>	67
Li, Dien, George D. Guthrie, D.G. Bish, J.W. Carey, S.J. Chipera, Los Alamos National Laboratory; Huifang Xu, University of New Mexico; and Nishijima, National Institute for Materials and Chemical Research; <i>Nature and Distribution of Ni and Mo in Ion-Exchanged Y-Type Zeolites</i>	68
Li, Jin and Paul L. Bishop, University of Cincinnati; <i>Fabrication and Evaluation of Ion Selective Microelectrodes for the study of Nitrifying Biofilm</i>	69
Li, T. and N. Melitas, University of Arizona; <i>Electrochemical Reductive Dechlorination</i>	
Li, X.Y. and L.S. Yat, The University of Hong Kong; <i>Disinfection of Wastewater Effluent by Electrochemical Method</i>	70
Ludwig, H. F. and J. Kelly, Seatec International, Bangkok, Thailand; <i>Environmental Process Technologies and Related Standards Appropriate for Developing Countries</i>	71
Manson, J. Russell and Steve G. Wallis, Rensselaer Polytechnic Institute and Heriot-Watt University, Scotland; <i>Next Generation Modeling Approaches for Fate and Transport in Fluvial Systems</i>	72
Mazyck, David and Fred Cannon, The Pennsylvania State University; <i>Enhancing Thermal Reactivation for Water Treatment Service</i>	73
Molof, Alan H. and Sungtai Kim, Polytechnic University; <i>Total Inorganic Nitrogen (TIN) Down to Clean Lake Levels</i>	74
Morgan, Susan, Southern Illinois at Edwardsville; <i>Environmental Engineering Case Studies for Higher-Order Learning</i>	75

Myers, H., L. Steinbert, and Glen Boyd, Tulane University; <i>Analysis and Design of a Sustainable Drainage and Water Supply System for New Orleans</i>	76
Noguera, D.R., C.H. Hung, and J.M. Regan, University of Wisconsin; <i>Simultaneous in Situ Visualization of Bacterial Identity and Polyphosphate Accumulation in Activated Sludge</i>	77
Oerther, D.B. and L. Raskin, University of Illinois; <i>Quantifying Growth of Acinetobacter Species in Activated Sludge Wastewater Treatment Systems Using Molecular Signature Methods</i>	78
Powers, Susan E. and Thomas L. Theis, Clarkson University; <i>A New Paradigm for Doctoral Research in Environmental Manufacturing Management</i>	79
Remington, T., M. Butkus, M. Kelley, J. Marin, and M. Labare, U.S. Military Academy; <i>Modeling the Impact of Water Quality Parameters on Waterborne Pathogens in Recreational Waters</i>	80
Riley, Donna M. and Valerie M. Thomas, Princeton; <i>Information Technology for Product Lifecycle Management</i>	81
Ruppe, L, J. Darby, and G. Tchobanoglous, University of California-Davis; <i>Decentralized Wastewater Management for a Sustainable Environment</i>	82
Scarpino, P.V. and H. Quinn, The University of Cincinnati; <i>Bioaerosol Distribution Patterns Adjacent to Two Swine-Growing-Finishing Housed Confinement Units in the American Midwest</i>	83
Scherer, Michelle M. and Vicki H. Grassian, University of Iowa; <i>Development of Spectroelectrochemical Tools for in-Situ Characterization of Surface Reactivity</i>	84
Scherer, Michelle, M., A.G. Williams, and M. J. Alowitz, University of Iowa; <i>Reactivity of Iron Minerals in Natural and Engineered Systems</i>	85
SenGupta, Arup and K. Kodoma, Lehigh University; <i>Preparation and Characterization of Magnetically Active Polymeric Particles (MAPP) for Enhanced Separation in Complex Environmental Systems</i>	86
Stacey, Mark T., (Post-Doctoral) and T. M. Powell, University of California-Berkeley; <i>Turbulence, Stratification, and Residual Flows in Estuarine and Coastal Ecosystems</i>	87
Tuntoolavest, Munruk and William Burgos, The Pennsylvania State University; <i>Biodegradation of 1-Naphthol in the Presence of Dissolved Humic Acid</i>	88
Uribe, A., M. J. Kramer, and Paul L. Bishop, University of Cincinnati; <i>Adsorption of Azo Dyes on Organophilic Clays</i>	89
Yeh, Gour-Tsyh and William Burgos, The Pennsylvania State University; <i>Modeling and Measuring Biogeochemical Kinetic Experiments: System Consistency, Data Needs and Rate Formulation</i>	90
Yiacoumi, S., C. Tsouris, and D.W. DePaoli, Georgia Institute of Technology and Oak Ridge National Laboratory; <i>Novel Environmental Technologies Driven by Electric and Magnetic Fields</i>	91
Yu, T. and Paul Bishop; University of Cincinnati; <i>Microsensors as Novel Analytical Tools for Complex Environmental Systems</i>	92

AEESP ENVIRONMENTAL ENGINEERING AND SCIENCE RESEARCH FRONTIERS: CONFERENCE SUMMARIES

A SUSTAINABLE ENVIRONMENT

Summarized by: William Ball, The Johns Hopkins University; Thomas Theis, Clarkson University; and John Novak, Virginia Polytechnic Institute; Brian Dempsey and Jack Matson, The Pennsylvania State University.

The participation of the environmental engineering profession is essential to any overall effort to achieve a sustainable economy and society. Thus, this is clearly an important area where research directions and needs should be identified. The Workshop report (Logan et al., 1998) highlighted many important topics related to sustainability, but it was concluded by this group that there was insufficient emphasis in that report on issues that are outside the "traditional" domains of environmental engineering and science. Group discussions indicated a need for better integration of environmental economics, environmental psychology, political science, human geography, and ecology into environmental engineering and science research, while also recognizing a need for continued focus on individual research efforts that are "deep" in their disciplines. As indicated by Prof. Zehnder during his presentation at the conference, researchers need to *"think in systems and act in disciplines."* Given the emphases already made in the Workshop report, but also reflecting the wider diversity of disciplines represented in the breakout session, much of the discussion centered on the broader issues of inter-disciplinary effort and better communication among disciplines.

There was some discussion about the definition of "sustainability," and whether this concept might be too restrictive to foster innovative research. Most discussants agreed that environmental sustainability is a timely and worthy goal, although what constitutes the "goal" is not easily defined or attained. In this context, the current Code of Ethics of the American Society of Civil Engineers maintains (in its first "Fundamental Canon") that "Engineers ... shall strive to comply with the principles of sustainable development in the performance of their professional duties." For the purposes of the workshop discussion, a definition of "sustainability" was taken from the presentation by Alexander Zehnder:

"Sustainability is the principle of ensuring that our actions today do not limit the range of economic, social, and ecological options open to future generations."

This parallels a definition of sustainable development from *Our Common Future* (Gro Brundtland, Editor, United Nations Press, 1987), as presented by Jerald Schnoor at the conference:

"Sustainable development is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs."

While these definitions embody an ideal, there is also a need to develop sustainability guidelines that might objectively differentiate among competing design alternatives in practice or in the classroom. Such guidelines need not be absolute and can change over time as further knowledge is gained; however, they can provide an immediate basis for putting sustainability principles into action. In a similar vein, better "metrics" or "indicators" of sustainability are needed at a variety of levels, including for individual manufactured products, processing techniques, entire firms or industries, and regional or national economic practices. Several discussants noted that environmental engineers and scientists are uniquely qualified to provide an integrated approach to issues of sustainability.

Discussion also highlighted the need for improved paths of information dissemination among multiple disciplines, including better means of integrating our understanding into societal practice. For example, Paul Roberts' conference presentation highlighted the need for environmental engineers to work more effectively with other disciplines to integrate research about chemical fate and transport into the practices of manufacturing and commodity production, including such issues as: pollution prevention and product substitution, green chemistry and environmentally benign synthesis, life cycle analysis of products, and the development of environmental management standards for manufacturing. Workshop discussants emphasized the need to minimize use of non-sustainable resources and discussed an additional research need into means of converting *existing* societal "waste" or residuals (e.g., leachate, refuse, and sludge) into valuable resources. More generally, there is a need to apply engineering and ecological principles into the design, management, and restoration of self-organizing ecosystems. In this context, there is also a need to develop methods of analysis of whole systems in a way that can better serve to guide public decision making.

There was a consensus that current practices of consumerism in the United States are not sustainable, and a sentiment that our profession should play an active role in developing and disseminating information about alternative and more sustainable lifestyles. Research is needed on how to foster better communication of environmental sustainability concepts to society and on how to stimulate two-way communication and mutual education. Recent advances in information technology should facilitate communications, but research is needed to apply such methods more effectively. Environmental engineers and scientists need to participate actively in inter-disciplinary efforts to both develop and apply such approaches. As noted by Mitch Small in his presentation,

"Environmental engineers and scientists have a critical role to play in the emerging area of human-environmental systems and interactions, both as partners with social and behavioral scientists, and as leaders in the formulation of strategies for analysis and evaluation."

It was agreed that there is a need to better understand ecosystems at all scales, ranging from laboratory through field, water-shed, air-shed, and regional scales to global systems. In this context, better understanding of uncertainty at even the smallest scales is still critically important and can help toward developing better confidence in larger scale predictions. There is a clear need to apply concepts of material balance, process control, and optimization (i.e., environmental engineering principles) to ecosystem study, as well as a need to incorporate principles of ecology in such study, with focus on understanding and restoring self-organizing systems. Overall, the issue of environmental sustainability offers many research needs and opportunities, both in its own light as a multi-disciplinary area of study and as an important contextual theme for guiding specific disciplinary research.

ENVIRONMENTAL PROCESS ENGINEERING

Summary by: Steven Dentel, The University of Delaware; and Fred Cannon, the Pennsylvania State University.

Environmental Processes, in a broad sense, includes both engineered and natural processes that affect or involve the environment. There are future opportunities in both of these directions. The latter category presents challenges of both scale and complexity that are considered separately in the Frontier topic of Complex Systems. The category of engineered environmental processes is one with a long history, traditionally embracing water and wastewater treatment but now encompassing numerous processes for pollution control that span a variety of media and applications. Advances in both societal demands and

scientific capabilities have assured that this research frontier will remain a dynamic one. Conversely, the world in which environmental engineers could thrive by implementing a few favored processes such as sedimentation and activated sludge is gone.

The development and implementation of newer engineered environmental processes must consider additional constraints that are dictated by advancements in both industrial and global ecology. These include the following factors:

- The role of each unit process in an overall system must be integrated in such a manner that the overall treatment system is consistent with environmental sustainability. Systems that minimize net energy use and accomplish the reuse of materials are becoming priorities. Even in cases where a traditional economic evaluation does not support the usage of such systems, a longer-term assessment may suggest its desirability. In some areas of the globe, the latter type of evaluation is also consistent with societal desires.
- The evolution of a global economy has led to a trans-national trade in environmental services. However, this trend is not so advanced or uniform that environmental engineers can assume one process fits all. Specific geographies and economies lead to quite different constraints. Use of local materials and low technology are essential in some regions, while processes that require minimal land area are priorities in others.
- In a more competitive market, the one process fits all approach is also obsolete. Industries are intent on controlling pollution in a cost-effective manner and seek treatment processes that are tailored to their own water, contaminants, resources, and regulations.
- The increased awareness of hidden costs in residuals management (in both direct expenses and future liabilities) is leading to the prioritization of processes that allow the reuse or destruction of a contaminant or residual, rather than its compartmentalization (for example, by use of separation processes alone).
- Greater understanding of air pollution and groundwater contamination has led to the search for processes tailored for these phases and media.
- The growing importance of minimizing the generation of greenhouse gases, and even sequestering those that have already been released, will ultimately be reflected in new priorities in how pollution is controlled in any application, and will also foster development of new technologies for controlling the environmental fate of CO₂.

Thus we may look toward a growing demand for engineered environmental processes that look quite different from those currently available off the shelf. In order to meet these demands, environmental engineers must make advances in the following research directions:

Targeted or Tailored Separation and Destruction Systems

- Membrane applications employing new advances in membrane chemistry, membrane physical properties, and flow configurations.
- Combinations of catalytic and microbial processes with membrane processes.
- Development of processes employing high or very specific energy application to accomplish treatment; electrochemical, photochemical and ultrasound applications are examples.
- Development of genetically tailored enzymes and microbes to mediate specific, and desired, chemical changes to a treated flow, in contrast to the use of microbial consortia as they naturally evolve by optimizing their own survival.
- Development of molecule-specific removal processes, such as ion exchangers and tailored sorbents

Engineered Subsurface Systems

- Improved understanding of physical, chemical, and biological phenomena that occur in the subsurface, coupled with improved fate and transport models.
- Use of this knowledge to perfect processes that utilize the subsurface much as tank reactors have been employed in the past for water and wastewater purification. Ultimately, the proven technical feasibility of such a system may affect the political feasibility of water reuse systems.
- Similarly, development of improved models and techniques for the use of landfills as controlled reactors, perhaps to be mined for resources and reused.

Process Control, Reliability, and Monitoring

- Development of molecular biological methods sufficiently robust to be applicable to complex treatment systems.
- New sensors with more rapid response times to enable use of such techniques in real-time process control.
- Advanced control systems such as expert systems that can deal with very complex processes. Ideally, this requires the use of comprehensive, validated models of the process system, and in many cases such models are not easily found.

Industrialized Applications

- New methods for treating the massive amounts of agricultural wastes created by intensified operations for the production of biomass for human consumption.
- Research and development of appropriate technologies for specific global categories, locales, and industries.
- Identification of environmental control technologies that treat pollution in a cost-effective fashion and account for the vicissitudes of individual nations, cultures, and climates.
- Networking with industries, manufacturers, and chemical producers to tailor and engineer processes for making products while not causing pollution.

Residuals

- Improved understanding of the properties of sludges, biosolids, and residuals: nutrient release rates, contaminant mobility vs. time and under various chemical conditions.
- Development of techniques for more effective reuse and/or reduction of these materials.
- Discoveries of new means for recovering resources from residuals.

MOLECULAR AND OTHER RESEARCH TOOLS

Summary by: Edward Bouwer, The Johns Hopkins University; Jean-Francois Gaillard, Northwestern University; and Richard Unz, The Pennsylvania State University.

The conclusions of the original Workshop report (Logan et al. 1998) were reaffirmed by participants of this session. It was agreed that new biological and chemical tools need to be used for the analysis of complex environmental systems. These tools enable environmental engineers and scientists to understand environmental processes in novel ways at a molecular scale where our knowledge base has major gaps. The tools themselves are not the endpoint, but are demanded in order to answer questions related to the study of processes and complex environmental systems. This improved understanding of the structure and function of large and complex systems can help us protect whole ecosystems, develop innovative

production, manufacturing, and treatment processes, prevent outbreaks of diseases across global scales, and minimize environmental damage resulting from the production and use of new chemicals. The complexities of environmental systems are often under-appreciated by chemists, biologists, and physicists who typically develop molecular tools for well-defined matrices. The discussion group concluded that environmental engineers and scientists are uniquely qualified to collaborate with different natural scientists to take maximum advantage of molecular tools in environmental systems.

In addition to the applications to water and wastewater identified in the original report, the discussion group concluded that molecular tools are also useful to explain chemical movement, fate, and impact in all engineered and natural systems, such as the atmosphere, wetlands, and the subsurface. Molecular tools are especially helpful in the development of mechanistic-based models. Chemical tools are useful for determining the speciation of exotic chemicals, predicting sorption/partitioning behavior, and for predicting reactivity in environmental media. Molecular biology tools are useful for identifying the microbial species present and their activity which are critical to predicting biodegradation of contaminant mixtures. When using molecular tools, it is important to verify their application to complex matrices and to give proper attention to upscaling which entails quantifiable relationships between the responses at the molecular scale, in bulk solution in the laboratory, and in the field.

The discussion group identified the development and application of micro-sensors for in-situ measurements as a fruitful "frontier". Examples here include microelectrodes to monitor chemical gradients in biofilms, sediments, and fluid boundary layers, micro-sensors for detection of organic compounds in groundwater, micro-sensors to detect signals from reporter genes in microorganisms, and DNA micro-arrays for enumeration of specific microbial populations. Some additional research topics that involve the integration of biological, chemical, and physical molecular tools include the molecular basis for responses in bulk toxicity tests, characterization of transformations of materials, detection and fate of emerging contaminants (e.g., polar hydrophilic compounds including endocrine disrupters and pharmaceuticals), design of product streams as the emphasis in pollution control moves away from end-of-pipe treatment to minimization in production processes, and laboratory green chemistry (i.e., minimal use of solvents for analytical methods).

A clear research need in the area of molecular biology tools is the development of simple, inexpensive quantitative tools. Simple and inexpensive tools are needed for wide adoption by both researchers and practitioners. Although qualitative information from the tools provides insight into system behavior, quantitative tools are especially needed to formulate and verify mechanistic models. It is often difficult to obtain quantitative results with the range of current molecular biology tools. Additional research opportunities with molecular biology tools include assessing the impact of environmental conditions and anthropogenic inputs on microbial community structure, assessing the assimilative capacity of systems in the context of bioremediation, and approaches for predicting rates and extent of biodegradation.

The research needs for the integration of chemical tools in environmental sciences and engineering stem from the use of analytical, microscopic, and spectroscopic instrumentation that requires collaborative efforts between environmental scientists, chemists, and physicists, and in some instances the use of national facilities. In order to characterize the speciation of elements and probe the chemical nature of organics in environmental samples, it is central to develop new instrumentation and methods that allow the use of sophisticated tools at relevant concentrations.

Molecular techniques have tremendous potential for monitoring the quality of both indoor and outdoor air. There is great interest in techniques for real-time measurement of chemical composition on individual aerosol particles. Laser ablation mass spectrometry techniques are viewed as showing great promise for delivering this capability, but require further development and testing to move from qualitative to quantitative analyses. While gas phase pollutants in indoor atmospheres have received much attention, the microbiological quality of indoor air has been largely ignored. The molecular techniques that have been successful for studying microbial processes in aquatic and terrestrial environments are equally applicable to the study of bioaerosols and aerosol-mediated disease transfer. Molecular biological tools are needed to assess the distribution and activity of indoor bioaerosols, and assess the response of airborne microorganisms to aerosol disinfection systems.

The original Workshop report and the above discussion address application of molecular tools to environmental engineering and science. However, the merits of using macroscopic tools in complex environmental systems needs to be better understood. Organisms within ecosystems respond in different ways to environmental stresses, therefore, a variety of biomarkers may be required to fully understand the structure and function. Macroscopic tools may be useful as ecological indicators or in the development of biocriteria.

Finally, the handling and analyzing large amounts of information, sometimes referred to information technology, will be important in analyzing environmental systems. Advances in computer technologies, software, and the methods to analyze complex data sets will be essential in modeling and understanding most environmental systems whether they be microscopic or macroscopic. Advances in information technology will be crucial for understanding how complex environmental systems work, and therefore, how to engineer systems to achieve desired outcomes such as sustainable systems.

COMPLEX SYSTEMS

Summary by: Catherine A. Peters, Princeton University; James R. Hunt, University of California, Berkeley; Susan M. Larson, University of Illinois at Urbana-Champaign; and William Burgos, The Pennsylvania State University.

Complex environmental systems share the common feature that they have a large number of biological and chemical components that interact through a web of reaction and transport processes. Our goal as environmental engineers is to understand these systems sufficiently to be able to predict the impacts of pollutants on humans and ecosystems to enable formulation of sound policy and management practices. As stated in the NSF Workshop report,

"Through exposure to many scientific and engineering areas, and by learning to use a team-based approach to engineer large systems, environmental engineers are well suited to direct the analysis of large biogeochemical systems and to devise solutions for their repair."

This group prioritized four complex environmental systems as important research frontiers. *The first complex environmental system is the watershed.* We need to be able to identify and manage the greatest threats to drinking water sources. We need to go beyond human health and understand the ecological effects of pollutants and watershed management activities. *The second complex environmental system is the atmosphere.* We need to fully understand the link between human exposure and air pollution sources, so that emission control practices are most effective in protecting human health. We need to quantify air pollutant deposition rates to land and water surfaces. *The third complex environmental system*

is the urban environment. We need to optimize the provision of clean air, clean water, land, food, and energy, within the constraints of protection of the environment, water resources, agricultural lands, and energy resources. We need to investigate the feasibility and applicability of water reconsumption practices. We need to understand industrial ecological systems, which provides an understanding of the flow of materials and energy through the economy and the subsequent implications for resource management and environmental protection. *The fourth complex environmental system is the global environment.* Environmental engineers can plan an important role in unraveling the biogeochemical, hydraulic, atmospheric, and ecological processes governing climate change, tropospheric ozone depletion, and marine impacts of coastal pollution.

To solve these large-scale problems, we need to couple our understanding of mechanisms that occur at a small scale with our understanding of the integration of these mechanisms over larger scales. *This will require the employment and development of new environmental monitoring tools that capture large-scale phenomena.* An example is the use of satellite-based remote sensing instruments to characterize atmospheric, surface water, and marine compositions. Such environmental monitoring tools must also be operative in field situations, for in-situ measurements and real-time reporting. These monitoring efforts must be integrated with emerging information technologies such as GIS. *Understanding large-scale complex environmental systems will also require integrated assessment approaches that bridge science, technology and policy analyses.* The modeling approaches that are useful in this context include systems analysis for upscaling and for understanding complex interactions, stochastic modeling for characterization of variability and uncertainty, and decision analytic tools for coupling scientific findings with engineering implementation and policy analysis.

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A SUMMARY OF ENVIRONMENTAL ENGINEERING AND SCIENCE FRONTIERS

By: Robin Autenreith, Texas A&M

The Workshop report identified several research frontiers which were supported by discussion groups. However, many new specific topics and other frontiers topics emerged from these group discussions. The combined Workshop and new topics are summarized in the table below.

Frontiers in Environmental Engineering Concerns for the Future

Emerging

Research Arenas General Needs

Specific Topics

A Sustainable Environment

- Multi-disciplinary research
- Effective communication
- Fundamental understanding of ecosystems
- Knowledge of the uncertainties in predicting performance
- Need for appropriate metrics

- Safe, adequate, sustainable water supply (reuse & conservation)
- Terrestrial & coastal resources
- Ecosystem stress
- Assessment of chronic exposure to trace contaminants
- Reduction of toxic materials used in industrial processes & consumer goods

Complex Environmental Systems

- Integration of complex, biogeochemical systems
- Ecosystem stability and diversity
- Watersheds
- Atmospheric systems
- Urban environment
- Global environment

- Identify greatest threats for human health and ecological impact
- Link human exposures more closely to emissions
- Quantify deposition
- Identify resources needed and track on use
- Potential for water reconsumption
- Industrial ecological systems
- Climate change
- Ozone depletion
- Coastal pollution
- Microbial ecology

Tools

- Information management
- Biological tools
- Tools to track chemical movement, fate and impact
- Molecular tools for mechanistic-based models
- Chemical tools to characterize behavior and reactivity
- Database management
- Species identification and activity assessment

Process Technologies

- Engineered and Natural
- Limitations on development & implementation
- Energy consumption
- Reuse of materials
- Global economy
- Tailored solutions
- Residuals
- Air pollution and green house gases
- Reactive separation systems
- Targeted chemical destruction
- Engineering subsurface system
- Membrane technologies
- Process technologies for the non-industrialized world

**AEESP ENVIRONMENTAL ENGINEERING AND SCIENCE
RESEARCH FRONTIERS:
SUMMARIES OF PRE-CONFERENCE WORKSHOPS**

We've Gotten This Far But Are We Having Fun Yet?

A Discussion on Gender and Diversity Issues

Panel Members: Steven Dentel, Kimberly Gray, Robin Autenrieth, Nancy Hayden

The focus of this preconference workshop was gender and diversity issues in environmental engineering and science. The following are summaries of presentations made during the preconference workshop by several of the panel members.

Jumping Through Hoops: The Promotion and Tenure of Women and Minorities

by Kimberly A. Gray, Northwestern University

The tenure and promotion process at many universities has become increasingly difficult as a growing number of institutions are seriously considering eliminating tenure all together. The tenure decision is typically based on an evaluation of one's accomplishments as a researcher, teacher, and volunteer, although the weight attached to each of these criteria may vary from place to place. While the conventional wisdom is that the assessment of research achievement, "objectively" measured by funding, papers, and students, overwhelms all other considerations, the additional requirement in the tenure of women and minorities is that they be exceptional.

It is often said that women and minorities must be twice as good as the competition in order to succeed. In a study of how post-doctoral fellowships were awarded at Gothenburg University in Sweden, two microbiologists, Christine Wenneras and Agnes Wold, noted that while women comprised 46% of the applicant pool, they only received 20% of the awards. In a rigorous analysis of the review process, these researchers discovered that women were routinely found to be less scientifically competent than their male counterparts, despite having equivalent credentials. In order to be successful in this particular competition, it was inadequate to be 2 times better than a male applicant; women needed to be at least 2.5 times better than men. In fact, the authors of this study, which was published in *Nature* in May 1997, determined that in addition to being male, the other important determinant of success was to know one of the reviewers.

Many studies have shown that women's achievements appear to be worth less than men's. In *"Sex, Schemas, and Success: What is keeping women back?"* an article appearing in a 1998 issue of *Academe* (84:5:50-55), Professor Virginia Valian explained that our judgements are affected by notions of gender differences. Since men are considered to be more capable, independent, task oriented, and instrumental than women-- who are regarded as nurturing, communal, and expressive-- we unconsciously, but unfairly, make non-meritocratic evaluations and decisions concerning women. Although beginning careers on equal footing, a Harvard study showed that women earning degrees in physical sciences, math and engineering after 1979 were almost a full rank behind their male peers 10 years later. AAUP data show that a tenure gap between men and women not only exists, but has persisted at the same level for over 20 years, e.g., in 1995-6 72% of male professors were tenured compared to 48% of women.

On March 23, 1999 a front-page article in the New York Times declared "MIT Acknowledges Bias Against Female Professors". In 1994 there were 15 tenured women and 194 tenured men in the

School of Science at MIT. Over the last 2 decades the number of tenured women has held steady at 7-8%. A 5-year study initiated by a prominent molecular biologist, Professor Nancy Hopkins, identified a pattern of gender discrimination driven by powerful, but unrecognized, assumptions and attitudes that worked systematically against women faculty even in light of obvious good will. Junior faculty was reported to feel supported, but as women's careers progressed they felt marginalized and dismissed by their male colleagues. Although sometimes subtle, substantive and demoralizing discrimination was documented in the areas of hiring, awards, promotions, and inclusion on important committees allocating space and money. The pervasive, if unintentional, bias against women at MIT was only uncovered through the collective action of female faculty, as it is difficult to identify discrimination against a single person.

The costs of success in academics for men and women of all races are enormous. Attaining tenure is an all-consuming process that tends to disrupt the balance that we all seek between work, family, friends, and avocational interests. According to Mary Morse, the author of the 1995 book, *Women Changing Science: Voices from a Field in Transition*, a radical restructuring of the working environments for scientists of both sexes is needed in order to accommodate successful rearing of children, the sustenance of community, and the growth of individuals' moral, physical, and spiritual lives. Although study after study has shown us that women and minorities face many obstacles along their paths, academic careers offer a unique combination of creativity, challenge, freedom, and flexibility. In addition to MIT, other schools are coming forward and admitting their unequal treatment of women. At the Johns Hopkins University School of Medicine, an ambitious program of mentoring and monitoring has turned around years of slow progress among women faculty. Within our own discipline of environmental engineering and science, we need to work to ensure the protection and promotion of an academic environment free of gender discrimination, no matter how subtle and unintentional.

Vive la Différence

by Nancy J. Hayden, University of Vermont

Celebrate the difference! Women and men are different in a variety of ways. They often have differing communication styles, different attitudes and values, and different emotional responses to various issues which should be viewed as strengths and welcomed in engineering and science. Unfortunately, societal and individual attitudes are often in denial towards women in engineering and feel that women shouldn't become engineers. Only recently have many individual and institutions come to accept women in engineering. For women faculty, this acceptance is usually for reasons such as providing role models for female students and as a means to help student enrollments by enhancing female student enrollments. Very rarely are women in engineering welcomed with enthusiasm because they offer diversity in thinking and different attitudes. In contrast, women often feel unwelcomed and unsupported not necessarily by things that have been said but by things that have not been said or by small "seemingly insignificant" actions. Ramsey (1992) stated it this way;

"Everyday there are small demeaning and condescending acts that wear away (on women) like water on a stone."

The 1998 statistics for women in engineering show that women graduating with a B.S. degree in engineering was slightly less than 20%. Women with M.S. degrees was about 20% but women attaining a Ph.D. in engineering was about 12%. *Why so few women in engineering?* Although some might argue that engineering is still almost exclusively a man's profession and this is a strong deterrent to women, the real answer is probably the one which has already been stated; that as a society we still don't believe that

women and girls can be engineers. The better question than why are there so few women in engineering might be-- *why are there any?*

There is strong pressure from the culture for women to split into true and false selves. This usually begins during adolescents when girls become aware of their own subordinate role in society. The media and music cultures send a strong message to girls and women that their primary roles in society are those of mother and/or sex object:

"Many women regain their preadolescent authenticity with menopause. Because they are no longer beautiful objects occupied with caring for others they are free once again to become the objects of their own lives. They become confident, self-directed and energetic. Margaret Mead noticed this and noted that some cultures revere these old women, others burn them at the stake." (Pipher, 1994).

"It is time to affect a revolution in female manners-time to restore their lost dignity-and make them, as part of the human species, labour by reforming themselves, to reform the world." (Wollstonecraft, 1792).

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Dual Career (Academic) Couples and dealing with the fork in the career path

by Robin Autenreith, Texas A&M.

Negotiating faculty positions with candidates who have 'spouse placement needs' is more common today than ever before and can be a substantial challenge for both the couple and the institution. Just how big this problem is can be difficult to quantify because the total numbers of candidates are still relatively small and few studies have been conducted. Often referred to as the 'two-body problem', the question to raise is whether placement of two people is a problem or could it be viewed as a challenge and opportunity? To date there have been many reported creative ways in which this challenge has been met by various couples and institutions.

Satisfying dual career needs is more of a women's problem than that of their male colleagues. This is mostly perception, but a recent study of physicists by McNeal and Sher (*Physics Today*, July 1999) revealed that 50% of women physicists married compared to 74% of their male colleagues and of those married women physicists 50% were married to other physicists. In contrast, only 7% of male physicists married women physicists. Assuming similar trends may occur in engineering, a greater percentage of the women engineering faculty may encounter the dual placement challenge, but in total numbers male engineers may be grappling with this issue as well. With more women entering academics as their profession, particularly in engineering, ways of meeting the dual career placement challenge have expanded.

How big the problem is may be a perception issue. The closer in proximity an institution is to a major metropolitan area, the easier it is to satisfactorily place a spouse owing to the greater diversity in job

opportunities. The university may not even be called upon to facilitate this placement. The perception of the seriousness of spouse placement can then be a function of geographic location and size of the community. In a study conducted by Shulz et al (1996), the majority (53%) of candidates seeking academic positions either required a tenure track or permanent position for a spouse. And a study of chemical engineers (Caruana, 1992) revealed that the younger the couple was in their careers, the more willing they were to live apart for a finite period of time. Flexibility in the couple and the institution can be key in successful arrangements. For an institution, dual career hires within a department are easier than if two departments or different colleges are involved. However, if the couple has the same research area, placement can be problematic. Some institutions have spousal placement programs. What is common is that each case is unique!

The most commonly expressed concern by candidates is when the spouse placement need should be revealed. From an institution's perspective, the earlier it is known the more time can be devoted to finding options. However, if there is the perception that spousal placement is not worth the time and energy required, a candidate may not get as favorable a review from the search committee whether intentional or not. Consequently, potential candidates may be reluctant to reveal a need in their application letter for fear that their credentials will not receive an unbiased review. Then sometime during the interview, the candidate will reveal the need to place their spouse and ask for assistance. As faculty progress in their careers and become better known in their fields, if they seek another position their spousal needs may be known by the time their packet is being reviewed. Timing is everything and it is very difficult to predict when is the best time to broach the dual career need.

Many alternatives have been tried in attempting to satisfy both the needs of the university and the individuals. The most common is split and shared positions. A split position is when one position is literally split between two people with two halves independent of each other. In effect there are separate contracts for each person. A shared position is one with shared salary, joint consideration for tenure and promotion, and responsibilities. The leading spouse/trailing spouse perception can become a problem in promotion or future mobility in these and other arrangements. The leading spouse/trailing spouse scenario occurs when one spouse takes the lead position and the other spouse 'makes do' with what opportunities may exist, choices which are frequently reflected in resumes. Another possible pitfall in accommodating dual-career placement is early salary loss which is difficult to ever regain. It has been noted by Shulz et al (1996) that dual career couples usually experience at least some portion of their careers as a commuting marriage. No one solution may be the optimum, more likely a combination of solutions will be necessary for each couple and their institution(s).

Many in academics further their careers by moving to a new institution or find it necessary to move locations to meet the needs of their research. Once again they must enter into negotiations to place their spouse, only now couples tend to be less flexible in what is acceptable. Or if faculty want to take sabbatical leave, it is doubly difficult to place two people which may be further complicated by the needs of children. The assistant professor usually has the greatest flexibility and fewer family concerns. The associate professor is less flexible, has more career and family concerns, and the potential loss of tenure with a new placement. The full professor or administrator is the least flexible. So the problem likely worsens as we progress in our careers.

Finally, one must be wary of the hidden costs. The pressure to perform is high on any faculty. Dual career couples may feel even more pressure knowing that if they or their spouse should want to relocate, they must be highly competitive as well or potentially jeopardize their future mobility and success. Marriage can be very difficult under the best of conditions; living under additional pressure to perform

professionally can take its toll on the best of relationships. To be successful can mean many long hours at the office, leaving little time to develop outside interests let alone raise a family. Finding the balance between work and family is not easy when one has a demanding professional career.

We can expect to see more dual career couple situations. Everyone needs to be open to the possibilities that couples can bring to an institution. If an institution is willing to accommodate a couple's needs, retention of faculty is enhanced. Further, a couple may be more committed to the institution. Creativity and flexibility are key for both the couple and the institution.

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Imagining the Feminization of Environmental Engineering

by Steven Dentel, University of Delaware

Data indicate that gender disparity, and inequity, are problems in environmental engineering that are progressive during career development. Although this field attracts a greater proportion of females at the undergraduate level than do most other engineering majors, the proportion is nonetheless unsatisfactory, as is the level of retention of talented women in the undergraduate degree and beyond.

The lower portion of Figure 1 uses data from the Engineering Workforce Commission showing the percentage of women enrolled in degree programs for *all* engineering fields. It indicates that, although 19.4% of the students entering undergraduate engineering programs are female, this decreases to 18.6% of all engineering undergraduates, suggesting that fewer women than men complete the undergraduate engineering degrees. Female enrollment for graduate engineering degrees decreases to 16.9% for MS/PE, and 14.6% for Ph.D. levels. Thus, if one assumes this to be indicative of professional progress, there is greater attrition of women than men.

A greater contrast is seen by comparing the percentages of women in professional organizations indicative of advanced achievements specifically within environmental engineering. The upper bars in Figure 1 show lower percentages of women in these organizations, particularly the AAEE.

Still, Figure 1 indicates a drop of only 5% from the 19.4% entering undergraduates to the 14.6% Ph.D. students in engineering degree programs. The greater discrepancy is in comparison to the percentage of females among those graduating from high school, which is somewhat above 50%. Why is the number of females interested in engineering so far below this? And furthermore, some of the factors suggested above as contributing to female attrition would ultimately be mitigated given greater numbers of young women entering into undergraduate engineering programs.

The enrollment data in the previous figure were for all engineering fields. Figure 2 shows percentages of women in undergraduate engineering degree programs by field, as provided by the NSF=s Engineering

Professional progression

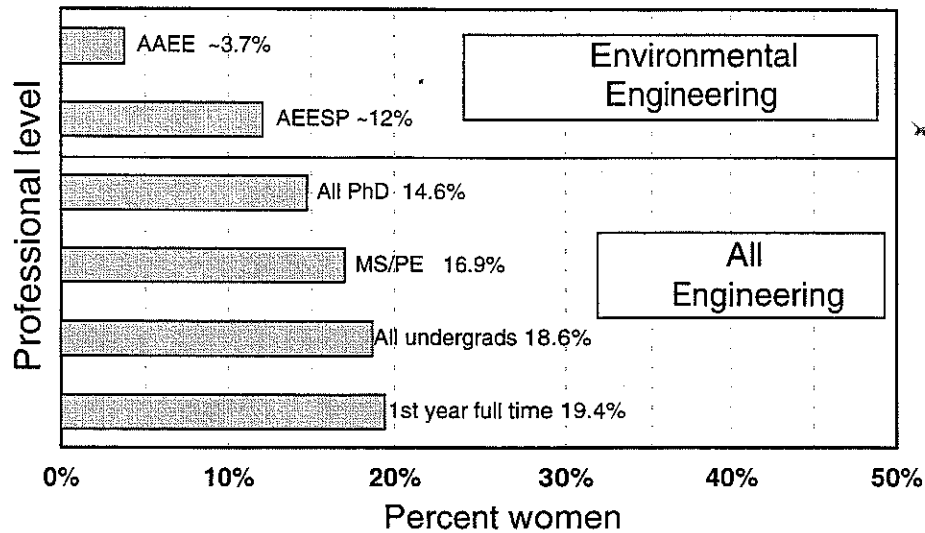


Figure 1. Lower bars: percent women in engineering degree programs in 1994, from Engineering Workforce Commission. Upper bars: percent women in the Association of Environmental Engineering and Science Professors and the American Academy of Engineering, 1998. Note that the right end of the horizontal scale (50%) would represent equity.

Workforce Commission in 1994. Environmental Engineering has among the highest percentages of women of all engineering fields.

The evident appeal of environmental engineering to women at this level does not guarantee that gender equity will ultimately be attained, particularly at higher rungs of the profession. While there may be less work to do in recruiting women into the field at the freshman level, one must ask why there is still such disparity at the professional levels of environmental engineering (Figure 1) in spite of the field's initial interest to women. It would be overly complacent to assume that this disparity will simply disappear over time, implying the absence of gender-related impediments to professional advancement. That such impediments exist is well established, and it is unlikely that they will disappear in the near future. Beyond the consideration of gender equity in the profession as an end in itself, it is surely desirable to offset or overcome any such impediments toward the optimal preparation of all upcoming environmental engineers. The retention of capable women at undergraduate, graduate, and professional levels should be equivalent to that for men with similar abilities.

What steps can be taken at the academic levels to foster an equivalent retention? This is not a new question; in fact, a number of universities have well-established programs to improve retention of women as they work toward engineering degrees. Typically, the following components may be included:

- Cluster dormitories or co-op housing for women majoring in engineering, to facilitate the formation of study groups and other types of networking. These also provide a center for other activities such as guest speakers.
- Special seminars, courses and field trips providing orientation and information of particular use to women in engineering.
- Mentoring programs which may match the underclass woman with an upper class counterpart for various activities, or set up electronic correspondence with a working woman engineer.

Engineering Enrollments, Fall 1994

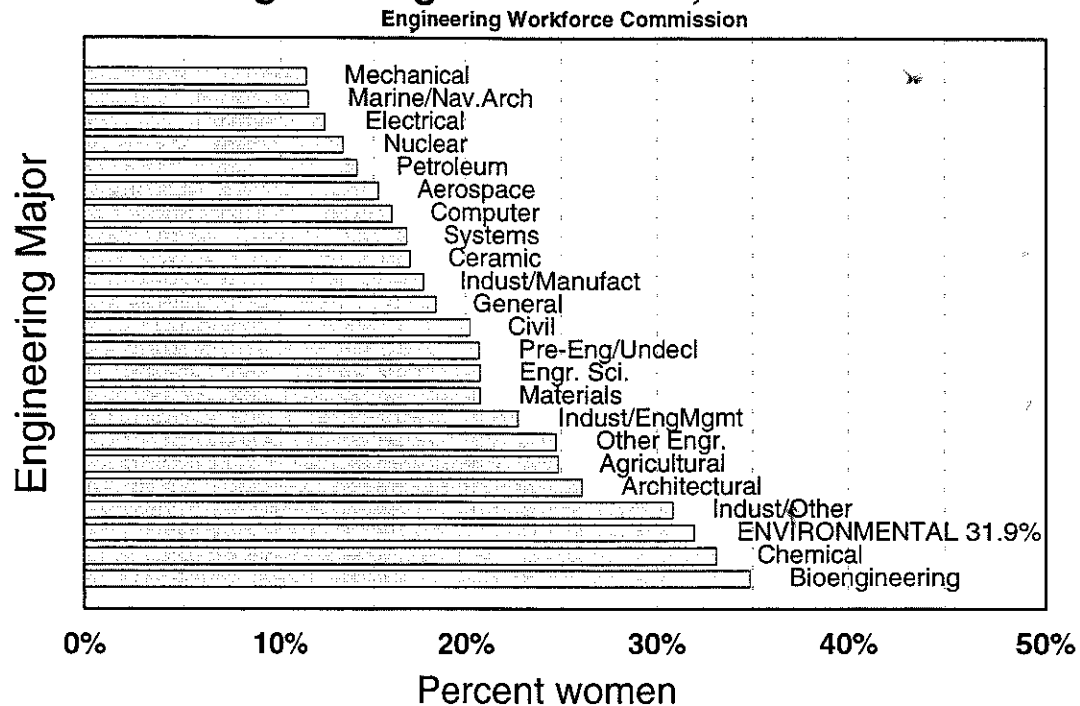


Figure 2. Enrollments in engineering degree programs by field in 1994, according to survey by Engineering Workforce Commission.

- Active student societies (SWE chapters and engineering sororities) as additional social and networking resources.
- Scholarships and other awards as specific incentives for female engineering students
- One-on-one assignments to work with faculty in their teaching and research to encourage the pursuit of advanced training.
- Encouragement of instructional methods in math, science, and engineering courses that some women may find more compatible with their own modes of learning.

Purdue University is one institution utilizing many of these strategies. Figure 3 shows the percentage women in its graduating engineering programs over the years, compared with the national average. Purdue's percentage is, in fact, among the highest, and yet exceeds the average by a modest amount. It appears that even these efforts to increase the retention of women in engineering face an uphill struggle. Comparable statistics for individual engineering majors are not currently available, and it would be worthwhile to determine whether students majoring (or concentrating) in environmental engineering suffer attrition rates comparable to those in engineering overall.

It is useful to imagine the steps that would lead to an equal balance of men and women in the environmental engineering field, and to consider the ways that current efforts in this direction might be strengthened. Beyond the academic arena, salaries and family issues may become paramount in limiting

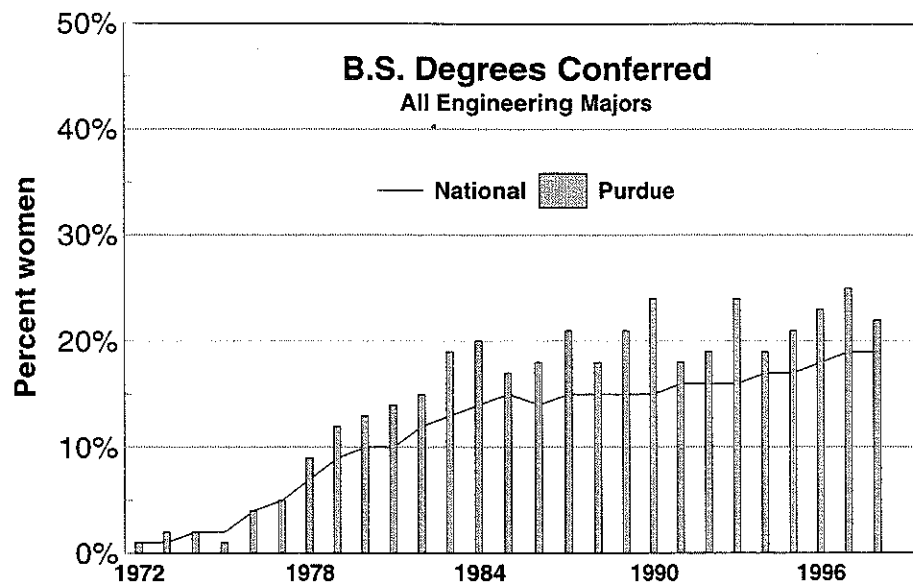


Figure 3 Percent women in graduating classes of engineering baccalaureate programs nationwide (line) and at Purdue University (bars) from 1972 to 1998. Source: <http://FrE.www.ecn.purdue.edu/~wiep/> (August 1999).

the number of women staying in the engineering workforce. Recent statistics suggest that the environmental job market pays somewhat better for women, as a proportion of the overall pay scale, than do other professions; many sectors, such as environmental engineering and science, show salaries for women that are 90% of the overall level. Given the possibility that the better-paying senior positions are predominantly filled by males at this point, this ratio appears promising.

Clearly, there is much to be done, first in documenting the gender-related trends in environmental engineering education and employment, then in discerning the reasons for such phenomena as lower retention of women, and ultimately, in equitably recruiting and retaining people of all genders and backgrounds. There is no clear reason that so few women enter engineering when over half of all high school graduates are female. At the extreme, professions such as teaching, nursing, and secretarial have actually shown declines in overall salary when they became perceived as women's work. While environmental engineering is unlikely to become overwhelmingly female in the near future, the forces behind this feminization of a profession and the historically decreased wages and stature should be re-examined for their impacts on both individuals and specific sectors of the environmental engineering field.

PROBLEMS IN THE PURSUIT OF SAFE WATER. *by: Daniel A. Okun, Kenan Professor of Environmental Engineering Emeritus, University of North Carolina at Chapel Hill, NC 27514, (919) 966-4898, fax (919)966-7646.*

The changing character of our profession over the last few decades deserves our attention. While this presentation may seem to be directed at the engineers among us, many of whom are registered professional engineers, implying a responsibility to serve society, the scientists among us have become essential to modern engineering practice. Even if not bound by the engineer's creed, they may want to reflect on their roles when they provide their expertise to consulting engineers who serve the public. A word or two about regulations. We have had federal regulations for drinking water since 1914, initially to protect only the traveling public, but extended 25 years ago with the Safe Drinking Water Act to all water supplies. If we examine the practice of water purveyors over the last century in their selection of water sources and methods of treatment, we would appreciate that they were not generally guided by regulations but most often by what they and their engineers believed was necessary to provide the best water for their constituents. Many cities went to great expense to develop upstream sources because they would provide a better quality of water than nearby rivers. Many cities installed filters long before they were required by regulations. The 1962 Public Health Service Drinking Water Standards called for a maximum turbidity of 5 units, yet many water utilities opted to provide coagulation and filtration to achieve turbidities of about 1 unit because it would provide a better quality of water for their customers.

Of course, the number of contaminants being regulated has grown exponentially as we have become aware of the presence of a great and increasing number of anthropogenic compounds of uncertain toxicity being invented and being introduced into waters drawn upon for drinking. We are all aware of the bisexual fish in British rivers, the pharmaceuticals in European rivers, and the endocrine disrupters everywhere. Yet, today, the general attitude among many water purveyors and their engineers, is to assure one and all that the water does or, for a new project, will "meet the drinking water standards."

Consulting engineering firms and their experts generally want the best for their clients and they do well for the clients that want the best for their constituency. My problem is that, too often, the client is often content with or even demands a program that will be least costly so long as their engineers can ensure that "the water meets the drinking water standards." Today, my experience is that their engineers will generally oblige.

The EPA Drinking Water Standards of 1976 and Public Health Service regulations before them have language that is still appropriate: "Because of human frailties associated with protection, priority should be given to selection of the purest source. Polluted sources should not be used unless other sources are economically unavailable..."

Many cities have opted for high quality water sources, while others, who have had opportunities to acquire such sources, chose to follow the more expedient (cheaper) route, drawing water from nearby, often heavily polluted, rivers. Their engineers assured them that the treated water "will meet the drinking water standards." (Milwaukee water in 1993 "met the drinking water standards.")

A publication of the American Philosophical Society (McCarthy, M.P. 1987, "Typhoid and the Politics of Public Health in 19th Century Philadelphia, American Philosophical Society, p.80) is interesting reading. When typhoid was rampant in the United States, with the highest rates for cities that drew water from run-of-river supplies, Philadelphia was one of the last to consider filtration. Under the leadership of one of its many "reform" mayors, funds were obtained for filtration of water drawn for the Schuylkill and Delaware rivers. The mayor suggested at the time that perhaps Philadelphia might consider getting better water from upstream. Their engineers state that water from upcountry sources might be preferable but the great cost of building aqueducts and reservoirs made that option very expensive and really unnecessary since filtration would provide safe water (i.e. meet the standards of the day). This was before chlorination had been introduced.

Many water issues are contentious and I seem to be drawn to them. One of my first was the Connecticut Water Company Lands case, which came up in the mid-1970s when EPA changed the turbidity standard for drinking water from 5.0 NTU to 1.0 NTU. Several, then private, water companies in the region, which had purchased watershed lands many years earlier at very low prices, sought to sell off their lands for development, ostensibly to pay for the filtration that would be required to attain the new turbidity standard. Being within commuting distance of New York City, these lands had become exceedingly valuable. The Connecticut State Legislature, at the behest of the State Health Department, declared a 2-year moratorium on the sale of land and held a large public forum at Yale University, where the water companies were represented by themselves and their consulting engineers, while I was the only engineer speaking on behalf of the state, that the watershed land should continue to be protected. Finally, the Commission recommended to the legislature and the legislature ruled that the watershed land sales might be made,

but not for development. The water companies appealed and lost in the U.S. District Court and in the U.S. Supreme Court.

In a case closer to home, the City of Asheville, N.C., in the Great Smoky Mountains, obtains its water from protected publicly owned watersheds. Because of a short interval of timer harvesting, the slight increase in turbidity had obliged the installation of filtration. In 1983, eager to attract industry, city officials sought to add to its supply by taking water from the heavily polluted French Broad River that runs through the city. Their engineers, two national firms, assured the officials that treatment could render the water of a quality to "meet the drinking water standards;" GAC was offered as one of the possible processes. The State Health Department approved the project and the State Environmental Management commission concurred by changing the river classification from "C" (not suitable for drinking) to A-II (suitable for drinking) for a few miles above and below the city. The entire "establishment", the city council, the county commissioners, the principal newspaper, the chamber of commerce, etc. endorsed a 40-million dollar bond issue in 1989 to build a water treatment plant on the river shore on land that had been purchased earlier.

However, it was clear that, in place of the high quality mountain water to which they had become accustomed, many customers would be obliged to drink water that had been drawn from a river which had been the scene of frequent fish kills. Other options, such as using the river water for industry, as the industrial sites to which industry was to be attracted are on the river, or to tap other sources of higher quality were hardly considered. A community Citizens for Safe Drinking Water group and an alternative newspaper (then called Green Line) organized opposition to the bond issue. At a formal debate organized by the League of Women Voters, partners of the two engineering firms spoke on behalf of the project, a young professor at UNC-Asheville, and I testified against the project. The bond issue was defeated 2 to 1. Today, a new source of supply, high up on one of the tributaries of the French Broad River, is to go into operation this year. When I asked one of the engineers who had testified for the project why he supported it, he relied that, if his firm had not undertaken the project, another would have been hired. I couldn't argue with that except to feel that the business of engineering had superseded the profession of engineering.

Too many RFPs allow the prospective engineers no latitude; they specify what they want, and they have no trouble finding any number of engineers competing for the project, whatever they want. An engineer submitting a response that would include a review of all the options open to the client knows that, in general, he would be stricken from the list of final candidates.

I can go on with many other examples. Engineers allow themselves to promote potable reuse of reclaimed wastewaters when other options are available at less cost, involved much less additional health risk, and are more acceptable to the public. I need only mention San Diego and Tampa.

For the last few years I have been involved in the issue of filtration of surface waters. New York City and Boston (MWRA) have both employed leading environmental engineers to make the case for them that they do not need filtration. In the case of Boston, which draws water from a highly developed and vulnerable watershed, engineers from three major firms have testified that ozone followed by chlorination "provides the maximum feasible protection of the public health." These same firms recommend to other of their clients, even when the source waters are better, the use of ozone, DAF, and filtration. The client calls the tune. The engineer plays the tune.

The U.S. Department of Justice is taking MWRA to court on behalf of EPA, but it cannot get the large expert consulting engineering firms to even consider testifying on its behalf; they're afraid, with good reason, that they might not ever be employed by MWRA in the future. Engineers and scientist are professionals; they should not be fearful of expressing professional opinions on behalf of what is good for all the people, not only on behalf of those who purchase their service. I believe that engineers who are seen to be candid in their advice even when it runs counter to the prospective client, will earn reputations that will greatly enhance their opportunities to serve in the future.

In conclusion, I might rationalize that these remarks may contribute to the sustainability of our water-related projects. If engineers who have an obligation to protect the public health act entirely on the basis of their business interest, I fear for the sustainability of our profession and its role in serving society by providing water facilities that serve to promote the public health.

INTEGRATED ABOVE-GROUND/SOIL-AQUIFER TREATMENT SYSTEMS FOR THE RECLAMATION OF DOMESTIC WASTEWATER. by: Robert G. Arnold (arnold@engr.arizona.edu), University of Arizona, AZ.

Background:

Soil-aquifer treatment is the sum of physical, chemical and biochemical processes that affect the quality of treated wastewater during infiltration through unconsolidated sediments and subsequent migration/storage in the underlying unconfined aquifer pending reuse. The process is especially attractive in certain areas of the semiarid southwestern United States, where land is relatively abundant, water is a critical resource and the depth to groundwater is frequently on the order of hundreds of feet. To provide some idea of the time scale on which natural processes may contribute to the final quality of waters subjected to soil-aquifer treatment, percolation through the biologically active surface layers of infiltration basins typically occurs in a matter of hours, and infiltration through the full vadose zone occurs over a period of days to weeks. Storage periods pending extraction and reuse are typically months to years.

Use of such waters for potable purposes has received increased attention in recent years in communities such as Los Angeles, San Diego, Phoenix and Tucson, where the incremental cost of water is particularly high, if additional water supplies can be found at all. The situation in Tucson is illustrative. That city currently relies entirely on groundwater to satisfy its potable water needs, although about 10,000 AFY of reclaimed water is used to satisfy irrigation requirements following soil-aquifer treatment. The practice has resulted in groundwater overdraft and a water table that currently recedes at a rate of approximately four feet per year at major extraction points. Municipal growth projections indicate that the renewable groundwater supply and the City's Central Arizona Project allotment (approximately 200,000 AFY, none of which is currently used) will be exceeded by local demands within 25 to 50 years. There is no question about the role of reclaimed water in satisfying Tucson's water requirements, only in the manner in which the use of reclaimed water will be regulated and used. In the Los Angeles area, the situation is considerably more complex because water supply is provided from a greater variety of sources (State Water Project, Los Angeles Aqueduct, storm runoff, groundwater, reclaimed water, Colorado River), although there is clearly sufficient economic or financial incentive to maximize the local use of reclaimed water.

Ongoing Research:

A number of potential water quality problems attend the use of reclaimed water for potable purposes. These include primarily the concentrations of available nitrogen forms (nitrate nitrogen is regulated at 10 mg/L as N) and the presence of organics of wastewater origin that might contribute to the formation of trihalomethanes upon water recovery and chlorination prior to reuse. The survival of pathogens of wastewater origin, primarily viruses and protozoan parasites, is a matter of obvious concern. Ongoing research is aimed at defining the conditions (primarily oxygen and organics) that provide an acceptable degree of denitrification during soil-aquifer treatment and characterizing residual organics in wastewater effluent before and after soil-aquifer treatment using a combination of separation/concentration and analytical techniques. Additional work is aimed at developing the most sensitive possible techniques for measuring pathogen attenuations during processes that comprise soil-aquifer treatment. Supporting studies are aimed at the identification of an adequate wastewater tracer, so that the fractional contribution of wastewater can be determined in groundwater samples, and at the application of suitable biochemical tests to determine the relative toxicities of alternative water sources.

MOLECULAR TOOLS TO STUDY CHEMICAL PHEOMENA IN ENVIRONMENTAL SYSTEMS. by: Kimberly A. Gray (k-gray@nwu.edu), Department of Civil Engineering, Institute of Environmental Catalysis, 2145 Sheridan Road, Northwestern University, Evanston, IL 60208.

An unprecedented array of chemical tools is available to acquire fundamental understanding of molecular interactions in the complex mixtures and at the mineral, organic, and biological interfaces that characterize environmental system. Yet, many of these techniques and associated methods of data interpretation were developed to study well-defined systems (i.e., single crystals) under ideal conditions (ultra-high vacuum). Application of these tools to environmental samples, however, is very challenging due to their amorphous, complex, and multiphase nature, and to the fact that meaningful results necessitate that analysis be made under *in situ* conditions. In order to provide insight into environmental phenomena and systems, then, the environmental engineer and scientist must determine how to adapt, modify, or refine a particular technique to an environmental application, devise a characterization strategy that combines multiple techniques to fully characterize the many components of environmental samples, and develop alternative ways of interpreting and quantifying the data generated by these sophisticated methods.

Use of these novel chemical tools promises to produce dramatic advancements in the understanding of many of our more difficult and persistent environmental problems. For instance, it has been shown that mechanistic descriptions of chemical behavior in laboratory systems may differ drastically from observed behavior in natural systems, indicating the need for analytical tools to determine speciation and probe reactions under real conditions. A very powerful suite of *in situ* methods that detail atomic structure and composition of materials in any matrix (i.e., crystalline and non-crystalline surfaces, adsorbates on surfaces, compounds in solution) is emerging with the new generation of synchrotron radiation sources. Chemical imaging techniques such as these can be coupled with time-resolved spectroscopic methods to follow chemical reactions in real time. In general, a combination of molecular tools is required to characterize comprehensively the important structural and functional relationships that explain environmental chemical fate. The novel aspect of this strategy may be in the tools themselves, or in their combination. Furthermore, since many critical environmental processes are influenced by biological processes, exciting new areas of study are opened up by the integration of biological and chemical molecular tools.

The pace at which compelling new molecular techniques are developed is extremely rapid and is certain to reveal unparalleled mechanistic insights into complex systems. Application of the new generation of molecular tools to environmental problems will probably not be limited by the availability of methodologies, but rather by those individuals capable of devising protocols for and interpreting the results of these sophisticated techniques. Serious consideration, then, must be given to establishing educational and research training programs at the interface of basic science and environmental engineering in order to create a new generation of "bridging scholars and researchers" and the next generation of environmental scientists.

LIMITING RESOURCE DEGRADATION IN COMPLEX ENVIRONMENTAL SYSTEMS. *by: James Hunt (hunt@ce.berkeley.edu) and David Sedlak (sedlak@ce.berkeley.edu) 631 Davis Hall, Department of Civil and Environmental Engineering, University of California, Berkeley, CA 94720-1710.*

Research Scope

The focus of environmental engineering research over the last twenty years has been largely driven by regulatory concerns in response to chemicals that were already on a list of hazardous substances specific to air, water, soil, or food. Instead of a limited focus on a set of already identified pollutants, there needs to be a redirection of effort towards the protection of resources essential for human and ecosystem health. This new focus will require environmental engineers to take a holistic view of their role in anticipating, identifying and remediating problems caused by chemicals, pathogens, heat, and non-native species.

Impact

The quality of life on earth over the next 10 to 50 years is highly uncertain. If history is any indication, we will find it difficult to anticipate how our activities will degrade environmental resources. One example of how an environmental problem was not anticipated is the expansion of the semiconductor industries in the 1970's. At that time there was the need for careful control of solvent storage facilities, but we failed to act because we were not thinking about problems associated with this new industry. Currently there are warning signs that the biotechnology and pharmaceutical industries are not as benign as their economic proponents would suggest. These industries offer another example of the kinds of problems that our current system fails to anticipate (i.e. the release of novel, unregulated chemicals designed to interact with biological systems). In the future, environmental engineering's primary charge will be understanding the sustainability of environmental resources and developing tools to predict how future activities could lead to their degradation. We should anticipate how environmental resources would be affected by new technologies, infrequent natural disasters and human-induced political and economic disruptions. On a global scale, we can assume that there will be more people requiring air, water, and food producing resources. In addition, there will be new technologies introduced that will have intended benefits and unintended consequences. These technologies and changes will not be distributed uniformly across the world, and if history is a reliable predictor, there will be more benefits for the richer countries and more negative consequences for poorer countries.

Long-Range Development

To limit resource degradation, the fundamental sciences of environmental engineering must be broadened to encompass the breadth of physical, medical, and social sciences. A foundation based only on mathematics, physics, chemistry and microbiology is inadequate for the holistic solution of problems. New efforts should be devoted to measuring environmental disturbances, understanding their cause, and evaluating engineering and nonstructural solutions.

First Steps

Research in environmental engineering and science has been driven by short-term regulatory agendas in federal agencies and public perceptions of risks. While there is some sense that governments are learning to anticipate future problems, it is generally not in their mandate to do so. An agency is needed to promote a future frontiers agenda. As part of that agenda, it might be useful to consider how the military anticipates future challenges by playing war games. Analogous "resource games" played by environmental engineers and scientists would help to develop tools to evaluate the consequences of actions and responses related to environmental resources. Results of such exercises could ultimately lead to a more efficient allocation of effort in the academic community.

ANALYTICAL TOOLS TO ASSESS SEQUESTRATION AND BIOAVAILABILITY OF ORGANIC COMPOUNDS. *by: Richard G. Luthy (luthy@cmu.edu) and Upal Ghosh (ughosh@cmu.edu), Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA 15213.*

Research Scope

Hydrophobic organic contaminants, such as polycyclic aromatic hydrocarbons (PAHs), may sorb very strongly to sediments and nonaqueous phase organic matter. This can greatly reduce contaminant bioavailability, exposure, and environmental risk. An objective of an on-going, multidisciplinary study is to investigate at the particle and sub-particle scale the physicochemical processes that may control the sequestration and bioavailability of PAHs in contaminated sediments. A novel aspect of this research is the use of unique, complementary spectroscopic and spectrometric techniques to assess more directly at the microscale exactly where and how organic compounds are bound to sediments. These techniques are providing information on PAH location and sorbent organic carbon location and type. These findings will be used to assess results from bioslurry treatment and toxicity testing. This work is important because it provides for the first time more direct information on the processes controlling PAH sequestration and how these processes impact biodegradation and toxicity. This research involves collaboration among Carnegie Mellon University, Stanford University Department of Chemistry, the US Army Corps of Engineers Waterways Experiment Station, and the Naval Research Laboratory.

Impact

A very important question is understanding the link between the total mass of substance that may be detected and that portion which is of environmental and human health concern. Our profession lacks appropriate tools to assess the bioavailability of contaminants, particularly for organic compounds wherein our mechanistic understanding of binding or sequestration lags greatly in comparison to inorganic compounds. This has enormous impacts on policy decisions for setting soil and sediment quality criteria, defining cleanup goals, and establishing priorities among various environmental problems.

Long-Range Development

We need to develop techniques that will tell us whether contaminants are bioavailable to receptors. Further, there is need for an assessment of the policy changes that may be warranted to reflect advances in our understanding of bioavailability and exposure. These efforts will require improved scientific and mechanistic understanding of phenomena that control mobility, degradation, and uptake, as well as an assessment of tools currently available and tools that are needed to advance such understanding. Bioavailability concepts are difficult to explain to the public and research on how to communicate the concept of bioavailability and exposure is needed also.

First Steps

The environmental profession must look beyond traditional boundaries to seek answers to these questions. We need to partner with physicists, physical chemists, and molecular microbiologists. For example, we are using Fourier transform infrared micro-spectroscopy to discern at the sub-particle scale the predominant types of sorbent carbon on sediments. This work is being performed at Brookhaven National Laboratory's synchrotron light source and at the Advanced Light Source at Lawrence Berkeley Laboratory. Collaborative work at Stanford University Department of Chemistry involves microprobe two-step laser desorption-laser ionization mass spectrometry to describe sub-particle scale surface and sectional distribution of PAH compounds on sediments. These are but two techniques that were unknown to us several years ago, but now which hold promise for significantly advancing our understanding of physicochemical processes affecting bioavailability and toxicity.

Role

Environmental engineers solve problems. Thus our first role is to help define the important questions. Secondly, we must present these questions to potential collaborators in other disciplines, particularly the sciences and policy professions.

FROM SOURCE TO EXPOSURE: COMPLETING THE CHAIN IN ANALYSIS OF AIR QUALITY.
by: *Jana B. Milford* (milford@colorado.edu) and *Shelly L. Miller* (Shelly.Miller@colorado.edu) Department of Mechanical Engineering, University of Colorado, Boulder, CO 80309-0427.

In 1997, the U.S. EPA issued new air quality standards for airborne particulate matter less than 2.5 μ m in diameter ($PM_{2.5}$), along with revised standards for PM_{10} and ozone. The agency is also charged with regulating ~190 toxic air pollutants. The primary basis for the regulations is human health effects. To understand the causes and design effective approaches for preventing these effects, consideration must be given to a chain of factors: emissions - atmospheric transport and transformations - ambient concentrations - exposure - effects. Research advances are needed across the entire chain.

For particulate matter, significant questions start at the effects end of the chain. The new PM standards are based on epidemiological associations between outdoor concentrations and morbidity and mortality, but the mechanisms of injury are unknown. Improved characterization of ambient air quality and human exposures is needed to help identify the active agents in PM and to understand synergistic effects of pollutant mixtures.

Because the U.S. has ambient air quality standards, research has historically focused on understanding and predicting outdoor concentrations. However, population-based exposure studies call this emphasis into question. In the late 1980's, the Total Exposure Assessment Methodology (TEAM) study found that average personal exposure concentrations of targeted volatile organic compounds (VOCs) were greater than outdoor concentrations and that exhaled breath measurements were correlated with personal exposures but not with outdoor concentrations. The more recent Particle TEAM study found that average daytime personal exposure concentrations of PM_{10} were greater than indoor and outdoor concentrations, and that indoor and personal exposures were poorly correlated with outdoor concentrations. Research ongoing at the University of Colorado at Boulder (CU) addresses the impact of PM of outdoor origin on indoor exposure. The relationship between penetration, deposition, and the concentrations of airborne particles indoors is being investigated.

One implication of the personal exposure studies is that control measures designed to reduce outdoor concentrations may not efficiently reduce human exposure. Current research at CU seeks to estimate the contributions that various sources make to human exposure to toxic VOCs, using receptor-oriented source apportionment techniques. The study seeks to distinguish between indoor and outdoor sources of personal exposure, as well as among various indoor and urban area sources.

Linking emissions and ambient concentrations, detailed photochemistry and transport models for O_3 and secondary particulates have been under development for about three decades. Current models are capable of matching observed O_3 concentrations within about $\pm 30\%$ for urban and regional-scale episodes of several days duration. Research at CU has propagated input and parameter uncertainties through the models using Monte Carlo methods. This approach gives uncertainty estimates of $\pm 30\%$ (1) for modeled O_3 concentrations. Because O_3 production is a highly nonlinear function of nitrogen oxides (NO_x) and VOC levels, uncertainties in predicted responses to emissions reductions may be either smaller or larger than the uncertainty in base case O_3 concentrations. Significant sources of uncertainty in photochemical air quality models include emissions rates, a subset of chemical parameters and deposition rates for O_3 and NO_x . Detailed models for $PM_{2.5}$ are at a relatively early stage of development compared to the O_3 models. Further testing and research is needed to estimate uncertainties in their predictive capability. Improved understanding of the mechanisms through which PM affects human health would help determine which characteristics of particulate matter need to be modeled most accurately.

HUMAN DIMENSIONS OF SUSTAINABLE ENVIRONMENTAL SYSTEMS. by: *Mitchell J. Small* (ms35@andrew.cmu.edu), Departments of Civil & Environmental Engineering and Engineering & Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213.

While private corporations and government agencies make many of the most important decisions which influence our environment, the role of the individual in shaping environmental futures is now more widely recognized. Individual decisions concerning which products to use, which activities to engage in, and which risks to accept or avoid, are now recognized as critical in determining the occurrence and magnitude of many new and emerging environmental issues, such as exposure to household chemicals, energy and water conservation, and the effectiveness of environmental alerts, such as fishery advisories or boil-water notices. Adaptive behavioral responses can greatly influence the magnitude of environmental exposure and human health impacts. A holistic, interdisciplinary research program is needed to learn more about these critical feedback mechanisms and determinants of environmental system behavior.

The address this need, research in three principal areas is proposed:

1. **Environmental Decision Making—Normative and Positive Models:** Much of the research on environmental choice has been *normative*, predicting how people *should* behave based on economic benefit or utility. Further development of *positive* models is needed to describe how people actually *do* behave, by invoking a mix of cognitive, psychological and economic principles and observations.
2. **Emergent Behavior in Aggregate Systems:** Adaptive agent models have been developed to simulate the emergent behavior of social systems with various rules for social and economic interaction. Rules for environmental decision making can likewise be explored to study issues such as regional waste management and recycling, nonpoint source pollution control and environmental equity.
3. **Holistic Ecosystem Models:** New research in *industrial ecology* has adopted many of the principals of natural ecosystem science to study the flow of materials and energy in modern society. The next logical step will be to consider the integrated role of human communities (where we live, how we communicate and travel, what we consume) within holistic ecosystem models of air, water and terrestrial quality, and overall species diversity and abundance.

The impact of this research will be to link a diverse set of disciplines and perspectives in the common pursuit of improved understanding of how individuals and societies shape, and are shaped by, their environment. This can help lead to improved methods for risk characterization and risk communication, and the development of more effective, incentive-based regulations.

To achieve better-integrated studies of human systems and the environment, further development of educational programs will be needed, as well as new opportunities for professional development, interaction and publication. Models for university programs which combine fundamental environmental science and engineering with the social sciences are described. The combination of social and environmental studies in applied research projects is illustrated considering recent NSF and EPA initiatives. New publication outlets for this type of research, including the *Journal of Industrial Ecology* and the Policy Analysis section of *Environmental Science & Technology* are briefly discussed.

Environmental engineers and scientists have a critical role to play in the emerging area of human-environmental systems and interactions, both as partners with social and behavioral scientists and as leaders in the formulation of strategies for analysis and evaluation. With our special skills at dissecting complex systems to isolate the behavior of individual elements, and putting the individual components back together to describe overall system performance, we can help guide both methods development and the selection and interpretation of important environmental applications.

ENVIRONMENTAL MANUFACTURING MANAGEMENT: A NEW PARADIGM FOR SUSTAINABILITY. by: *Thomas L. Theis*, and *Thomas P. Seager*, W.J. Rowley Laboratories, Department of Civil and Environmental Engineering, Box 5710, Clarkson University Potsdam, NY 13699-5710.

Society's motivation for environmental protection has progressed over the years from one based largely on practical needs and aesthetic perceptions to the heavily regulated "command-and-control" nature of the cradle-to-grave approach to waste management. Although both of these motivations are still active factors, there is now evident a new, emergent paradigm based on the concept of waste and resource management for sustainability. In this view, expenditures which impact environmental quality positively are perceived as investments with the potential to generate tangible returns. Such changes are already evident in the market place where, having found that the costs of "end-of-pipe" controls on wastes have often been underestimated, and that more environmentally sophisticated consumers are demanding products resultant from cleaner manufacturing methods, many corporations have begun to view investments in waste management as an integral part of overall operations instead of exterior costs resulting in "negative profit".

Such trends underlie the philosophy of a new doctoral program in Environmental Manufacturing Management at Clarkson University. Established through NSF's Integrated Graduate Education Research and Training (IGERT) program, EvMM takes as its point of departure the concept that changes currently underway in the market place have created new and fertile areas for in-depth research which, upon investigation, will yield important advances in the knowledge base in this field, and will facilitate implementation of new ideas consistent with the concept of sustainability. The EvMM program is highly interdisciplinary, involving faculty from all four of Clarkson's educational units (engineering, science, business, liberal arts). Two difficulties are often encountered with such expansive efforts: a large and complex knowledge base that no one person can have a comprehensive grasp of, and the distinctive disciplinary cultures involved. EvMM addresses these concerns through reliance on an engineering systems approach as a means of providing a common framework for defining research problems. This also has the advantage of congruency with the new paradigm for environmental management described above. Thus as knowledge is created or gained, the systems framework provides a means of evaluating and using it, and is a powerful research tool as well.

There are many potential research areas that can be addressed within this new program such as topics in environmentally conscious design, costs and benefits of pollution prevention, risk assessment and communication, integrated environmental data management, process modification for waste minimization, and the roles of environmental regulation versus enlightened market forces as drivers of environmental innovation, to name a few. A specific example of research currently being investigated under EvMM auspices is the development of a thermodynamic basis for life cycle assessment (LCA) in the optimization of manufacturing systems for environmental performance. LCA has historically been used as a means of assessing the potential of manufacturing, including the product cycle, on the environment. However it suffers from several limitations, chief among them being the lack of a common basis for expressing LCA results that are comparable across manufacturing sectors. The most common practice is to perform a linear mapping of consumptive or waste units for each facility or manufacturing process, however comparison of these "scores" in an environmentally meaningful way is problematic requiring subjective judgements on the relative effects on impacted environmental systems (including human health effects). Since essentially all manufacturing systems and ecosystems possess material and energy flows, and function under various (but knowable) conditions of pressure and temperature, one possible way of overcoming the LCA limitation is through the application of thermodynamic principles, particularly system energy, (a measure of the capacity to perform work) as a means of providing a common basis for comparison.

In this presentation, the EvMM program's educational and research components will be presented in greater depth, and the ways in which a thermodynamic approach to manufacturing management can be implemented will be explored more fully.

DRINKING WATER RESEARCH NEEDS: A WATER UTILITY PERSPECTIVE. by: Mark W. LeChevallier, Director, Research American Water Works Service Company, Inc., 1025 Laurel Oak Rd., P.O. Box 1770, Voorhees, NJ 08043.

The American Water Works Company is the largest investor-owned water utility in the United States, serving over 7 million people in 22 states. The company supports a staff of 20 full-time researchers with an annual budget over \$2 million. To ensure that the research program focuses on the highest needs of the utility subsidiaries, a five year research agenda is developed and regularly updated. The foundation of the agenda is a questionnaire sent to all utility subsidiaries, managers, water quality and engineering professionals. A Research Advisory Group then organizes the questionnaire results into top priorities in 6 categories ranging from source water to management issues. The research needs are organized into a specific agenda and tasks assigned to various principal researchers. Periodic review of past agendas ensures that the scheduled needs are being met. Based on the 1999-2004 agenda the following three themes are highlighted for the next decade:

- *Cryptosporidium* will continue to dominate issues related to analytical methodology, treatment, and health risks of potable water. New methodologies to measure live, infectious oocysts in drinking water systems will be needed to establish health risks. Depending on the outcome of this monitoring, upgrades to current treatment technologies may be needed. Advanced disinfection procedures including ozone, ultra-violet light, membranes, etc. may be necessary to control *Cryptosporidium*, and at the same time achieve low disinfection by-product levels.
- Distribution system water quality issues will gain attention. For the past three decades attention has focused on the treatment plant as a means of controlling water quality. The next decade(s) will devote increasing attention to how water quality is degraded within the distribution system. New approaches including hydraulic modeling, surge analysis, reaction kinetics, and growth rates will be used to further understand and control distribution system problems.
- Pharmaceuticals will emerge as the next major class of environmental pollutants. Fate, transport, treatability, biodegradation, and bioaccumulation will be principle areas of study in understanding the role of these contaminants in human health. As with disinfection by-products, emphasis will be focused on short-term, reproductive health concerns.

The environmental scientist in the third millennium will need to be multi-disciplinary, collaborative, and capable of integrating various information sources to solve the looming challenges to producing safe drinking water.

FOUNDRY AIR POLLUTION PREVENTION WITH ADVANCED OXIDATION AND ADSORPTION.
by: *Fred S. Cannon* (fcannon@psu.edu), Civil and Environmental Engineering, The Pennsylvania State University, 212 Sackett Building, University Park, PA, *Robert C. Voigt* (rcv2@psu.edu), Industrial and Manufacturing Engineering, the Pennsylvania State University, *James Furness*, Furness-Newburge.

Research Scope

An important direction for future research in industrial pollution prevention will result from collaborations between environmental engineers with industrial engineers or chemical engineers. This is particularly true for the manufacturing sector, where each category of companies may develop a different product and hence generate a different pollutant. Identifying modes of preventing the pollution in the first place often causes planners to understand both the process and the mechanisms for creating and treating the pollutants, and then integrating the treatment scheme right into the manufacturing unit processes. This is the case for ongoing research at Penn State, where we are developing and improving a full-scale technology for preventing air pollution from foundries by integrating an advanced oxidation and adsorption process directly into green sand molding processes.

Previous Relevant Research

Many foundries employ green sand molds to retain molten metal in a desired shape while the metal solidifies and cools. Green sand consists of bentonite clay, coal, silica sand, water, cereal, and organic binders. When the greensand becomes exposed to molten metal temperatures, the coal, cereal, and organic binders can release volatile organic compounds (VOCs). Full-scale plant operations at green sand foundries have shown that advanced oxidation (Sonoperoxone™) treatment systems will significantly reduce emissions. Our bench-scale and pilot-scale tests at Penn State confirm these results. These advanced oxidation systems have successfully controlled VOC emissions at three large foundries for 1-3 years. The current advanced oxidation systems pre-condition water and bond additives to effectively enhance VOC and benzene capture and decomposition. At the same time, advanced oxidation systems permit active clay from waste green sand, wet scrubber, or baghouse fines to be extracted and returned to green sand systems. We further anticipate that the combination of advanced oxidation and plasma treatment will reduce benzene and VOC emissions even further.

Impact

Based on documented appraisals of full-scale foundry performance, we anticipate that if all green sand foundries were to employ advanced oxidation -plasma systems, the total US air pollution (from both foundries and all other sources) could be diminished by 0.1 to 1.0 percent. Similar benefits can be expected for in-plant VOC level reductions that impact worker health and morale. The Role that environmental engineers and scientists could play with interdisciplinary teams in developing this research area is for us to be engaging ourselves in entering manufacturing plants that generate pollution, understanding the unit operations that are performed in these plants, and then identifying modifications that could be developed in-situ to eliminate this pollution. The long-range development of research infrastructure could result in a far cleaner environment than we now have. The first steps will be to interface with industries, such as foundries, which have not actively engaged with environmental engineers, and then manipulate environmental engineering fundamentals to their existing manufacturing processes.

IMPROVING BACTERIA FOR BIOREMEDIATION. by: K. Pagilla* (pagilla@charlie.iit.edu), D. Webster** (dwebster@charlie.iit.edu), B. Stark** (bstark@charlie.iit.edu), *Chemical and Environmental Engineering Department, **Biological, Chemical, and Physical Sciences Department, Illinois Institute of Technology, Chicago, IL 60616.

Genetic engineering of bacteria to improve their functional capabilities such as bioremediation of contaminants in the environment is the focus of research described here. The main aspects of our past research include isolation of the hemoglobin gene (*vgb*) from *Vitreoscilla* sp., transformation of different bacteria such as *Pseudomonas*, *Serratia*, *Xanthomonas*, *Escherichia*, and *Burkholderia* with the *vgb* gene, determination of *vgb* expression and stability, and investigation of how this genetic engineering can improve the beneficial properties of these strains. The *vgb* gene encodes hemoglobin which improves the oxygen uptake by bacteria under hypoxic conditions, thereby enhancing their growth and productivity. Our current work involves investigation of the individual species to demonstrate improvements in their function, particularly with regard to bioremediation of contaminated soil and water. For example, *Burkholderia*, which is known to biodegrade 2,4-DNT, is being investigated with regard to improvements in growth and 2,4-DNT degradation resulting from genetic engineering with *vgb* under hypoxic conditions. The impact of this work is: 1) in improving the ability of microorganisms such as *Burkholderia* to degrade specific contaminants in the environment when conditions such as low dissolved oxygen concentrations are not favorable to the native species, 2) in developing methods which could serve as a template to isolate and use other genes which are responsible for specific functions, i.e., enhanced biological phosphorus removal, biosurfactant production during aromatic compound degradation, and biomarkers such as bioluminescent "bioreporter" genes.

The key infrastructure items necessary to conduct the research mentioned above include typical molecular biology/genetic engineering tools found in traditional biology programs, and laboratory and pilot scale bioremediation systems found in most environmental engineering programs. Hence, the existing resources can be shared between engineers and scientists from their respective programs without duplication in each program. Such collaborations will facilitate interdisciplinary interaction of researchers and students from both biological sciences and environmental engineering, and provide a synergy in research and educational activities. For example, the isolation of *vgb*, transformation of bacterial species, and their functional characterization was predominantly conducted in the biological laboratories. The application of these engineered strains for bioremediation of DNT-contaminated water and soil was conducted in the environmental engineering laboratories. Both tasks were parts of the same common project, and actively involved researchers from the other group.

Our current and future tasks include chromosomal integration of *vgb* to improve stability such as for field bioremediation applications, scale-up of laboratory bioremediation work to pilot and field scale demonstrations at actual contaminated sites, and addressing issues concerning the use of genetically engineered organisms in the field.

MICROSCOPIC AND MOLECULAR METHODS TO ELUCIDATE THE SPECIATION OF METALS IN ENVIRONMENTAL SYSTEMS. *by: Jean-François Gaillard (jf-gaillard@nwu.edu), 2145 Sheridan Road, Department of Civil Engineering, Northwestern University, Evanston, IL 6028-3109.*

For the next decades, one of the greatest challenge facing us will be to assess the fate of metal contaminants in environmental systems. The remediation of contaminated sites, and the management of hazardous waste products generated by governmental or industrial activities require the use of sophisticated engineering and scientific approaches. The success of these approaches depends on our ability to obtain a detailed knowledge of the chemical speciation (*i.e.*, the physical and chemical forms) of metal contaminants.

The chemical form under which metals are present plays an important role in determining their toxicity and bio-availability. Conversely, certain biological species (*i.e.*, microbes) develop resistance mechanisms that effect changes in metal speciation. To determine the fundamental principles that govern the behavior of metals, their reactivity, and their biogeochemical cycles we need to use analytical tools that probe their speciation at different spatial scales, *i.e.*, from the size of microorganisms down to chemical bonds.

With recent advances in the development of microscopic tools and spectroscopic techniques, it is now possible to obtain germane information on metal speciation in contaminated sites. For example, we have studied the speciation of Zn in the sediments of a small lake contaminated by the operation of a smelter. Using transmission electron microscopy coupled to energy dispersive spectrometry (TEM-EDS) we can identify clearly the major elemental associations in inorganic and organic particles with a nanometer scale resolution. In addition, the utilization of other techniques or instrumentation attached to the TEM, such as selected area electron diffraction (SAED) or electron energy loss spectrometry (EELS), provided us with complementary information about the structures of the particles. The elemental associations determined by the microscopy studies served as a basis to probe, by x-ray absorption spectroscopy (XAS), the same material to unravel the average local environment of Zn, *i.e.*, its coordination. Using these two complementary tools, we were able to determine the changes in the chemical speciation of Zn, as a result of diagenetic processes.

The next analytical challenge, that will improve drastically our understanding of environmental processes relevant to metal speciation, resides in our ability to do spectroscopy at the microscopic level. Recent advances in the development of x-ray spectro-microscopy indicate clearly that the coordination environment, and the valence state of elements can vary at a small scale, *i.e.*, within an organism. This finding has tremendous implications on our ability to understand how electron transfer reactions are effected, and to estimate the reactivity of mixed valence compounds formed by microbes (*i.e.*, manganese and iron oxides) in order to use their scavenging potential in an efficient manner. As environmental engineers and scientists we need to catalyze the development of national instrumentation facilities that will provide us the necessary tools to comprehend better environmental processes at the microscopic scale and the molecular/atomistic level.

ANALYTICAL TOOLS IN MOLECULAR SCIENCES: CHARACTERIZING BACTERIAL POPULATIONS IN ACTIVATED SLUDGE - COMPOSITION, QUANTIFICATION AND BEYOND.

by: Ian M. Head (i.m.head@newcastle.ac.uk), T.P. Curtis (tom.curtis@newcastle.ac.uk), Mike R. Barer (m.r.barer@newcastle.ac.uk), and A.G. O'Donnell (tony.o'donnell@newcastle.ac.uk.) Departments of Fossil Fuels and Environmental Geochemistry, Civil Engineering, Microbiology and Agricultural and Environmental Science and Centre for Molecular Ecology, University of Newcastle, Newcastle upon Tyne, NE1 7RU, UK.

There have been enormous advances in the methods for the detection of microorganisms in environmental matrices. These methods are now being applied to study the microbial ecology of wastewater treatment systems. Procedures such as PCR-amplification, cloning and sequence analysis of ribosomal RNA genes have greatly increased our knowledge of microbial populations in natural and engineered systems. Furthermore, the development of whole cell *in situ* hybridization and electrophoretic techniques (i.e. DGGE, denaturing gradient gel electrophoresis) has allowed patterns to be observed in microbial communities and population dynamics in response to environmental factors can be determined. Studies of two bacterial groups important in wastewater treatment systems (autotrophic ammonia-oxidizing bacteria - AOB - and mycolata involved in foaming) have revealed how differences in operational parameters and plant configuration affect the composition and abundance of these bacterial communities resulting in deleterious effects and process failure. When used in a qualitative manner this technology gave valuable insights into the morphology of the organism in the environment but could not be associated with particular problems. However, more rigorous, statistically valid, quantitation of the mycolata for example, permitted the determination of a threshold abundance which must be exceeded for foaming to occur. This threshold could be related to the physical layout of an activated sludge plant. The same approach has been extended to the ammonia-oxidizing bacteria. Quantitative analysis was used to determine the effect of population size on the performance of a lab-scale bioreactor and associated changes in population structure, in relation to operational factors, were determined.

While the abundance of specific groups of organisms has consequences for treatment performance their specific activity is also crucial. A number of methods have been developed to assess metabolic activity in individual cells of particular bacterial groups. Their potential application in studies of wastewater treatment will be discussed.

Recognition of particular patterns in microbial populations and observing population shifts does not in itself provide an explanation for the composition of microbial populations that is observed, and essentially extends the suite of empirical tools applied to optimize wastewater treatment systems. In the design of wastewater treatment facilities our primary aim is to engineer microbial populations to optimally achieve a specific favorable outcome (i.e. reduction in BOD, conversion of ammonia to nitrate). Our future goal must be to engineer wastewater biotreatment microbiota in a predictive fashion. In order to objectively engineer a system we must first be able to make meaningful quantitative measurements of its component parts - one cannot engineer what cannot be measured. This can currently be achieved in the research laboratory, but the development of simple, reliable, routine quantitative assays is required. Moreover, common features observed in the structure of microbial communities in relation to environmental and operational parameters can provide the basis for theoretical explanations of their occurrence and composition. This potentially provides a framework for understanding the patterns observed in microbial communities as a whole. Ultimately this may permit the development of approaches to select for a particular community composition and activity by objectively engineering the resident microbiota in a wastewater treatment system.

USE OF MOLECULAR TOOLS TO QUANTIFY MICROBIAL POPULATIONS AND SPECIFIC GROWTH RATES IN MATHEMATICAL MODELS OF BIOLOGICAL TREATMENT PROCESSES.

by: Lutgarde Raskin (lraskin@uiuc.edu), University of Illinois, Department of Civil and Environmental Engineering, 3221 NCEL, 205 N. Mathews Ave., Urbana, IL 61801.

The desire to develop compact and reliable waste treatment systems is prompting environmental engineers to rely more heavily on mechanistic mathematical models to design and optimize the operation of bioreactors. These models consist of systems of mass balance equations for various compounds present in the waste stream or produced during treatment, and for microbial populations that utilize these compounds as substrates and nutrients for growth. The mass balance equations include kinetic and stoichiometric parameters that allow descriptions of biomass growth, biomass decay, substrate utilization, hydrolysis, etc. Therefore, an important aspect of the modeling exercise involves obtaining reliable kinetic and stoichiometric parameters. Furthermore, model outputs consist of predictions of effluent concentrations of substrates and nutrients, and concentrations of microbial populations and other particulate fractions. Thus, experimental determination of these concentrations is necessary to calibrate and validate the models.

Mechanistic models rely on kinetic and stoichiometric parameters that have been determined indirectly or *ex situ* with pure cultures or environmental enrichments. In addition, the concentrations of microbial populations currently are not determined as part of model calibration and validation efforts. At best, an overall concentration representing the concentrations of all particulate organic fractions combined is estimated by measuring particulate chemical oxygen demand (COD) concentrations or volatile suspended solids (VSS) levels.

Nucleic acid based techniques have only recently become available to environmental engineers. They rely on the identification of signature sequences present in the DNA or RNA of a population (i.e., ribosomal RNA [rRNA], precursor rRNA, metabolic genes). These signature sequences provide unique target sites for oligonucleotide probes, which can be used for the detection and quantification of phylogenetically defined populations and for the determination of some kinetic information (i.e., specific growth rates) *in situ*.

Recent advances in nucleic acid based techniques have improved the quantitative nature of hybridization assays. However, correlations between concentrations of microbial populations predicted by mechanistic models and quantitative information obtained with oligonucleotide probe hybridization's are not yet well developed. Future work should further develop such correlations, while addressing the limitations and assumptions made when using molecular assays.

Progress in this research area will only be possible when a team of environmental engineers and scientists will strongly integrate their areas of expertise. Engineers with experience in the development and application of mechanistic models will need to understand the basics of molecular techniques to appreciate the advantages and limitations of molecular tools to study microbial population dynamics and microbial activity in complex bioreactor systems. Similarly, engineers and scientists proficient in the application of molecular tools need to be on par with biological process engineers, need to understand the conceptual basis of the models, and develop an appreciation of the numerical difficulties associated with solving dynamic models. This strong integration of traditionally separate areas of expertise can be accomplished when graduate students in environmental engineering and science are trained in both fields through their research and course work. Although opportunities currently exist to provide such training, few graduate programs make use of such opportunities because most research projects are not designed to allow for advanced training in two areas that are traditionally considered inherently different.

APPLICATIONS OF MASS SPECTROMETRY (ICP-, ELECTROSPRAY-, AND ISOTOPE-MS) IN ENVIRONMENTAL CHEMISTRY. by: Janet G. Hering (jhering@cco.caltech.edu), Environmental Engineering Science, California Institute of Technology, 1200 E. California Blvd. (138-78), Pasadena, CA 91125.

Mass spectrometry (MS) offers a powerful, sensitive, and versatile tool for obtaining molecular level information in complex natural systems. With the appropriate "front end", mass spectrometry can be applied to a wide variety of analytes in gas, liquid (including aqueous), and solid media. Most well known in environmental chemistry is, of course, gas chromatography (GC)-MS, which has been widely applied for the analysis of hydrophobic organic compounds. The requirements of the GC "front end" for analyte volatility, however, previously limited the applications of MS for analysis of non-volatile (i.e., hydrophilic) analytes.

Recent advances in mass spectrometry offer a much broader range of environmental applications. Inductively coupled plasma (ICP)-MS allows the direct analysis of a wide array of elements in aqueous media. ICP-MS has a very wide dynamic range and its sensitivity is limited primarily by the ionization potential of the element and by interferences by species formed in the plasma (i.e., ArO^+) with co-incident masses for a given analyte. Detection limits in the sub-ppb (and even ppt) ranges are achievable for many elements and the technique is rapidly becoming the analytical method of choice for many environmental applications especially when large sample throughput is required.

Although not yet widely used in environmental applications, laser ablation-ICP-MS allows the determination of analytes in solid matrices. Differential ionization of analytes poses some problems for quantification but this technique holds great promise as an alternative to exhaustive digestion of solid samples.

In addition to elemental composition, molecular information can be obtained for non-volatilizable compounds using electrospray (ES)-MS. Variations of this technique include the mode of ionization (generating positive or negative ions through imposition of a strong voltage gradient or by atmospheric pressure chemical ionization). The ionization is generally sufficiently gentle that molecular ion signals can be detected; fragments of the molecular ion can be generated by imposition of a secondary "fragmentor" voltage.

Stable isotope MS has been widely applied in geochemistry but the potential of this technique has not yet been fully appreciated in environmental applications. Isotopic signals are detectable and can be quite useful in both ICP-MS and ES-MS. Tracing isotopic fractionation in environmental reactions, however, requires specialized high precision instruments to detect small changes in isotopic ratios.

The fundamentals of these various MS techniques will be reviewed briefly with emphasis on their application to environmental problems. Specific examples will be presented for each technique and their most significant limitations will be addressed.

NEW ANALYTICAL TOOLS FOR DETERMINING METAL ION SPECIATION AND LIGAND SPECIATION IN AQUEOUS MEDIA. by: Alan T. Stone (astone@jhu.edu), 313 Ames Hall, Department of Geography and Environmental Engineering, Johns Hopkins University, Baltimore, MD 21218.

The importance of speciation is widely recognized. Nutrient metal ion activity has been linked to rates of biotransformation in subsurface media and undesirable algal growth in surface waters. Toxic effects on plants and soil microorganisms have been linked to changes in metal speciation accompanying contaminant inputs, acidification, and changes in redox status. Adverse effects on a variety of industrial processes (i.e. paper-making, dyeing, photographic processing, materials synthesis, pharmaceuticals production) have been linked to metal ion and ligand contaminants in raw water sources.

Present-Day Approaches Towards Speciation

At present, most laboratory analyses involve the separation of dissolved from particulate species (by filtration or centrifugation) followed by total analyte measurement (AAS, ICP, elemental analysis). Although determinations of total elemental concentrations have been routine for more than 20 years, only recently have methods been developed to measure biologically-derived ligands (i.e. siderophores, phytosiderophores, and phytochelatins) and synthetic ligands (i.e. EDTA, NTA, phosphonates) at ambient levels. Additional steps taken to discern speciation are seldom routine. The diphenylcarbazide test is used to distinguish Cr^{VI} from Cr^{III} at chromium-contaminated waste sites; ion selective electrodes are used to monitor process-water quality during materials synthesis.

At present, a heavy reliance is placed on computer-based speciation programs that are built on a series of assumptions: (i) key chemical constituents have been identified and appropriately represented; (ii) heterogeneities and polydisperse properties of particulate matter and natural organic matter are either insignificant or appropriately represented by simplistic models; (iii) speciation is controlled by thermodynamics, not by kinetics. Instances where each of the three assumptions fail have been reported, and calculated speciation in some instances bears little resemblance to analytically-determined speciation.

New Opportunities and Directions

Capillary electrophoresis is an exceedingly simple and low cost technique that separates ions on the basis of charge and hydrodynamic radius. Capillaries can be selected that are chemically inert (i.e. Teflon) and electrolytes can be employed that closely match the sample medium (fixed pH and major ion concentration). The degree to which speciation can be resolved by CE depends upon the response factor for individual analytes (i.e. molar absorptivities) and upon rates of metal ion exchange and ligand exchange during electrophoretic migration. Ion-paired HPLC, ion chromatography, and electrochemistry are examples of other low-cost methods of speciation determination. Electrospray MS is a much more powerful yet technically difficult and more expensive approach towards metal ion and ligand speciation. The ability of this technique to provide parent ion and fragment mass information will substantially improve our understanding of metal ion-ligand complexes which exchange too rapidly for detection by other methods, or pose other analytical difficulties.

Improved analytical techniques will assist in identifying metal ion-ligand complexes with unique toxicological properties (i.e. complexes that mimic nutrient species or are capable of hydrophobic partitioning). Our ability to monitor the course of chemical and biological transformations and identify reaction intermediates and products will improve. New information regarding speciation can provide the basis for testing and reformulating computer-based speciation models, and for developing structure-activity relationships. All of these activities improve our ability to predict the consequences of existing engineering practices and devise long-term strategies for minimizing undesirable consequences of human activities.

USING THE MOLECULAR STRESS RESPONSE AS AN INDICATOR OF SYSTEM STRESS IN COMPLEX ENVIRONMENTAL SYSTEMS. *by: Nancy G. Love (nlove@vt.edu), 418 New Engineering Building, Department of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0246.*

Research Scope

Biological treatment systems are generally effective, but disruptions to these systems through changes in upstream water quality or operational practices can result in incomplete treatment and downstream toxicity. Some existing early warning monitoring devices exist, but these devices do not indicate the nature of the stress, nor do they clearly correlate with deterioration of process performance. New technologies are needed that are rapid, flexible (i.e., not limited to aerobic conditions), descriptive (what is the SOURCE of the problem?), and operator friendly. My research group has been investigating the existence of stress proteins in complex activated sludge cultures in response to xenobiotic shock events. Previous work with the molecular stress response in microorganisms has, to date, been limited to pure culture systems. Our data is probably the first demonstration that stress proteins are prevalent in complex activated sludge consortia and some stress proteins are induced to elevated levels in response to sublethal concentrations of xenobiotic compounds that can cause significant process performance problems. I propose that the molecular stress response deserves considerable attention as a potential indicator of system stress in environmental systems containing complex microbial consortia.

Impact

I predict that relative changes in patterns of stress gene expression will serve as strong indicators of not only the SOURCE of the stress but also the potential consequences of the stress event (i.e., deflocculation in an activated sludge system). Additionally, regulation of stress gene expression may be found to activate selected responses in complex consortia that explain the cause for overall system deterioration, or provide a basis for overcoming a potential detrimental response by the microbial system. Finally, as correlations between stress gene expression patterns and functional microbial responses are developed, it may be possible to use this information for pollution prevention purposes as a screening device for new wastes or products. Developing a fundamental understanding of the nature of stress at the molecular level in complex microbial systems will likely lead to better control of engineered systems that rely upon microbial cultures for proper function, and improved levels of environmental protection.

Long-Range Development of Research Infrastructure

Our level of knowledge into the potential of the microbial stress response to indicate the state of microbial health in complex systems is extremely limited. We are hindered by a lack of knowledge regarding the diversity of stress genes that exist, their structure and function, and how to best implement detection of stress gene expression so that real time monitoring technologies can be implemented into engineered systems. Molecular studies integrated with environmentally relevant cultures grown under environmentally relevant conditions are needed.

Interdisciplinary Roles

The current work completed in my lab with stress protein expression in complex activated sludge cultures was accomplished only through the work of a truly interdisciplinary team of engineers, microbiologists, and molecular biologists. As we attempt to better understand the molecular world around us and how human actions influence the manner in which the molecular world functions, it will be necessary to draw upon the expertise of broadly trained scientists and engineers.

First Steps

The short-term research need for this area of inquiry involves conducting proof-of-concept studies. In particular, it will be important to determine the diversity of distinct molecular stress responses to a broad range of stressors. Once the diversity of the molecular response in complex environmental systems is determined, several stress proteins or genes that appear to be selectively important for the types of environmental system stresses of concern should be characterized further.

USE OF MOLECULAR TOOLS IN UNDERSTANDING THE ATTENUATION, FATE, AND ECOTOXICITY OF TRACE ORGANIC CONTAMINANTS IN NATURAL SYSTEMS. *by: David Graham¹ (dwgraham@kuhub.cc.ukans.edu), and C. Larive² (clarive@caco3.chem.ukans.edu), ¹ 2006 Learned Hall, Department of Civil and Environmental Engineering, University of Kansas, Lawrence, KS; ² Department of Chemistry, University of Kansas.*

Understanding mechanisms that affect the attenuation, fate, and toxicity of trace level organic contaminants in nature has been difficult until very recently. Previously, assessing of the fate and effects of such compounds has only been possible through controlled laboratory experiments or through empirical field studies. Although both these approaches have merit, both have limitations and frequently provide incomplete or inconclusive results. Field studies rarely elucidate specific transformation mechanisms because of the innate complexity of natural systems, whereas laboratory studies rarely provide data that translates well to the field because "nature" is hard to approximate in lab experiments. Due to these limitations, an alternate research strategy is proposed here aimed at overcoming the above problems. This strategy combines the use of small field-scale, microcosms (11.3 m³ volume fiberglass tanks) in concert with the use of both molecular biological and molecular chemical techniques. Field-scale microcosms provide the advantage of accurately simulating complex natural systems, while also permitting the controlled creation of many contamination scenarios and adequate replication to allow statistical analysis of the results. The molecular techniques provide tools that allow accurate monitoring of the biological and chemical systems created at a level of detail only previously possible in laboratory studies.

The utility of this holistic research approach is exemplified in our study of the attenuation, fate, and ecotoxicology of herbicides in natural aquatic systems. Laboratory studies have shown that such compounds can affect selected species at very low concentrations; however, little data exists on whether specie-level effects translate into significant ecosystem effects. The determination of ecosystem-level effects is critical to developing reasonable water quality guidelines and for contaminant registration assessments. The use of field microcosms in conjunction with the application of new molecular and other techniques permits preliminary ecosystem-level testing.

Examples of how the new techniques can be used include: 1) the assessment of interactions between trace organic contaminants and natural organic matter as they affect the bioavailability of contaminants in natural waters (using lab and field experiments, and molecular modeling); 2) the evaluation of microbial community structure and its effect on biotransformation mechanisms (using Terminal-Restriction Fragment Length Polymorphism analysis); 3) the use of gene probes and Southern Blotting techniques to assess the role of Key genes potentially responsible for contaminant transformation in nature; and 4) the use of molecular biological techniques, including reverse transcription of RNA followed by Polymerase Chain Reaction, to assess sub-chronic exposure effects in higher organisms such as fish. Without these sophisticated new analytical tools in controlled field experimental systems, defining the broader effects of such contaminants on natural systems is almost impossible.

We believe that the holistic approach described above should be the primary means of study for all natural and engineered systems in the future. We believe such an approach is essential because of the high interconnectedness of all natural systems. Although the approach suggested here is currently limited to research groups that have suitable experimental facilities and molecular capabilities, we believe that the short (<5 years) and long (>10 years) term goal of any group assessing contaminants in nature should be to develop in-house skills where possible (i.e., molecular techniques) or seek out collaborations where helpful. Environmental problems are innately multidisciplinary and collaborations are essential for success.

We believe the role of the environmental engineer in this type of research program should be both as a facilitator and a specialist. Individuals cannot be experts in everything; however, some specialist skills must be developed by environmental engineers to contribute in the future. This will require new skill development for some individuals, but we believe most studies with any long-term merit will require new and special skills, and environmental engineers and scientists should adapt accordingly.

ENVIRONMENTAL ANALYSIS OF URBAN ECOSYSTEMS. *by: Larry Baker (lbaker@asu.edu), Department of Civil and Environmental Engineering, Arizona State University, Tempe, AZ 85287-5306 and C. Redman (iacclr@asuvm.inre.asu.edu), Center for Environmental Studies and Department of Anthropology, Arizona State University, Tempe, AZ 85287-3211.*

Research Scope

Ecologists have traditionally avoided urban ecosystems whereas environmental engineers have traditionally dealt with issues within a narrow regulatory focus. As a consequence, we have little basic understanding of the ecosystems in which most of us live. Our nascent NSF-funded Phoenix-Central Arizona Long-Term Ecological Research project (Phoenix-CAP LTER) is one of two new "urban" LTER sites (along with Baltimore). A key component of the project is measurement of key state variables and processes over long periods of time to determine how ecosystems change over time.

Impact

Various aspects of the project will find immediate practical value. Examples of projects now underway which are likely to have direct impact within the next five years include a spatially explicit model of nitrogen inputs and movement, a microclimatological model, a predictive model of residential growth patterns, and appraisal methods for valuing "open space". Broader integration of social and physical sciences will be slower to evolve, in part because of a lack of a common denominator of valuation. Use of "ecosystem valuation" approach for urban areas was discussed in an internal workshop last summer but was not well received. The concept an object-oriented, interactive urban planning model (like SimCity©, but based on "real" algorithms) has been discussed informally. Such a model might include widely used engineering submodels (i.e., stormwater runoff and transportation routing) together with new submodels to predict plant species diversity, impact on animal movements, nitrogen accumulation, primary productivity and other factors. Over the long run (decades), intensive examination of the environment we live in will diminish the "man-nature" dichotomy that pervades our culture and major religions.

Role Of Environmental Engineers And Scientists

Environmental engineers are well-suited to the role of hydrologic and materials balances. Moving from traditional civil and environmental engineering (generally project-based) to ecosystem scale management will require skills not widely acquired by today's environmental engineers, including database management, GIS-based modeling, and remote sensing. Understanding urban ecosystems will require far more teamwork that generally occurs within universities, and universities may have to modify their reward systems to encourage this type of effort if they are to be successful.

First Steps

A first step in the Phoenix-CAP LTER project has been to assemble an enormous amount of existing data and to develop "early synthesis" projects to utilize these data. For example, we have developed a preliminary N balance for the whole ecosystem. This is in turn being used to refine the development of the monitoring network and to develop more narrowly targeted proposals for specific aspects of the work that will require more resources than are available through the LTER project. The acquisition and organization of existing data is proving to be a powerful leveraging tool in developing new lines of research. The project has received very favorable reception from local management agencies, leading to a number of informal and formal collaborations that would not otherwise have occurred.

WHAT IS GOING ON IN THE REAL WORLD?: CHALLENGES AND OPPORTUNITIES FOR RESEARCH ON ENVIRONMENTAL PROBLEMS AT LARGER SCALES. *by: Dr. Charles T. Driscoll (ctdrisco@mailbox.syr.edu), Distinguished Professor of Environmental Engineering, Department of Civil and Environmental Engineering, Syracuse University, Syracuse NY 13244, (315) 443-3434, fax (315) 443-1243.*

Over the last century, the scope of problems that environmental engineers have been asked to address has broadened considerably, from relatively focused local issues to problems involving complex stresses occurring over large scales. Such emerging problems include: 1) increasing atmospheric concentrations of carbon dioxide (i.e., climate change, changes in carbon cycling), 2) air pollution (i.e., soil and surface water acidification, nitrogen saturation, ozone, hazardous air pollutants), 3) eutrophication of coastal waters, and 4) management of watershed and groundwater resources. Laboratory studies are inherently more attractive and satisfying (at least over the short-term) because of the ease in which a process of interest can be isolated and examined in under controlled conditions. Moreover, laboratory studies are easier to obtain funding to support, and the results are generally easier to interpret and publish than large scale field studies. Understanding large regional or global environmental problems requires the pursuit of research questions under complex field conditions and over large spatial scales. Due to their broad understanding of physical, chemical and biological processes and phenomenon, and quantitative approach, environmental engineers are uniquely qualified to play a critical role in assessments of these complex problems. Environmental engineers and scientists should be actively engaged in research design, experimentation, modeling, integration and synthesis of large scale problems. Although large scale research problems are complex and difficult, the most important questions are generally basic, such as: What are the inputs of a pollutant to an ecosystem?; How are pollutants transported within and from an ecosystem? What is the fate of a pollutant?; What are the effects of disturbance?; or How does an ecosystem respond to remediation? Large scale problems are multifaceted and necessitate a multidisciplinary approach. Environmental engineers and scientists should team with scientists from other disciplines who have expertise and interest in complex environmental problems. These linkages should be extended to social scientists and resource managers so that research findings can be utilized by the public. Environmental engineers and scientists need to utilize traditional methods (i.e., long-term monitoring, synoptic surveys, experimental manipulation, modeling) coupled with newer innovative approaches (i.e., use of stable isotopes, remote sensing, geographic information systems) to understand ecosystem response to environmental disturbance over complex landscapes.

Joseph Addison (1672-1719)

ARMY OFFICERS ON CAMPUS: A JOINT UMR-ARMY PROGRAM PROVIDING MASTER'S DEGREES. *by: C.D. Adams (adams@umr.edu), M.W. Fitch (mfitch@umr.edu), J. G. Burken (burken@umr.edu), 202 Butler-Carleton CE Hall, Department of Civil Engineering, University of Missouri-Rolla, Rolla, MO 65409*

Through a joint effort with the Army Engineering School, the Environmental Engineering Program at University of Missouri-Rolla (UMR) has developed a program to offer Master's degrees to US Army Officers completing the Engineering Officer's Advanced Course (EOAC) at Fort Leonard Wood. The program provides a limited amount of credit for the EOAC coursework completed by the officers, subject to evaluation by program faculty. All credit offered for the EOAC coursework is augmented by instruction from UMR faculty. The EOAC students are also enrolled in evening classes at UMR during the fall semester, while they are concurrently attending EOAC classes during the day. During the spring semester, students enrolled in the program are given leave from active duty responsibilities and take courses on campus. This time on campus often includes research experience for the student-officers. These students are allowed flexibility to develop their own plan of study that meets the UMR criteria, while still allowing them to complete their non-thesis degree in a total of nine months. While program met resistance when initially proposed, it has since been extremely successful, receiving broad praise from UMR and the Army. This presentation outlines the steps taken to establish the program and gain approval from the Army and UMR, following the strict regulations of each entity. The program is a unique means of expanding engineering education to non-traditional students with minimal alteration the existing degree program.

The program is now seen as a "win-win" venture as the Army student-officers are allowed to receive a superb degree from a top engineering school and bring that knowledge to their profession. UMR benefits from these students with a high degree of professionalism, a drive to learn, and a vast background of experiences. The program outline is presented along with the negatives and positives that have been encountered along the way.

PARTICLE MEASUREMENTS BY *IN SITU* LASER LIGHT SCATTERING. by: A. Adin (avner.adin@uc.edu) P. Biswas (pratim.biswas@uc.edu), G.J. Dutari (dutarigi@email.uc.edu) and V. Sethi (sethi.virendra@epamail.epa.gov) Environmental Engineering and Science Division, ML -71, University of Cincinnati, Cincinnati, OH 45221-0071.

Establishing a relationship between turbidity, particle size and concentration would provide the basis for evaluating the effectiveness of particle removal processes. Urgent need arises to develop good detection techniques for the characterization of microorganisms and other particles in water. In this poster, an *in-situ* laser light scattering (ISLS) to measure the light scattering characteristics of suspensions is presented and measurements using turbidimeter and optical particle counter are compared. Another objective was also to use this *in situ* measurement technique for establishing transport characteristics of particles in water.

Preparations of clay, *Cryptosporidium parvum* oocyst, monodispersed latex particles and silica particles suspensions were followed by measurements in the light scattering optical setup, turbidimeter and optical particle counter (OPC). The *in situ* technique mentioned above, was used to estimate the settling characteristics of particles used in the earlier experiments.

The 90 % cut off size for the *Cryptosporidium parvum* oocyst using OPC was approximately 2.5 μm , while microscopic determination resulted 4-6 μm . The clay suspension size was approximately 1.9 μm , a larger number remained below the detection limit of the instrument. In summary, the optical particle counter measurements undersize the *Cryptosporidium parvum* oocyst. This discrepancy in sizing may be attributed to its partial transparency. A linear dependency is observed by plotting the scattered intensity, I_{sc} as a function of number concentration for *Cryptosporidium parvum* suspensions of 10^4 oocysts/ml and higher, demonstrating the potential application of ISLS. The turbidimeter readings also correlate well with the number concentrations, again not in the lower range. 5.0 μm Silica particles (1.96 g/cc) settle faster and the measured light scattering intensity drops rapidly. Assuming settling of an initially uniform suspension, the settling velocity of the silica ranged 9.26-13.88 m/s, close to theoretical calculations. Preliminary settling velocity findings for *Cryptosporidium parvum* range 0.068-0.5 m/s. Although the size of the oocyst is larger than the mean size of the clay particles, they settle more slowly. The density differences alone cannot account for the order of magnitude differences in the settling velocity. Other local transport mechanisms may affect the sedimentation rates. Experiments are being performed to clearly elucidate these effects. Increasing the sensitivity of the ISLS measurement system will increase its future application.

Acknowledgements

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BENZENE AND TOLUENE DEGRADING CAPABILITIES OF A NEW JERSEY SOIL MICROBIAL POPULATION. *by: Gunaseelan Alagappan and Robert M. Cowan, Department of Environmental Sciences, Rutgers, The State University of New Jersey*

Gasoline contamination of sub-surface environments has been prevalent in many parts of the U.S. for several years. Although microbial populations capable of degrading various constituents like BTEX (benzene, toluene, ethylbenzene, and xylene isomers) are found in the natural environments, their activity levels are dictated largely by the prevailing conditions such as temperature, pH, availability of nutrients, concentrations of the chemicals, *etc.* In this study, we focus on the effect of high concentrations of benzene and toluene on the growth kinetics of the aerobic microbial enrichments and compare those results to our prior work with pure cultures, which are capable of degrading these compounds.

An uncontaminated soil sample from Adelphia, New Jersey was used as the source of inocula for development of the enrichment cultures. Separate enrichments were developed under aerobic conditions for each contaminant at low (<35 mg/L benzene and toluene separately), and high (~650 to 700 mg/L for benzene; ~400 to 450 mg/L for toluene) concentrations. These enrichments were then used in initial rate biodegradation studies designed to determine the effect of substrate concentration on specific growth rate. The resulting specific growth rate versus substrate concentration data were fit to appropriate inhibition/toxicity models. The results showed that these enrichments followed the same functional inhibition relationships we observed for the pure cultures (benzene degradation follows Luong inhibition function, toluene follows either Wayman and Tseng or a Modified W&T inhibition function). Additionally, the enrichments had lower observed maximum specific growth rates than the pure cultures, but were more resistant to high solvent concentrations. The enrichments developed under conditions of high benzene or toluene concentrations were found to have, at best, only slightly improved resistance to solvent toxicity versus the microbial communities enriched under low concentration conditions.

The data presented here further supports the argument that the Andrews equation, which is widely used to represent the inhibitory effect of high concentrations of groundwater contaminants on the rate of biodegradation, is not representative of the true effect of these solvents. This is particularly important in regions where high dissolved phase concentrations of these contaminants can be expected because an Andrews equation based model is likely to over-predict microbial activity.

DEVELOPMENT OF ECOLOGICAL ENGINEERING PROGRAMS AT U.S.A. UNIVERSITIES. by M. T. Brown (mtb@ufl.edu) Dept. Environmental Engineering Sciences, University of Florida, Gainesville, FL 32611, U.S.A. and W.J. Mitsch (mitsch.1@osu.edu) School of Natural Resources, The Ohio State University, Columbus, OH 43210.

Ecological engineering is defined as "*the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both*"¹. It involves the design, construction and management of the self-organization of ecosystems that have value to both humans and the environment. Ecological engineering combines basic and applied science from engineering, ecology, economics, and the natural sciences for the restoration and construction of aquatic and terrestrial ecosystems.

At a recent meeting at The Ohio State University, representatives of 12 USA Universities, from departments of Environmental, Civil, and Agricultural and Biological Engineering as well as Natural Resources and Environmental Sciences, met to discuss degree programs and curriculum development for the emerging field of Ecological Engineering. Programs in Ecological Engineering fit very well within the mission of the Colleges of Engineering and specifically within Departments of Environmental Engineering Sciences where students are trained in the application of the sciences and mathematics to deal with complex environmental problems. The main objectives of the proposed degrees are to build ecological and systems thinking of students and to address the complex questions of resource use and allocation facing humanity in the 21st century through research and service. Degree programs in Ecological Engineering, will improve the curriculum for students seeking a more "ecological oriented engineering degree" providing an attractive option for future students. The visibility that results will increase enrollments and strengthen our research agenda, ultimately leading to greater national recognition.

Degree programs in Ecological Engineering at the bachelors and graduate levels were discussed and a curriculum template for the bachelors degree developed that included 48 semester hours of course work in Ecological Engineering and Ecological and Environmental Sciences along with 82 hours in general education and basic engineering requirements. ABET goals discussed included proficiency in: Ecology through systems ecology, earth and physical sciences, biological sciences, math through differential equations, and basic engineering principles. Graduates should have the ability to: understand and design self-organizing systems, design and carry out lab and field experiments, and critically analyze and interpret complex data sets from a societal and ecological perspective. Further, graduates should have knowledge and understanding of: biogeochemical processes, aquatic and terrestrial ecosystems, and legal and societal constraints on ecological engineering.

There is no question that some of tomorrow's engineers must be fully capable of managing natural environments. Degree programs in ecological engineering will prepare students for challenging engineering careers where they will be called upon to integrate engineering principles of problem solving with ecological and systems principles of self-organization. Current careers in industry and government where degrees in ecological engineering would be appropriate include reclamation engineering (reclamation of altered lands from mining, "brownfield" reclamation, and bioremediation), waste treatment and recycle engineering, stormwater engineering, and planning of appropriate organization of urban technology and environmental systems. The future will hold expanded opportunities for students with degrees in ecological engineering as government and industry, increasingly, focus on ecological problems and their solutions.

¹ Mitsch, W.J. and S.E. Jorgensen, eds. 1987. Ecological Engineering: an introduction to ecotechnology. John Wiley and Sons, New York.

EMERGY EVALUATION OF THE ENVIRONMENT: QUANTITATIVE PERSPECTIVES ON SUSTAINABILITY AND ENVIRONMENTAL CARRYING CAPACITY. by: *M. T. Brown* (mtb@ufl.edu)
Dept. Environmental Engineering Sciences, University of Florida, Gainesville, FL 32611, U.S.A. and *S. Ulgiati* (ulgiati@unisi.it) Dept. Chemistry, University of Siena, Piano dei Mantellini 44, 53100 Siena, Italy.

The "free" and necessary environmental resources and services that support society and its economic processes can be evaluated on the same basis using emergy analysis techniques. Emergy is the amount of energy of one form (usually solar) that is required, directly or indirectly, to provide a given flow or storage of energy or matter. Solar emergy is expressed in solar emergy joules (sej, solar emjoules).

Environmental support at several different spatial and temporal scales is evaluated both as an input (source of value) and as a sink (absorbing and recycling by-products) using emergy analysis. Environmental services to deal with by-products of electricity production are defined and calculated in several case studies. Then, the same approach is suggested for other production processes. Accounting for environmental services provides a way to evaluate the carrying capacity of the environment in relation to human dominated processes. The requirement for environmental services at different space-time scales translates into a requirement for a suitable support area. When the evaluation is done at the larger scale of the economy, the approach provides an evaluation of the amount of economic activity that can be supported by available area and environment. When done at the smaller scale of an individual process the analysis provides an evaluation of the environmental services (and ultimately area of the globe) required to absorb and recycle by-products

Six electricity production systems were evaluated to rank their relative thermodynamic efficiencies using an Emergy Yield Ratio and their environmental efficiencies using an Environmental Loading Ratio. The generation of CO₂ and other by-products (SO_x and NO_x) were also accounted. The production systems include both plants using non-renewable energy sources (natural gas, oil, and coal thermal plants) and the so called renewable energy sources (geothermal, hydroelectric, wind, and photovoltaic plants). Emergy yield ratios of plants varied from a high of 8.2/1 for wind generation to about 5/1 for thermal plants to a low of 1.0/1 for the photovoltaic plant. The renewable energy plants required the highest environmental inputs per unit of output while fossil fuel plants required relatively small environmental inputs for cooling. Environmental loading was highest with thermal plants, although the photovoltaic plant was very high as a result of the electricity required for production of solar cells, by means of a still developing technology.

An emergy evaluation of the economies of several countries and their use of global environmental services revealed patterns of sustainability. Renewable emergy flows (i.e. sunlight, wind, rain, tidal, etc) are the environmental services used by each country that occur within their land and continental shelf area. Percent renewable emergy, the percent of the total emergy economy that is contributed through environmental services, varies from a low of 10% (USA) to a high of 50% (developing countries). The environmental loading ratio which is the ratio of non-renewable emergy use to renewable emergy flows indicating development status, varied from a high of 9/1 (industrialized economies) to a low of 1/1 (developing economies).

A global emergy footprint was calculated for each country which shows the surface area of the globe that is necessary to provide environmental services. The USA requires an area of the globe nearly 12 times as large as its land area to supply its environmental services while Italy, almost 49 times its area and Taiwan requires 99 times its area. Most developing countries that have global emergy footprints less than 1.0.

MONITORING WATER QUALITY PARAMETERS FROM ABOVE: USE OF DIGITAL AERIAL PHOTOGRAPHY. by: *M. Butkus* (bm8375@exmail.usma.edu), Department of Geography and Environmental Engineering, *J. Brockhaus* (bj9296@exmail.usma.edu), Department of Geography and Environmental Engineering, *M. Kelley* (bm3913@exmail.usma.edu), Department of Geography and Environmental Engineering, *J. Marin* (dj7900@exmail.usma.edu), Department of Electrical Engineering and Computer Science and *R. Klingseisen* (br5639@exmail.usma.edu), Department of Geography and Environmental Engineering, United States Military Academy, West Point, NY 10996.

Water quality parameters of three lakes within the West Point Military Reservation were assessed and mapped using imagery acquired from a digital aerial camera. During the time of the aircraft fly over, water quality measurements and samples were taken at several sites in each of the lakes. Global positioning system receivers were used to determine the geographic position from which the water samples were obtained. The relationship between light reflectance in the visible and near infrared wavelengths as measured with the digital aerial camera and the measures of water quality were investigated. Statistical analysis was conducted to relate light reflectance and turbidity, particle size, total particle counts, bacterial counts and chloryphll. Models predicting the occurrence and level of these water quality parameters are being developed. Maps depicting the spatial distribution of these parameters will be generated through the application of these models to the digital imagery within a raster based Geographic Information System. Results will be presented.

MEASURING BACTERIAL INTERACTION FORCES USING ATOMIC FORCE MICROSCOPY AND IMPLICATIONS FOR BACTERIAL ADHESION IN POROUS MEDIA. *by: Terri A. Camesano and Bruce E. Logan (bblogan@psu.edu), Department of Civil & Environmental Engineering, The Pennsylvania State University, University Park, PA 16802.*

Atomic force microscopy was used to measure the interaction forces between bacteria and silicon nitride cantilevers. Measurements were made in MOPS buffer at various ionic strengths and pH values and the results were compared with classical DLVO theory simulations. Qualitatively, measured forces agreed with DLVO theory in terms of trends with pH and ionic strength, but measured forces were greater in magnitude and extended over longer distances than would be predicted by DLVO theory. This was attributed to cellular polysaccharides which may extend ~ 20 nm beyond the cells' surfaces. The presence of these molecules can lead to additional electrostatic or steric repulsions that are not included in the classical DLVO theory model. Although the attachment of bacteria to the soil grains of a porous media was hypothesized to be electrostatically controlled, no correlation was observed between repulsive electrostatic interactions measured with the AFM and repulsion of bacteria towards the soil grains. Ongoing research will further clarify the controlling factors in determining bacterial adhesion to soil.

INVERSE AND FORWARD MODELING OF FLUID FLOW AT WASTE ISOLATION PILOT PLANT. by: *Mary Cardenas* (mary_cardenas@hmc.edu), 301 E. 12th Street, Department of Engineering, Harvey Mudd College, Claremont, CA 91711.

Inverse Modeling

The numerical modeling tool ITOUGH2 was examined to determine its effectiveness in parameter estimation for the small scale seals performance tests (SSSPT) at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. Gas flow injection tests were performed at various distances inward from the wall of Room D to estimate the effects of creeping of the disturbed rock zone (DRZ) since excavation of Room D and boreholes, and to estimate the amount of healing of the DRZ that has taken place due to an emplaced concrete seal. Salt creeping into an excavation is expected to show increased porosity and absolute permeability values compared to undisturbed halite. Healed halite is expected to show porosity and absolute permeability values comparable to that of undisturbed halite. Single-phase flow estimates of absolute permeability were made using ITOUGH2. Estimates of DRZ absolute permeability ranged from 10^{-11} near Room D to 10^{-21} m² at the seal.

Forward Modeling

The numerical code TOUGH28W was modified to calculate porosity and permeability changes due to salt consolidation. The porosity change was modeled as a function of pore pressure and depth in the salt. The permeability was coupled to the porosity using log-linear models. The WIPP lower shaft seals and surrounding formation were modeled. Crushed salt is one of the key components of the sealing system, and to gain understanding of the consolidation of the crushed salt after seal emplacement, TOUGH28W simulations were performed. The results showed the salt consolidation is greatly affected by the pore pressure. After 100 years of simulation, the porosity of the crushed salt for the log-linear model has decreased from an initial value of 0.1 to a value of 0.035 at the bottom of the crushed salt column, and the minimum permeability in the crushed salt column after 100 years of consolidation is 10^{-22} m².

Turning the concept of Sustainability into a reality requires a deep understanding of what it really means to be Sustainable, as well as some adjustments in various cultural thoughts and practices. Namely, there is a need for a review of the way in which the concept of "waste" is understood. Furthermore, this review also needs to encompass common understanding of basic ecology, with special emphasis on how the concept of waste plays into the picture. The crux of this abstract proposes that the current perspective on waste not only hinders the attainment of Sustainability, but it actually is a core component of the current societal state of Unsustainability.

This can be more easily viewed by drawing a simple control boundary around an average person, dwelling, community, or even the entire population, with a mass balance applied across it to help illustrate the issue. All four pictures are generally the same in outlining major concepts, but the directness and simplicity of the picture of an average person lends itself to further explanation. Neglecting gases, the inputs are various combinations of food, water, and chemicals. The outputs are simply in the form of urine and feces. The inputs are highly energy and material intensive/dependent in their production, which mainly relies on finite resources. The outputs are misunderstood commodities, termed "waste", and in being treated as wastes, disposal also becomes a highly energy and material dependent process. A major imbalance exists across this control boundary, fitting into the greater picture of the ecosystem, with "take" but no "give". Likewise, the other control boundaries mentioned above, also outline fundamentally similar imbalances. The function of a Sustainable Environment relies on these inputs/outputs to be somehow balanced, producing and consuming equally with respect to the pool of life.

The most basic understanding of ecology or natural systems reveals that there is no parallel to this concept of waste in nature. EVERYTHING becomes a source of energy for other forms of life. Life has depended on this continual flow of energy from the beginning and the fact that humans hold this definition and idea of waste reveals that we have a major misunderstanding as to the way things work. In this misunderstanding, fundamental cycles of nature are disrupted or broken, resulting in the starvation of all of the components of the ecosystem that depend on these "wastes" to function. Further more, a slightly deeper understanding of the interconnectedness of all the components of the ecosystem, shows how an ecosystem depends on the consumption's and productions of each individual system within it. An individual system can't sustain itself by consuming its own outputs, but *some* system depends on those outputs for its own inputs. The entire ecosystem can be seen in this light, where success depends on the ability to link all the various systems, with all the various systems, with all of the outputs becoming matching inputs for others.

Therefore, seen in this light, the concept of waste is fundamentally disruptive to the success of ecosystems and to Sustainability. For this reason, a general proposal for research frontiers is into ways of eliminating this concept of waste, rather than designing the systems that support this notion. Rather than designing Solid Waste Management systems that accept MSW for around \$50/ton, thereby supporting a sense of cultural apathy towards the topic, major research thrusts in areas such as composting and nutrient cycling are needed to help increase the visibility and public awareness of the importance of maintaining the cycles of the Earth.

Finally, a specific area in need of future research is in handling the "outputs" of the human body with various processes such as composting that cycle the nutrients back into the ecosystem. The compost process produces heat, methane, and humus, all of which can be collected for various forms of energy generation. The humus could replenish deteriorating topsoil quality and begin to replace the use of synthetic fertilizers, which have significant footprints in both their production and application. By avoiding the flush toilet, average domestic water usage could be cut in half and many difficulties surrounding wastewater treatment could be avoided. There is a need for research that will help humans see "waste" as commodity. Starting with human bodily wastes and directly seeing personal nutrient cycling may prove most beneficial.

INFLUENCE OF PARTICLE SURFACE CHEMISTRY ON THE IN-SITU IMMOBILIZATION OF PHENOL BY HORSERADISH PEROXIDASE. *by: Jason C.-M. Cheng, Harold W. Walker (walker.455@osu.edu), Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210.*

Phenolic compounds are waste products of a number of industrial processes, such as coal-conversion, pulp and paper manufacturing, and petroleum refining, and are common environmental contaminants. A promising new approach for remediating phenol-contaminated groundwater involves using horseradish peroxidase (HRP), and other plant oxidoreductases, for the precipitation and immobilization of phenolic compounds in-situ. Little is known, however, about the primary factors controlling the immobilization and retention of phenolic precipitates in groundwater systems. In this study, we examine how the surface chemical properties of soil influence the removal of phenol by HRP.

In initial experiments, the removal of phenol was examined in the presence of kaolin clay particles. These experiments were carried out at near-neutral pH and at varying ionic strength. At low ionic strength (0.0003 M), the efficiency of phenol removal was approximately 45%, which was similar to the removal efficiency obtained using HRP in the absence of clay. Increasing the ionic strength resulted in a marked improvement in phenol removal, with a maximum removal of 70% observed at a salt concentration of 0.1 M NaCl. The increase in ionic strength may facilitate immobilization of phenolic oxidation products by influencing hydrophobic and/or electrostatic interactions with the particle surface.

Phenol removal experiments were also carried out with kaolin clay particles containing an adsorbed layer of natural organic matter. A well-characterized humic acid was used as a model organic compound for these experiments. When humic acid was adsorbed to the surface of kaolin clay particles, phenol removal efficiency ranged from 45 to 80%, depending on humic acid surface coverage.

Surface layers of humic acid appeared to facilitate immobilization of phenolic oxidation products on the kaolin surface. Adsorption of humic acid may provide sites for covalent coupling of oxidation products, or increase the hydrophobic properties of the clay particles thus enhancing adsorption of phenolic precipitates.

It should be noted, however, that adsorbed humic acid was less effective in enhancing phenol removal than solution-phase humic substances. Without clay, addition of 10mg/L humic acid resulted in greater than 95% removal of phenol by HRP. It appears that attachment of humic acid to the surface of kaolin significantly reduces the potential for hydrogen bonding and/or covalent coupling of phenolic oxidation products. These results suggest that in natural systems phenolic oxidation products may preferentially bind to the dissolved fraction of humic acid, and this may hinder the immobilization process.

A SENIOR CAPSTONE PROJECT: TEACHING ENVIRONMENTAL ENGINEERING THE DESIGN PROCESS ON A REAL WORLD PROJECT, by: *Captain Douglas Clark (BD0584@exmail.usma.edu)*, US Air Force Department of Geography and Environmental Engineering, United States Military Academy, West Point, NY 10996.

Following a devastating indoor fire in 1996 that destroyed an entire facility, the United States Military Academy, through an alumni- and donor-funded project, is engaged in rebuilding the indoor rifle and pistol range. When complete, it will be the largest and finest indoor shooting facility in the country. One-quarter of the cost of the new facility is the equipment and installation cost of the heating, ventilation, and filtration (HV) system. Because exposure to airborne lead inside the range is a significant concern, and because EPA regulations prohibit the venting of untreated air to the outside environment, the design of this equipment is not a trivial matter. Another one-quarter of the cost of the project is the construction costs of necessary modification of the indoor facility stemming from the need to maintain laminar and unidirectional air flow within the actual shooting ranges, and from related features such as airlock doors and windows to enable viewing from "clean" areas outside the range.

Prior to the actual contracting of the facility design, senior cadet Jamie Turner (USMA '98, Environmental Science) undertook an ambitious independent-study project to provide the Post Engineer at the US Military Academy with a concept design and set of recommendations, which the Post Engineer could then use as a basis for balancing the basic requirements of the project against the recommended design later delivered by the contractor.

While developing his design, Cadet Turner was forced to bring together elements from his Environmental Science major and his five-course Civil Engineering track. In addition, he was forced to learn much about turbulent flow, a concept outside of his program of study. Furthermore, he conducted much of his research through industry, and not in the library. He defended to an audience composed of the Environmental Engineering faculty and the Post Engineer's staff. His recommendations were presented to the contractor. The project, now at the 35% design stage, retains many of his suggestions, which are presented here.

MOLECULAR ECOLOGY STUDIES OF METHANOTROPHS IN A FRESHWATER LAKE SEDIMENT. by: A.M. Costello (costello@syr.edu) and M.E. Lidstrom (lidstrom@u.washington.edu), Syracuse University, Department of Civil and Environmental Engineering, Syracuse, NY 13244 and University of Washington, Departments of Chemical Engineering and Microbiology, Seattle, WA 98195.

Major advances have been made recently in the application of molecular biological techniques to environmental settings. The methane oxidizing bacteria, methanotrophs, are ubiquitous in nature and grow on methane as their sole source of carbon and energy. They have important roles in both the global carbon cycle and the degradation of hazardous compounds. Methanotrophs are capable of degrading a number of halogenated compounds including the common groundwater contaminant, trichloroethylene (TCE). In spite of their environmental importance, genetic tools for the methanotrophs have not been widely developed or applied for studying natural populations of these organisms in situ.

In this study, genes for the particulate methane monooxygenase (pMMO) and the 16S ribosomal RNA (16S rRNA) were cloned from pure cultures of methanotrophs. Using these data and others, robust molecular tools were developed for use in the methanotrophs. These include PCR primers and oligonucleotide probes designed for both the 16S rRNA and *pmoA* genes. The molecular tools were utilized to examine the diversity of methanotrophs in the sediments of Lake Washington, a freshwater lake habitat. The data obtained suggest that the methanotrophs detectable using the newly developed genetic tools demonstrate a diversity as broad as the known methanotrophs from all mesophilic environments. These results are in contrast to other environments, such as peat and marine environments, that appear to be dominated by a limited diversity of methanotrophs.

THE ROLE OF FILAMENTS IN ACTIVATED SLUDGE FOAMING: INSIGHTS FROM OLIGONUCLEOTIDE PROBE HYBRIDIZATION STUDIES. by F. de los Reyes III (delosrey@uiuc.edu) and L. Raskin (lraskin@uiuc.edu), Department of Civil & Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801.

Filamentous foaming in activated sludge systems has long been associated with thick masses of microbial filaments. In particular, the mycolic acid-containing actinomycete *Gordonia amarae* (formerly *Nocardia amarae*)^{2 and 3} and the actinomycete "*Microthrix parvicella*"⁴ have been implicated as the causative agents in foam formation. It has been proposed that filaments cause foaming because of (1) cell wall hydrophobicity, (2) biosurfactant production, and (3) particle bridging preventing liquid drainage and film thinning^{5 and 6}.

While these mechanisms for foam formation are widely accepted, the seemingly random occurrence (and disappearance) of foam in activated sludge plants is not completely understood. Anecdotal reports from treatment plant operators show contradicting operational causes of foaming (i.e. high or low MCRT (mean cell residence time)). Compounding the confusion is the reliance on traditional microscopic techniques for identification and quantification of filaments in activated sludge. The similar morphologies and staining characteristics of the mycolata, for example, have led to the oversimplification of the diversity of filaments in foam (all foams are considered "*Nocardia*" foams). The possibility that there are other causative organisms (with significantly different physiological requirements) can explain the contradictions in operational causes reported in surveys (i.e., low vs. high MCRT, low vs. high temperature).

Recently, we proposed a conceptual framework for analyzing filamentous foaming⁷. In this framework, the ecology of foam-causing filaments in activated sludge and the relation of foaming occurrence to filament levels were explored. The ecology of the mycolata was explained on the basis of "life strategies," and we proposed that the mycolata use K and L strategies to survive in activated sludge. In examining the relation of filament levels to foaming, the concept of triggers was introduced and used to hypothesize possible foam initiation scenarios. To address these hypotheses, we developed group-, genus-, and species-specific small subunit (SSU) rRNA-targeted oligonucleotide probes for the mycolata *Gordonia*, and *Gordonia amarae*, respectively⁸. We also characterized probes specific for "*Microthrix parvicella*". We used membrane hybridization to quantify relative rRNA levels in environmental samples and developed a quantitative fluorescence in situ hybridization method for estimating *Gordonia* mass⁹.

The two methods were used to follow shifts in population of *Gordonia* and "*Microthrix parvicella*" before, during, and after a seasonal foaming incident in a full-scale plant¹⁰. The results show that the rRNA and volatile suspended solids (VSS) percentages of *Gordonia* (but not *Microthrix parvicella*) increased during foaming, and that these values decreased as the foam disappeared. Differences in rRNA and VSS levels were further investigated using genus-specific immunofluorescence probes and live/dead stains. The results show that a significant fraction of the filaments in foam was not actively growing. This finding implies that: (1) the trigger, or initiation event for foaming, is the important phenomenon, and (2) methods to control filament growth after foaming has occurred may not be beneficial, as even inactive cells contribute to foaming.

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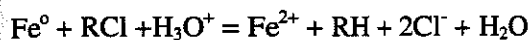
BENEFICIAL REUSE OF WASTEWATER AT PENN STATE & THE STATE COLLEGE AREA. *by: Brian Dempsey (bad5@psu.edu), Department of Civil & Environmental Engineering, Pennsylvania State University, 212 Sackett Building, University Park, PA 16802, and Bill Burgos (bburgos@psu.edu), Department of Civil & Environmental Engineering, Pennsylvania State University, 212 Sackett Building, University Park, PA 16802.*

Penn State is located in the ridge and valley province of the Appalachians and the population benefits from high-quality streams and green spaces. Most streams in the area have non-degradation status and are threatened even by temperature increases due to wastewater discharges. The valleys are underlain by karst structures, making groundwater resources vulnerable to contamination from surface sources. Increasing population and associated development are increasingly affecting the eco-system. Planning agencies have identified wastewater discharge as the limit to responsible growth in this area.

The State College area has proposed a "beneficial reuse" of treated wastewater, which involves treatment beyond the tertiary quality currently achieved and recycling to the aquifer up-gradient from regional potable water supplies. Base-flows in some area streams should be restored to pre-development levels and summer stream temperature will be decreased. Meanwhile Penn State University already spray-irrigates 100% of its wastewater effluent, and has recently improved cropping and management systems to avoid impacts on groundwater reservoirs. Penn State is investigating new reuse options that are compatible with 21st century needs. In addition, a variety of local organizations are involved in developing sustainable use of the University area's resources. The history, current status, and plans for these regional activities will be described in this talk.

REDUCTIVE DECHLORINATION OF TRICHLOROETHYLENE BY METALLIC IRON: EFFECTS OF IRON CORROSION AND CORROSION INHIBITION. by: B. Deng (bdeng@nmt.edu) and S. Hu
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Metallic iron-based reductive dechlorination of aliphatic chlorinated compounds has been used in permeable reactive barriers for contaminated site remediation. In order to predict the performance of the technology under widely varied groundwater conditions and optimize design parameters, we must understand the kinetics and mechanism of the dechlorination and related reactions. It is known that the dechlorination reaction begins by the adsorption of reactants such as trichloroethylene (TCE), followed by electron transfer. The dechlorination reaction stoichiometry can be described by:



which indicates that the dechlorination results in iron oxidation, or corrosion. Metallic iron may also corrode through reactions with water and oxygen dissolved in water. The interaction among the various parallel reactions is unclear. In addition, there is insufficient information on the effect of ambient groundwater constituents on the iron corrosion and dechlorination reaction.

The objective of this study is to explore whether naturally occurring groundwater constituents and other chemicals compete for TCE adsorption sites, thus affect iron corrosion and TCE degradation. Sorption and reduction of TCE on zero-valent iron were examined using batch experiments in the presence and absence of natural organic matters (NOM), cysteine, and potassium sulfate. TCE exhibited nonlinear sorption behavior and could be fitted by a Langmuir adsorption isotherm. Competition for sorption sites was observed between TCE and NOM. NOM sorption also inhibits iron corrosion as being characterized by measuring hydrogen (H_2) production. Cysteine, an amino acid containing a -SH functional group, did not significantly affect TCE adsorption at concentrations lower than 1 mM. The rates of TCE degradation and iron corrosion, however, were dramatically decreased in the presence of 0.5 mM cysteine. This suggested that there were at least two types of surface sites on the iron: the reactive sites responsible for TCE reduction and the non-reactive sites for the bulk of TCE adsorption. The reactive sites only accounted for a small fraction of the total surface sites. A two-site model was proposed to explain experimental results, in which adsorption took place on both reactive and non-reactive sites, but dechlorination reaction occurred only on reactive sites. It was observed that the rate of TCE reduction was directly proportional to the rate of iron corrosion. This suggests that the same kind of surface sites be responsible for both TCE dechlorination and iron corrosion.

THE INFLUENCE OF MEMBRANE TREATMENT ON BACTERIAL REGROWTH POTENTIAL IN DRINKING WATER. by: I. Escobar (isabelcpe@aol.com) and A. Randall (randall@mail.ucf.edu), 4000 Central Florida Blvd. ENGR 207, Department of Civil and Environmental Engineering, University of Central Florida, Orlando, FL 32816-2450.

Goal

The impacts of membrane treatment on Assimilable Organic Carbon or Biodegradable Dissolved Organic Carbon levels in drinking water pipe networks in full-scale distribution systems has had little investigation. The main objective of this project was to collect and analyze full-scale distribution system data to quantify its response to the introduction of membrane treatment, which affects the AOC and BDOC of the drinking water, with respect to its impact on bacterial regrowth potential in the systems.

Rationale

Organic matter impacts the water quality of distribution systems by generating color, undesired taste, and odors. When a chlorine residual is provided for disinfection, organic compounds are responsible for high chlorine demands and the formation of disinfection by-products. Also, the biodegradable organic matter that is not removed during drinking water treatment can lead to the proliferation of bacteria along the distribution system, which deteriorates the water quality, accelerates corrosion rates of pipes, and can potentially increase the incident of bacteriological diseases. A treatment process that can remove the majority of pathogens, water pollutants, and organic carbon is membrane filtration. Some types of membranes, such as reverse osmosis membranes, may remove a large portion of the organic material present in the water. This presumably translates into a corresponding reduction in both disinfection by-product formation potential and bacterial regrowth potential. However, little is known about the effect of membrane treatment processes with respect to changes in Assimilable Organic Carbon (AOC) or Biodegradable Dissolved Organic Carbon (BDOC) concentrations for finished water. Since these are the parameters normally used to quantify regrowth potential, the actual effect of membrane systems on regrowth potential needs further evaluation to generate a quantitative assessment.

Approach

Two water treatment plants operated by Palm Beach County Water Utilities Department, WTP #3 and #9, treat the same raw water source via membrane filtration (nanofiltration) in parallel with lime softening and lime softening alone, respectively. These two plants were monitored monthly for one year to compare the effects of nanofiltration on distribution water biostability, as measured by AOC and BDOC. Samples taken from the distribution systems were analyzed for AOC using *Pseudomonas fluorescens* P17 and *Spirillum* NOX (LeChevallier et al. 1993), BDOC (Joret et al. 1991), UV absorbance at 254 nm, temperature, residual disinfectant, heterotrophic plate counts, and coliform counts.

Status

The results of these experiments were that nanofiltration produced a considerable gain in potable water quality by decreasing bacterial counts and concentrations of organic matter, resulting in more efficient post-disinfection, maintenance of chlorine residuals, and decreasing the THM formation potential. However, the study also determined that nanofiltration membranes might let through a low but significant concentration of biodegradable organic matter that is easily assimilable by bacteria; i.e., AOC.

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SENIOR ENVIRONMENTAL DESIGN AND MOTIVATIONAL COMPETITION AT FLORIDA INTERNATIONAL UNIVERSITY. *by: H. Fuentes (fuentes@eng.fiu.edu), G. DiCarlo, C. Hernandez and R.S. Rodriguez, Department of Civil & Environmental Engineering, Florida International University, University Park, EAS-3680, Miami, FL 33199.*

Senior undergraduate design has expanded into a different perspective at Florida International University (FIU) over the last years. An annual competition with other universities has enhanced student motivation and performance in a required senior design course. The competition, which began in 1995, is sponsored by the Florida Water Environment Association (FWEA), the member association of the Water Environment Federation (WEF) in Florida. The event takes place within the framework of the annual Florida Water Resources Conference (FWRC).

FWEA selects a facility that copes with an engineering problem. The facility, private or governmental, is located in Florida. The engineering problem becomes the official design theme for all eligible and participating universities. University teams work during the spring academic term to produce their best solution to the problem. They then meet at the annual FWRC wherein they present their results. The results are judged based on engineering and professional criteria. Main drivers of criteria are content, organization, deliver and effectiveness.

Design themes have addressed the following areas: a) rehabilitation of sanitary sewer collection systems; b) reuse of effluent from municipal secondary wastewater treatment plants; c) tertiary treatment of wastewater treated effluent for reuse in energy recovery boilers; and d) sludge treatment, reuse and disposal. Teams present their results in the form of a written technical report, a poster and an oral presentation.

FIU has been a participant since the beginning in 1995. It obtained second place in 1997 and won first place two years in a row, 1998 and 1999. Prizes have included a traveling trophy and scholarship, among others. The experience has proven to be highly satisfactory and rewarding to all parties involved in the event: the sponsor, the facility, the university and, above all, the students. This poster presents two of the FIU design solutions.

SPECIATION OF ZN IN CONTAMINATED SEDIMENTS: MICROSCOPIC AND SPECTROSCOPIC INVESTIGATIONS. by: *Jean-François Gaillard* (jf-gaillard@nwu.edu), Department of Civil Engineering, Northwestern University, Evanston, 2145 Sheridan Road, IL 6028-3109; *Samuel M. Webb*, Department of Civil Engineering, Northwestern University, Evanston, 2145 Sheridan Road, IL 6028-3109; *Gary G. Leppard*, National Water Research Institute, Burlington, Ontario, Canada, L7R 4A6.

We have investigated the chemical speciation of zinc in the sediments of Lake DePue (IL) by transmission electron microscopy (TEM) and x-ray absorption spectroscopy (XAS). The primary goal of this study was to combine a nano-scale characterization of zinc bearing particles with a spectroscopic analysis to determine the various proportions of the different ligation environments of zinc. Ultimately, this information will enable us to understand better the fate of Zn in a contaminated system, and in particular, probe the changes in metal speciation as a result of microbial processes.

The observation of TEM micrographs, together with elemental analysis of environmental particles by energy dispersive spectrometry (EDS), revealed that Zn was present in a variety of structures of either biological or inorganic origin, and primarily associated with Fe, P, and S. The analysis of the XAS data showed that, near the source of contamination, zinc is primarily ligated by water, phosphate, sulfide and carbonate. Away from the contaminated area, Zn is predominantly coordinated with sulfide, a rather inert solid phase. In the contaminated area, the relative proportions of the various coordination environments of Zn vary with depth in the sediments. This suggests that microbial reactions, that control most of the diagenetic processes responsible of chemical change, are still effected under metal stressed conditions.

THE USE OF ULTRAVIOLET GERMICIDAL IRRADIATION (UVGI) IN DISINFECTION OF AIRBORNE BACTERIA. by: C.F. Green (greenf@email.uc.edu) and P.V. Scarpino (pscarpin@uceng.uc.edu), Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH 45221-0071.

Contamination of indoor air by microbial pollutants has been increasingly recognized, as a public health problem, and may be responsible for building-related illness and sick building syndrome. Bioaerosols such as fungi, bacteria and viruses in indoor air can cause allergic and irritant responses, infectious diseases, respiratory problems, and hypersensitivity reactions. Indoor exposure to air contaminants is an important area of concern especially when one considers that an average person spends 80% to 90% of his/her time indoors whether he/she is at home or at work. People sensitive to indoor environmental problems complain of a wide variety of symptoms ranging from headache, fatigue, nausea, sinus congestion, to eye, nose and throat irritations.

Although UVGI has been used for air disinfection for many years to minimize microbial numbers in the air, little quantitative data is available on the radiation susceptibilities of individual airborne microbes. There have been a number of UVGI studies documenting the effectiveness of UVGI for the control of microbes in controlled settings (Wells and Wells, 1936; Sharp, 1940; Wells, 1942, 1955; Riley and O'Grady, 1961; Riley et al., 1962; Riley, Knight, and Middlebrook, 1976; Macher et al., 1992, Macher, 1993). Many of these studies documented the effectiveness of UVGI against airborne tuberculosis organism.

There are three ways that UVGI can be used in indoor air disinfection: duct irradiation of the air being removed from a room; upper-room air irradiation using shielded lamps in upper room areas; and self-contained fan-powered air cleaning fixtures placed in a room at usually the ceiling level. The studies described here used the latter commercial type fan-powered fixtures to evaluate the individual effectiveness of UVGI.

In this work aerosolization tests were done in the contained environment of negative pressure bioaerosol stainless steel testing chambers 0.75 m square X about 3.7 m. long described by Jensen et al. (1992). The chambers were designed so that microbes could be safely aerosolized and contained while traversing the chamber. Four commercial (Pur Air UV Germicidal Systems) fan-powered ultraviolet germicidal irradiation (UVGI)-containing fixtures were evaluated for their ability to disinfect bioaerosols of airborne microbes. The UVGI units were placed separately inside the bioaerosol chamber for test purposes, and bacterial and viral aerosols were generated separately into the chamber using a Collision nebulizer.

Air samples were taken upstream and downstream of the UVGI-containing units using Ace Glass all-glass impingers (AGI-30) and Andersen six-stage microbial air samples. Four bacterial species were individually aerosolized to evaluate their kill. The bacteria used to test all of the UVGI-containing units were Escherichia coli, Micrococcus luteus, Pseudomonas fluorescens, and Staphylococcus aureus. Based upon the concentration of bioaerosols collected at the inlet and outlet of the fixtures tested, the total overall microbial kills for the four fixtures with the filters in place and the UVGI lamps on were: more than 99% for the airborne bacteria.

All of the fixtures tested were efficient in inactivation/kill of the test vegetative bacteria used, and even the more UVGI-resistant M. luteus cells. Units such as these may provide an economical way to supplement existing air dilution rates in indoor environments, and to kill/inactivate airborne bacteria effectively without human exposure to UV light.

ESTIMATING THE COST OF A REVISED ARSENIC DRINKING WATER STANDARD. *by: Patrick Gurian (gurian@andrew.cmu.edu), John Lockwood, Dominic Boccelli, Mark Schervish, and Mitchell Small (ms35@andrew.cmu.edu)* Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh PA 15213.

A statistical system simulation approach for estimating compliance behavior at U.S. Community Water Suppliers is applied to the case of a more stringent drinking water standard for arsenic. Source water arsenic occurrence is simulated using a statistical model fit to a recent national survey of water utilities, applied with the observed national distribution of model explanatory variables (location, size, and type of source-water). Treatments in place and removal efficiencies are also simulated. Utilities with finished water arsenic concentrations above the MCL are assumed to select the least-cost option compatible with the treatment in place from among 24 available compliance strategies and treatment processes for meeting the standard. Estimated costs and arsenic exposure reductions at individual suppliers are aggregated to estimate national compliance costs and exposure reduction benefits. There is considerable uncertainty in the cost estimates produced by the model. Uncertainty in the raw water arsenic occurrence and treatment technology costs were found to contribute significantly to overall uncertainty, while uncertainty in treatment technology removal efficiencies contributed only modestly. The methodology presented here may provide an alternative to EPA's current practice of estimating compliance behavior with more highly aggregated size categories and the use of expert judgement for determining treatment adoption strategies for utilities.

SUSTAINABLE AND SAFE SUPPLY OF POTABLE WATER FROM WELLS IN WEST BEGAL, INDIA AND BANGLADESH COMPLETED IN ARSENIC-BEARING AQUIFERS. *by: Janet G. Hering* (jhering@cco.caltech.edu), Environmental Engineering Science, California Institute of Technology, 1200 E. California Blvd. (138-78), Pasadena, CA 91125.

Beginning in the 1960's, major efforts were initiated to develop groundwater resources in West Bengal, India and Bangladesh for irrigation and drinking water supply. In an unfortunate and unforeseen consequence of this groundwater development, millions of people have been supplied with arsenic-contaminated drinking water. West Bengal has an approximate area of 34,000 km² and population of 30 million people. The arsenic affected areas constitute about 20% of the West Bengal. It has been estimated that over a million people consume drinking water with arsenic concentrations above 50 µg/L; over 200,000 people exhibit symptoms of chronic arsenic exposure. In Bangladesh, over 16 million people live in regions where elevated arsenic occurs in the groundwater. In a preliminary survey, over 50% of the 1630 individuals examined exhibited arsenical skin lesions.

Arsenic concentrations in the groundwater in West Bengal and Bangladesh vary widely with the highest values in the mg/L range. Of the more than 20,000 samples analyzed from tubewells in West Bengal, over 8700 contained arsenic at concentrations between 50 µg/L and 3.7 mg/L with an average of 220 µg/L. Groundwaters in Bangladesh have not been as extensively sampled but surveys of almost 3,000 samples indicate similar patterns of arsenic distribution.

The arsenic-contaminated wells in West Bengal and Bangladesh draw groundwater from the alluvial aquifers of the Ganges Delta. This area is roughly bounded by the Ganges in India and the Padma in Bangladesh. The area is underlain by sediments of the Younger Deltaic Deposit. Two theories have been proposed for the proximate source of arsenic in groundwater. In West Bengal, analysis of borehole sediments has suggested that arsenic-rich source materials may occur in thin layers; particles of arsenic-rich pyrite (between 100 and 2,000 ppm arsenic) have been isolated from the sediments. In Bangladesh, sediment analysis has indicated disseminated arsenic associated with iron oxyhydroxides. Some correlations were observed between arsenic, iron, and carbonate concentrations in groundwater; the sediments contain elevated levels of organic carbon and it has been suggested that reduction of iron oxyhydroxides and release of arsenic are coupled with organic carbon oxidation. It is not necessarily the case, however, that the same source materials and release mechanism govern the occurrence of arsenic in groundwater over the entire region. Little information has been reported on the detailed chemical composition or redox potential of the groundwater. Arsenite (As^{III}) and arsenate (As^V) have been found to co-exist in groundwater samples. On average, 50% of the total arsenic is in the +III oxidation state.

Many treatment technologies are capable of removing arsenic from potable water. For application in West Bengal and Bangladesh, however, the choice of treatment technologies is greatly complicated by both economic and technical factors. As a short-term intervention, use of economical household devices should be expedited. However, the long-term effectiveness of household devices in actual practice is often unreliable. A major concern in developing a long-term strategy is the difficulty in maintaining the integrity (i.e., with respect to pathogenic organisms) of stored water; it is preferable, in this setting, to avoid above-ground water storage. This could be accomplished either with an on-demand system (that is, a system in which water is treated only as needed) or with an *in situ* system in which the treatment is accomplished without withdrawing the water from the subsurface. Ideally, the system would require minimal maintenance and monitoring, would be effective over an extended period and under the range of anticipated environmental conditions, and would be able to be regenerated or renewed after exhaustion. It should be stressed that, for a problem as widespread as this, there is not likely to be a single best remedy. Rather multiple strategies for water treatment and use of alternative water sources should be evaluated with an emphasis on rapid intervention. Phased implementation of alternative strategies should be accommodated as the understanding of the problem and its possible solutions improves.

SURFACTANT SOLUBILIZATION OF POLYCYCLIC AROMATIC HYDROCARBONS FROM MULTI-COMPONENT NAPLS. by: Alex Hill (ahill@civil.lan.mcgill.ca) and Subhasis Ghoshal (ghoshal@civil.lan.mcgill.ca), Department of Civil Engineering and Applied Mechanics, McGill University, 817 Sherbrooke St. West, Montreal, Quebec, Canada, H3A 2K6.

Subsurface contamination by non-aqueous phase liquids (NAPLs) such as creosote, petroleum products and coal tar is widespread at sites where prolonged industrial activities related to these products have occurred. These NAPLs often contain various polycyclic aromatic hydrocarbons (PAHs) which are of significant interest due to their potential as carcinogens and because they have negative impacts on soil biota. As PAHs are relatively water insoluble it is difficult to remove significant masses of them from NAPLs by aqueous dissolution.

When present in aqueous concentrations exceeding the critical micelle concentration (CMC) surfactant molecules form aggregates called micelles, the inner core of which is a hydrophobic environment into which hydrophobic organic hydrocarbons partition. By partitioning significant quantities of PAHs from sorbed phases or NAPLs into micelles, PAHs may be efficiently extracted from contaminated sites and thus it is believed that surfactant flushing could significantly speed the remediation process at NAPL contaminated sites.

Research to date has investigated surfactant aided dissolution of solid PAHs in single component systems. However, the rates and extents of PAH partitioning from multi-component NAPLs is not well understood and thus it is difficult to determine the feasibility of using surfactants for remediation of contaminated sites. This research aims to improve the understanding of the role of surfactants in increasing the rate of PAH dissolution from multi-component NAPLs. In order to investigate the dissolution process, multi-component NAPLs have been synthesized using hexadecane as the bulk compound and naphthalene as a component ranging in mole fraction from 1-17%. These NAPLs were contacted with aqueous solutions containing one of the following non-ionic surfactants: Brij 30, Brij 35, Tergitol NP-10, Triton X-100 or Tween 80. Equilibrium partitioning was achieved in a partially mixed batch reactor, in which the NAPL and aqueous phases remained distinct, in order to study the relative partitioning between the NAPL phase, the aqueous bulk phase and the aqueous micellar pseudo-phase.

It is our hypothesis that PAH equilibrium partitioning between the three phases should follow a Henry's law type relationship which states that the concentrations of a given compound in the aqueous and micellar pseudo-phases should be a function of the compound's activity in the NAPL phase. From this it follows that a given surfactant's molar solubilization ratio (MSR), should also be a function of the PAH activity in the NAPL phase (MSR is defined as the number of moles of a given PAH that partition into the micellar pseudo-phase per mole of surfactant added to the system, above the CMC). Experiments with naphthalene show that its activity coefficient in the NAPL phase does not change as a function of its mole fraction within the range of interest. It has been observed that just as naphthalene's aqueous solubility increases linearly with increasing NAPL phase mole fractions, so do the MSRs of five non-ionic surfactants studied when contacted with NAPLs containing naphthalene. This suggests that both the activity coefficient of naphthalene within the NAPL and the activity coefficient of naphthalene within the micellar pseudo-phase remain constant over the range of mole fractions studied. Further investigation shows that the maximum MSR for each surfactant occurs when aqueous surfactant solutions are contacted with naphthalene-saturated NAPLs. This maximum MSR is equal to the MSR observed when aqueous surfactant solutions are contacted with pure naphthalene crystals. This result is analogous to the case in which the equilibrium aqueous concentration of a given NAPL component is equal to that of the pure compound when the NAPL is saturated with that particular compound. These results pertaining to the relationship between MSR and NAPL mole fractions are essential for predicting the relative rates of PAH dissolution from a multi-component NAPL into surfactant-water solutions.

MULTI-METHOD INVESTIGATION OF 1-NAPHTHOL SORPTION BY DISSOLVED HUMIC ACID.
by: K.G. Karthikeyan (gkk101@psu.edu) and Jon Chorover (jdc7@psu.edu), Soil Science Program, 116 ASI Building, The Pennsylvania State University, University Park, PA 16802; Patrick G. Hatcher, Department of Chemistry, Ohio State University, Columbus, OH; Railynn Saunders, Department of Chemistry, The Pennsylvania State University, University Park, PA.

Interaction with humic substances (HS) can control the environmental fate and transformation of polycyclic aromatic compounds (PACs). Non-polar PACs have received considerable attention from researchers interested in studying PAC-HS interactions. However, several polar and ionizable PACs [i.e., 1-naphthol] are formed as intermediates during the degradation of non-polar PACs [i.e., naphthalene]. While evaluating the ultimate fate of contaminants it is, therefore, necessary to consider interactions between polar PACs and HS. Mechanisms of interaction between HS and PACs are affected by the polarity and functional group chemistry of both the PAC and HS. In the case of 1-naphthol, its sorptive interactions with HS are poorly understood. Changes in solution chemistry will affect humic charge and conformation and, hence, reactivity towards the PACs. Therefore, the major objective of this research includes determining the effects of solution chemistry (pH [4-11], ionic strength [I ; 0.001 and 0.1 M LiCl], dissolved O_2 [DO; 0 and $\approx 8 \text{ mg L}^{-1}$] concentration) and reaction time [1-15 d] on the interaction of 1-naphthol with dissolved HS using a variety of complementary techniques including equilibrium dialysis, and fluorescence and ^{13}C NMR spectroscopies.

The extent of ^{14}C -1-naphthol binding to HS as measured by dialysis (batch) experiments revealed a pH-dependent trend with minimal sorption below pH 7.0, a sharp increase over a narrow pH range, and maximum sorption around pH 9.0. Effects of ionic strength were observed only between pH 8 and 9.5 where a hundred-fold increase in Li^+ concentration doubled the amount of 1-naphthol sorbed. Fluorescence spectroscopy provides complementary *in situ* information on the fraction of 1-naphthol bound to HS; the ratio of 1-naphthol fluorescence in the absence and presence of the quencher (HS) provides a means to calculate the sorbed fraction from the Stern-Volmer equation. There is good agreement in the amount of PAC sorbed to HS as estimated from dialysis and fluorescence quenching (FQ) methods. A significant increase in the sorption of 1-naphthol with increasing equilibration time [from 1 to 15 d] was observed. Since a reaction time of 1 to 3 d is sufficient for direct complexation, lack of sorption after this contact period indicates poor affinity of 1-naphthol to HS. Enhanced sorption with increasing equilibration time could be due to transformation of 1-naphthol [slow] coupled with strong sorption of a secondary product. The relative instability of 1-naphthol under alkaline pH conditions was evident by the decrease in measured fluorescence intensity values in the absence of HS (F_0) with increasing reaction time. Oxidation of 1-naphthol mediated either by DO [HO_2^- and O_2^{2-} , peroxide ions, are the operative oxidizing species in aerated water] and/or HS [electron poor moieties such as quinones] produces (hydroxy) naphthoquinones which could be involved in dimerization (ultimately polymerization) reactions with 1-naphthol. Exclusion of DO from the reaction vessel [by $\text{N}_2(\text{g})$ purging] resulted in a moderate, but incomplete, decrease in the amount of bound 1-naphthol which underlines the ability of quinone ($\text{C}=\text{O}$) functional groups in HS to participate in electron-transfer reactions. Using F_0 measurements, it was also found that the stability of 1-naphthol decreased with increasing I which could help explain the higher sorption (measured by dialysis) at the higher I . Since it is difficult to achieve complete phase separation (i.e., free 1-naphthol vs. dissolved HS bound-1-naphthol) in the above system, use of complementary analytical techniques (i.e., dialysis and FQ) and good agreement between them is necessary to obtain reliable information on the extent of PAC sorption to HS. Spin-lattice relaxation time (T_1) measurements of ^{13}C -labeled 1-naphthol were obtained using liquids NMR for solutions with variable HS. The T_1 values of 1,4- ^{13}C -1-naphthol progressively decreased with increasing HS concentration indicating significant interaction with HS, which is consistent with the dialysis and FQ results.

EFFECT OF CLIMATIC VARIATIONS ON POLLUTANT BIOAVAILABILITY. *by: Arturo A. Keller (keller@bren.ucsb.edu) and P. Holden (holden@bren.ucsb.edu).* Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106.

Research Scope

Natural biological attenuation in the vadose zone may occur for a wide range of pollutants. However, the physical, chemical and biological factors that control natural attenuation are not well understood for many pollutants. Reliance on an inadequately understood remediation strategy such as natural attenuation leaves at risk water resources, as well as human and ecosystem health. Pollutant bioavailability, a composite of mass transfer and biodegradation processes, determines natural biological attenuation. Factors controlling pollutant bioavailability over time must be understood if natural biodegradation is to become predictable and reliable. Of primary importance is the natural variation of environmental factors such as temperature and moisture regimes that have an effect at the pore, core and field scales.

Impact

Research in this area will provide guidelines for environmental engineers and regulators with respect to those conditions where natural attenuation can be expected to succeed and those where it may fail. Since natural attenuation is potentially a cost-effective solution to many contaminated sites, this research can have profound impact on the societal cost of dealing with contamination.

Long-range development of infrastructure

This research requires the development of advanced physical micromodels of the pore space which can be imaged using either conventional microscopy or Environmental Scanning Electron Microscopy (ESEM). Field scale studies require the development of automated multi-functional probes for collecting information on climate variables as well as indicators of microbial activity such as the evolution of gases (i.e. CO_2 , CH_4).

Suggested Research Steps

Studies at the three scales can determine the influence of wetting and drying cycles on residual pollutant mass transfer and biodegradation. Research at the microscale using physical micromodels and ESEM can be used to determine:

- The effect of wetting and drying cycles, coupled with thermal variations, on pollutant spreading and mass transfer to the aqueous, gaseous and sorbed phases;
- Variations in solid surface wetting properties as a function of climatic variability as well as time of contact with organic phases;
- How the presence of bacterial exopolymeric substances affects pollutant mass transfer into the cell's enzymatic system;
- Patterns of microbial activity and growth that occur as a result of wetting and drying cycles and thermal variations.

Research at the core scale can be used to determine the above factors in an integrative manner, using bulk-averaged parameter values, such as average residual pollutant saturation or concentration as a function of wetting and drying cycles; rate of biodegradation as a function of time and climatic cycling; patterns of microbial behavior. The core scale provides a controlled environment to test multiple configurations and provides a link to the field scale studies.

Field scale natural attenuation studies can be used to evaluate the effect of climatic variations on a seasonal and annual scale on the rate of natural biodegradation. To bridge between the various scales, the pore scale is used to develop a mathematical representation of the processes that can then be tested at the core and field scales. Of primary importance is the development of a functional relationship between an index of bioavailability and time-dependent environmental conditions.

Role of Environmental Engineers and Scientists

Expected results of this work will be an interdisciplinary understanding of the mechanisms that determine bioavailability under realistic climatic conditions. The results will be useful to predict the effectiveness of natural biological attenuation and active bioremediation as a function of pollutant properties and moisture regimes. This requires the combined effort of specialists from disciplines such as environmental microbiology, pollutant fate and transport and probe development. In addition, this research area will span several scales, requiring specialists with different skills to address the challenges at each scale.

FIRING RANGE LEAD CONTAMINATION OF A WEST POINT WETLAND AND CREEK - A PROJECT IN UNDERGRADUATE ENVIRONMENTAL SCIENCE EDUCATION. *by: M. Kelley (bm3913@exmail.usma.edu), A. Elliott, A. Shetty, W. Kavanagh, and R. Lonardo, Department of Geography and Environmental Engineering, US Military Academy, West Point, NY 10996.*

At West Point, the Environmental Science curriculum, sponsored by the Department of Geography and Environmental Engineering, presents our cadet students with an opportunity to do a single semester, three credit independent study project under the guidance of one or more faculty advisors and support staff. Cadet Aaron Elliott, and Environmental Science major of the Class of 1999, undertook such a project to evaluate the lead contamination of a wetland and creek area at West Point caused by years of firing range activity from two ranges. Assisting in this project were faculty advisors and supporting staff from the Department of Geography and Environmental Engineering, the Department of Chemistry, and the Installation's Directorate of Housing and Public Works. The catalyst for this project was the environmental chemistry course taken by Cadet Elliott last academic year. In the environmental chemistry course, taught by Captain R. Lonardo, Cadet Elliott and his class did a course project to develop a screening sampling plan for lead at the wetland and creek site. They learned of the environmental significance of this area as the creek serves as a tributary to Class A body of water that is a source water for the drinking water treatment system for our community.

The benefit of this project is that it built upon the student's previous experience in the environmental chemistry course and taught him the research project process. The student was able to build a capstone project, taking what he had learned in his previous courses [including English (communications and writing), statistics, chemistry, physical geography, water resources planning and design, geographic information systems, environmental science and environmental engineering] and apply it to a real-world problem with tangible value to the community. Higher order learning skills such as analysis, research activities, and self-learner attributes are fostered in this kind of work.

The student learned life skills in project management as he developed the scope of work, sampling and analytical plan, coordinated implementation of the sampling and analytical plan, struggled with quality control issues, and developed the "consultants" report which integrated numerous previous efforts at "getting a handle on this issue" conducted over the last decade or more. The greatest lessons learned were gleaned from the difficulty of pulling the project off and synthesizing the newly learned and previously available information.

We will present the results of this undergraduate independent study project along with recommendations for future work at this site. Our aim is to promote undergraduate research as a vehicle for enhancing the undergraduate education of environmental science (and environmental engineering) students. With the assistance of conference attendees we will assess current and anticipated use of independent study projects in undergraduate environmental science (and environmental engineering) education. This conference provides that vehicle.

VISUALIZING UNIT PROCESSES AND NATURAL SYSTEMS IN UNDERGRADUATE ENVIRONMENTAL ENGINEERING EDUCATION. by M. Kelley (bm3913@exmail.usma.edu), R. Getz (br7672@exmail.usma.edu) and M. Butkus (bm8375@exmail.usma.edu), Department of Geography and Environmental Engineering, US Military Academy, West Point, NY 10996.

At West Point all cadets must select and successfully complete a five-course engineering minor of their choice as part of the overall curriculum leading to their Bachelor of Science degree. This includes cadets who major in the various engineering disciplines offered as well as cadets majoring in other non-engineering disciplines (i.e., history) who take a five course engineering sequence beyond the core science and engineering requirements of the academy. Approximately 150 cadets (~17% of the graduating class) each year take the environmental engineering sequence to satisfy this requirement.

We at West Point pride ourselves in the attention we pay to our teaching. We strive to make our classes "come alive" and to excite the cadets to want to actively participate in the learning process. In our introduction to environmental engineering class, a component course of our environmental engineering sequence, we "go the extra mile" to help cadets to visualize the unit processes and the mathematical and natural models they learn about. We think that we can enhance the learning process and thereby make our graduates better problem solvers and more effective leaders of tomorrow by supplementing traditional classroom methods with web-based mathematical video/computer models, 3-d constructed models, and other visualization tools.

Abstract ideas must take shape in reality in order for students to fully visualize natural and engineered systems. We believe that an introductory course in environmental engineering affords the student many opportunities to grow intellectually, especially in the understanding and visualization of these 3-d systems. This poster will identify and present several models that we use or are currently under development to visually present topics in a traditional water-based introduction to environmental engineering course.

With the assistance of conference attendees we will assess current and anticipated use of classroom enhancement tools in undergraduate environmental engineering education. Our goal is to synergize our classroom enhancement activities with other environmental engineering programs. This conference provides that vehicle.

We will present several enhancements in the poster session. We have developed a web-based instructional supplement to enhance understanding of the Streeter-Phelps Dissolved Oxygen Sag Model, which we will introduce at the conference and make available in the public domain on the external web. We have also developed a web-based instructional enhancement tool to depict carbon-adsorption break-through. Using 3-d constructed models we demonstrate the sequence, relative size, loading rates, design parameters and geometry of a conventional drinking water treatment plant employing rapid mixing, flocculation, gravity sedimentation clarification and rapid sand filtration – all important unit processes discussed in our course. We are also developing a model septic system for an individual residence and a detailed conventional rectangular sedimentation tank. Septic tank systems are used by millions of homes and small commercial activities across America. Learning about them presents an opportunity to link discussion of physical, chemical and biological processes. We feel that the scale model sedimentation tank, currently under development, is a particularly effective tool in helping the cadets decipher the various design parameters such as weir loading rate, horizontal velocity, surface overflow rate and see the relative geometry and dimensional analysis in actual 3-d.

MICROBIAL TREATMENT OF PERCHLORATE CONTAMINATED WATER. *by: Kijung Kim (kxk215@psu.edu), and Bruce E. Logan (blogan@psu.edu), 212 Sackett Building, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, 16802.*

Perchlorate (ClO_4^-) salts have been widely used in large quantities by the chemical, aerospace, and defense industries. Its contamination of surface and ground waters may affect the drinking water supplies of over 12 million people in the US. These contaminated waters are of concern to human health, and the action level of 18 $\mu\text{g/L}$ of perchlorate was set by the California Department of Health Services. While perchlorate is chemically stable in the environment, under anoxic conditions it can be degraded by microorganisms using acetate as an electron donor. The feasibility of biological treatment of perchlorate contaminated water to drinking water levels was tested in a series of experiments using fixed-film packed bed reactors. In sand-packed biofilm reactors, perchlorate was reduced to below the detection limit ($<4 \mu\text{g/L}$) at detention times as low as 13 minutes. Acetate was used as an electron donor, and it successfully supported microbial perchlorate reduction. The amount of acetate consumed to remove perchlorate was determined to be 2.9 (± 0.9 ; $n=6$) as a molar ratio of acetate to perchlorate. Similar removals were initially achieved in columns packed with granular activated carbon, but after column backwashing reactor efficiency substantially deteriorated due to perchlorate desorption and loss of biomass. Increasing the concentration of acetate in the feed partially restored reactor performance, however, effluent perchlorate levels fluctuated between 1.1 mg/L and the detection limit due to continued desorption from the carbon and insufficient microbial activity in downstream portions of the column. It was concluded that fixed film reactors are a feasible technology for the treatment of perchlorate contaminated waters as long as a packing material is relatively non-perchlorate-adsorbing.

Introduction

Interpretations of molecular-level analytical data in complex environmental systems is not always straightforward. Molecular modeling techniques can be useful in helping bridge the gap between analytical data and an understanding of environmental chemistry. For instance, several interpretations of a single vibrational spectrum may be defended, leading to controversy regarding molecular bonding. Theoretical calculations of the infrared and Raman spectrum of a suggested model can be used to test the accuracy of the hypothetical structure. In a similar manner, predicted nuclear magnetic resonance (NMR) chemical shifts can be predicted based on a given model and compared with observed values. When a single model can reproduce both types of spectroscopic observations, then a reliable interpretation has been found.

Computational chemistry can also be used to predict fundamental behavior of chemicals in the environment. Such commonly used parameters as octanol-water partition coefficients (K_{ow}) are readily calculable. By calibrating the modeling techniques for compounds where such parameters are known, the calculations can then be used to predict behavior where experimental data is not available. This predictive capability is particularly useful with regard to chemical toxicities such as phototoxicity. Molecular properties, such as the HOMO-LUMO gap ($\Delta E_{HOMO-LUMO}$), can be an excellent indicator of potential phototoxicity. Values of the $\Delta E_{HOMO-LUMO}$ can be calculated more rapidly and with less cost than performing toxicity tests. Thus, although never completely replacing field and experimental data, molecular modeling can be used to screen compounds for further testing which can save significant amounts of time and money.

Lastly, computational chemistry can be used to simulate the complex interactions among natural materials and contaminants. For example, the sorptive capability of natural organic matter (NOM) towards organic contaminants can be a function of the NOM bonding. Complexation of humic acids in aqueous solution may affect the ability of this dissolved organic matter to co-dissolve relatively insoluble organic contaminants. Furthermore, bonding of NOM to different mineral substrates also has an effect on the capability of the NOM to adsorb non-polar organics. Bonding between NOM and mineral substrates has dramatic effects on the organic carbon turnover rates in soils as well which has consequences for the storage of carbon and CO_2 levels in the atmosphere.

Methodology

A variety of molecular modeling techniques exist. In general, there is a trade-off between system size (realism) and the level of theory (accuracy). However, by making judicious choices of techniques, checking lower levels of theory against highly accurate calculations, and always testing computed results against experimental data, it is possible to extract a great deal of useful information from molecular modeling calculations. Starting off with smaller, simpler systems, one can break down bonding interactions in terms of basic functional groups. Such an approach is commonly used to design experiments. Once confidence in model results has been established, larger systems may be simulated with somewhat lower levels of theoretical robustness to examine long-range effects not included in the simple components. However, the accuracy of these larger scale simulations must always be compared to results for higher levels of theory and experimental data where possible. By selecting from methods such as, molecular orbital theory, density functional theory, semi-empirical quantum mechanics and molecular mechanics, reasonably accurate, realistic and practical simulations can be carried out.

Results

Research illustrated in this poster will describe results obtained on modeling mineral surfaces, metal-organic complexation mechanisms, partitioning behavior, phototoxicity, and adsorption of organics to mineral surfaces. The first topic, protonation of mineral surfaces is important for the adsorption of metal contaminants in soils and aquifers because the charge of the surface strongly controls the amount of metal adsorbed. Aqueous-phase complexation reactions between NOM and metals can affect the transport and bioavailability of metal contaminants and also influence the interaction of NOM with organic contaminants. Partitioning behavior of organic contaminants between aqueous and organic phases can control bioavailability and bioaccumulation of compounds like polycyclic aromatic hydrocarbons. Phototoxicity predictions are important for predicting the influence of sunlight on the possible adverse environmental effects of a given chemical; a parameter not always considered in laboratory testing. Finally, sorption of both NOM and organic contaminants to mineral surfaces can affect the bioavailability, transport and fate of the contaminants. A fundamental understanding of the molecular-level sorption process may be useful in designing remediation plans.

PAST AND PRESENT CONTRIBUTION OF VEHICULAR SOURCES TO THE GLOBAL DIOXIN BUDGET. by: Whitney Leeman (wrleeman@engr.ucdavis.edu) and Daniel P.Y. Chang (dpchang@ucdavis.edu), Department of Civil/Environmental Engineering, UC Davis, One Shields Avenue, Davis, CA 95616.

A large body of evidence exists to suggest that polyhalogenated dibenzo-p-dioxin/polyhalogenated dibenzofuran (PCDD/F) emissions to the environment increased dramatically post-1940, reached a peak in the 1960s/1970s, and began declining through the late 1970s, 1980s, and 1990s. Unfortunately, the dominant mechanism of dioxin reduction is not clear at this time. Possibly, the contribution of PHDD/F from vehicular sources, in particular, motor vehicles burning leaded gasoline, has been underestimated. Ethylene dichloride and ethylene dibromide were added to leaded gasoline to function as "lead scavengers"; excess chlorine and bromine along with other precursors may have led to post-combustion PHDD/F formation in motor vehicle exhaust systems. Although motor vehicles are now equipped with catalytic converters and leaded gasoline is no longer used in the United States, the effects of PHDD/F may be experienced years into the future due to environmental persistence and long residence times in the fatty tissues of animals. Additionally, leaded gasoline is still used in much of the world, affecting animals and ecosystems both locally and distantly since long range transport of fine particle-phase PHDD/F is possible.

To determine whether motor vehicles have ever been significant non-point sources of PHDD/F, we are attempting to analyze archived hi-vol. air filters from an area in the South Coast Air Basin (SCAB) where the PHDD/F sources are thought to be primarily vehicular. Analyses of filters from 1974, 1977, and 1980 suggests that measurable levels of PCDD/F are present on the filters and may be comparable to levels measured in the late 1980s by the California Air Resources Board. Population levels and vehicle miles traveled (VMT) have increased in the SCAB since the 1970s; ambient dioxin levels would have also increased if motor vehicles were a significant source unless changes in gasoline composition or emission controls reduced the source strength. Additional filters are being analyzed to determine whether statistical correlations between ambient PCDD/F concentrations and ambient lead, scavenger concentrations in gasoline, or gasoline and diesel fuel consumption exist during leaded gasoline phaseout.

Due to the high cost associated with HRGC/HRMS, the possibility of using an ELISA developed by investigators in the Superfund Basic Research Program at UCD has been investigated. The ELISA is inexpensive, has an IC_{50} of 4 ± 2.5 pg. TEQ/well, is specific to PHDD/F, but had not previously been tested on real environmental samples. Experiments were initially performed to optimize ELISA sensitivity, determine antibody cross-reactivity with individual and mixed halogen PHDDs and PCBs, identify solvent interferences, examine the effects of PHDD/F mixtures, and minimize and quantify analyte losses during the analytical procedure. Additionally, ELISA analyzed real tissue and air samples that had undergone HRGC/HRMS for quantitative comparison.

To determine the level of cleanup needed for the hi-vol. air filters, blank filters and real samples were spiked and Soxhlet extracted. Matrix interferences in the extracts proved to be too high to dilute, so a single Florisil column cleanup step has been implemented with promising results. Experiments are underway to 1) optimize PHDD/F recovery during solid phase extraction cleanup, 2) determine whether PHDD/F contaminated wastewater generated by the ELISA can be treated directly with UV irradiation for the purposes of detoxification and disposal, and 3) determine the effects of an organic co-solvent to aid in introduction of organic extracts into the assay after conventional soxhlet extraction, to enhance solubility of the more chlorinated PCDD/Fs, and aid in dispersing PCDD/F into the aqueous ELISA solution.

The ultimate goal of the study is to analyze a sufficient number of hi-vol. filters to be able to draw statistical conclusions regarding motor vehicle fuel additives, fuel consumption and ambient PHDD/F levels in various locations around California. The results of our proposed research may establish a valuable link to historical exposure patterns from PHDD/F.

NATURE AND DISTRIBUTION OF NI AND MO IN ION-EXCHANGED Y-TYPE ZEOLITES. *by Dien Li, George D. Guthrie, D.L. Bish, J.W. Carey and S.J. Chipera, EES-1 MS D462, Los Alamos National Laboratory, Los Alamos, NM 87545; Huifang Xu, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131; Nishijima, Department of Surface Chemistry, National Institute for Materials and Chemical Research, Tsukuba, Ibaraki 305.*

Japan New environmental regulations have lowered the limit for sulfur in diesel fuels from ~0.2 wt% to 0.05 wt% (i.e., in Japan), a level that cannot be achieved by the γ -Al₂O₃ based catalysts now used extensively in industry. To meet these levels requires new generation catalysts with Bronstedt acidity and well dispersed metal phases. These characteristics would make the new catalysts more efficient at hydrodesulfurization (HDS) of the dominant sulfur compound in diesel fuels (dibenzothiophene or DBT), as well as effective at HDS of DBT derivatives (such as 4-methyl-DBT and 4,6-dimethyl-DBT). Our recently developed ultrastable Y zeolite (USY) is a promising candidate as a support for these new catalysts due to its high Bronstedt acidity, thermal stability, shape selectivity, and ion-exchange capability. USY was made by de-alumination of Na Y zeolite (NaY). Ni- and Mo-exchanged USY and NaY (Ni-Mo/USY and Ni-Mo/NaY) were sulfided to produce the Ni-Mo sulfide catalysts. The catalytic HDS of DBT over sulfided to produce the Ni-Mo sulfide catalysts. The catalytic HDS of DBT over sulfided Ni-Mo/USY and Ni-Mo/NaY was carried out at 340°C and the HDS activity was determined based on gas chromatography. The Ni-Mo/USY and Ni-Mo/NaY were characterized using NH₃ temperature programmed desorption, X-ray photoelectron spectroscopy, diffuse reflectance spectroscopy, transmission electron microscopy (TEM), powder X-ray diffraction (XRD) and Rietveld structure refinement. This work focused on the use of TEM and XRD (combined with Rietveld analysis) to determine the nature and distribution of Ni and Mo in Ni-Mo/USY and Ni-Mo/NaY, because this apparently impacts the HDS activity of the sulfided catalysts.

TEM shows that Ni-Mo oxide aggregates occurred rarely in Ni-Mo/USY, and energy dispersive spectroscopy (EDS) and XRD suggest that most Ni and Mo were incorporated into USY. However, in Ni-Mo/NaY, a large number of Ni-Mo oxide aggregates were observed by TEM. EDS analysis of NaY demonstrated that about half of the total initial amount of Mo but almost none of Ni was present within the zeolite. Rietveld structure refinements of Ni-Mo/USY and Ni-Mo/NaY indicate that both Ni and Mo were incorporated into the supercavity of USY, but Mo was found primarily in the sodalite cage of NaY. Thus, for Ni-Mo/USY, Ni and Mo species in the supercavity were sulfided to form Ni-Mo-S clusters, and the Ni-Mo-S clusters and Bronstedt acid sites in Ni-Mo/NaY, Ni and Mo preferentially formed (NiMoO₄) aggregates, causing Ni and Mo to be poorly dispersed and poorly sulfided, with most of the excess Mo incorporated into the sodalite cage. The Mo in the sodalite cage was not accessible to DBT due to its size, which partially explains the low HDS activity over sulfided Ni-Mo/NaY. In addition, the Bronstedt acidity of Ni-Mo/NaY is low relative to that for Ni-Mo/USY, which also contributes to the low HDS of sulfided Ni-Mo/NaY.

FABRICATION AND EVALUATION OF ION SELECTIVE MICROELECTRODES FOR THE STUDY OF NITRIFYING BIOFILM. by: Jin Li (lijin@email.uc.edu) and Paul L. Bishop (Paul.Bishop@uc.edu), 741 Baldwin Hall, Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH 45221-0071.

Three different kinds of ion-selective microelectrodes-hydrogen, ammonium and nitrate were fabricated and evaluated to investigate the microbial profiles of nitrifying biofilms. In nitrifying biofilm, the transformations of ammonia to nitrite and nitrite to nitrate are primarily carried out by two different groups of bacteria, *Nitrosomonas* and *Nitrobacter*. These biological processes are very sensitive to pH changes. Information on the distribution of pH, NH_4^+ and NO_3^- in biofilm is very important to understand the structure and function of microbial nitrifying communities.

The fabrication of ion selective microelectrodes involves several steps. Micropipette with an internal capillary was pulled on a horizontal puller and then broken to a tip size of 3-5 micrometers. To make the tips of microelectrodes hydrophobic, micropipettes were dipped into silane solution for 30 seconds and then baked in a preheated oven at 180°C for 24 hours. The micropipettes were back filled with electrolytes (pH7 buffer for pH microelectrodes, 0.01M NH_4Cl for NH_4^+ microelectrodes, 0.05M KCl +0.05M KNO_3 for NO_3^- microelectrodes) and front-filled with cocktails containing ionophores (Fluka, NH_4^+ ionophore I cocktail A, H^+ ionophore I cocktail A, NO_3^- ionophore cocktail A). After hardening of the cocktail in air for 2 hours, a thin layer (<1 μm) of cross-linked protein was coated on the micropipette tip.

In order to evaluate whether these ion selective microelectrodes could be used for environmental biofilm studies, calibrations of NH_4^+ and NO_3^- microelectrodes were carried out in Mill-Q water, biofilm reactor bulk solution and solutions containing different ionic strength backgrounds. The concentration of nitrogen used for the calibration ranged from 0.5ppm to 100ppm, which covers most of the situations we expect in biofilm systems. pH microelectrodes were calibrated in pH 6-10 buffers because the optimum performance of nitrifying biofilm is under pH 8. All three kinds of microelectrodes exhibited linear responses with slopes of 49-57mv/concentration decade. The response times (90%) were less than 10 seconds. No major interference from other ions occurred under all calibration conditions. The best performance of microelectrodes was observed with calibration in biofilm reactor bulk solution, which had an ionic strength background of 3.5 mM. However, in order to avoid biodegradation of the protein layer by bacteria and to prolong life time of the microelectrodes, calibration should be done in solutions containing similar ionic strength backgrounds with experimental biofilm conditions.

DISINFECTION OF WASTEWATER EFFLUENT BY ELECTROCHEMICAL METHOD. *by: X.Y. Li (xlia@hkucc.hku.hk) and L.S. Yat, Department of Civil Engineering, The University of Hong Kong, Pokfulam Rd., HONG KONG.*

A lab-scale electrochemical contractor was used for disinfection of wastewater effluent collected from a 2nd biological treatment plant in Hong Kong. Under moderate conditions, such as voltage=2.8 v and current=0.25 A, more than 99.9% of total coliforms were killed, while the hydraulic retention time (HRT) in the disinfecting contractor was under 5 sec and the power consumption rate was less than 0.004 kWh/m³. In the extreme case, the HRT could be further reduced to 0.9 sec with a power input of 0.01 kWh/m³, while the same degree of disinfection efficiency was maintained.

The experimental set-up included an electrochemical contractor, a direct current (DC) power supplier and volumetric pumps. The contractor is cylindrical in shape, consisting of the outside stainless-steel column as the cathode and a metal bar in the center as the anode. The anode surface was treated with durable metals such as titanium and SnO₂ coating. The contractor is 235 mm in height and 39.7 mm in internal diameter, and the diameter of anode is 11.8 mm. Wastewater can be pumped continuously in an up-flow pattern through the space between the electrodes in the contractor that has an effective volume of 265 ml.

The wastewater effluent has a high salinity content, 8-9‰, resulting from the domestic usage of seawater for toilet flushing in Hong Kong. High salinity content can enhance the electrochemical reactions and processes. It was demonstrated that the disinfection efficiency increased and the power consumption decreased as the salt concentration increased. However, the main disinfecting action of this process might not be due to the formation of Cl₂ from Cl⁻ oxidized at the anode. Under the experimental conditions, the residual Cl₂ (C) in wastewater after the electrochemical treatment was usually <0.3 mg/L. With a contact time (t) as short as 5 seconds or less, the Ct value of chlorination was too low to result in a significant germicidal efficiency. There could be the productions during the electrochemical process of other short-lived, more powerful lethal species such as ozone and related free radicals, active oxygen radicals and atoms, and hydroperoxide ions. These species are very unstable and difficult to be detected, but they are extremely reactive germicidal agents that may exert a strong disinfection action of a short lifetime. In addition, the direct contact of bacteria with the anode could kill the bacteria immediately, although may not be accounted as a major disinfective mechanism because of the short contact time.

The electrical field might also cause the inactivation or destruction of microorganisms by electrochemical reactions occurring inside the cells. This action can take place in the entire water bulk at the time of electrochemical process. According to the theory of electroporation previously proposed, electrical field could result in the formation of small pores in the cell membrane. Bacteria were killed due to the release of cell components from the pores formed. In brief, the mechanism of electrochemical disinfection is rather complex. The great capacity of this electrochemical disinfecting facility could be contributed to the combination of various effective processes and therefore further investigation is needed.

ENVIRONMENTAL PROCESS TECHNOLOGIES AND RELATED STANDARDS APPROPRIATE FOR DEVELOPING COUNTRIES. by: *H.F. Ludwig* (ludwig@mozart.inet.co.th) and *J. Kelly* (jkelly@mozart.inet.co.th), Seatec International, P.O. Box 8-101, Bangkok 10800, Thailand.

Following World War II a new concept of global development emerged stemming from the operations of UWRRA (United Nations relief and Rehabilitation Administration) during World War II. The new concept was based on recognition that the affluent industrialized countries (ICs) of the world should take the lead in furnishing continuing assistance to the non-affluent developing countries (DCs) to assist them to develop their own economies to be able to support their growing populations on a sustainable basis, in associate with the economies of the ICs. This led to establishment of the World Bank (as successor to UNRRA) and its associated Multilateral Development Banks and of numerous U.N. affiliates, and of Bilateral governmental agencies. Now, these various international assistance agencies (IAAs) have, over the past fifty years, made investments for helping the DCs amounting to hundreds of billions of dollars, including both loans and technical assistance grants, all presumably dedicated to the goal of assisting DC governments. It seems very timely now, as the 20th Century ends and a new century looms ahead, to take stock and evaluate the impact of this massive effort by the IAAs, to determine its actual effectiveness and merits and deficiencies and how it needs to be modified to meet the 21st Century situation. This is especially needed in the environmental sector of development because in the past several years it has been recognized that the IAA program on environmental has not at all been successful; indeed, environmental degradation in the DCs has become steadily worse and worse so that, unless some meaningful changes are made, it appears that by 2050 most DCs will be in drastically unacceptable conditions in terms of national resource losses and in terms of unmanageable urban slums.

A number of reasons have contributed to this failure, and one of the most important has been the imposition by the ICs (who furnish the leadership) on the DCs (who depend on this leadership) of design criteria and related standards for the planning of DC infrastructure facilities including sanitary engineering systems but also others including highways, harbors, etc. This practice stems from the fact that practically all of the design guidelines are produced in the ICs, which are formulated to meet IC environmental standards. But the standards of the ICs represent affluent country affordability, and generally are not appropriate for use in DCs simply because their resources cannot apply them effectively both in terms of funds and available technical skills. And the training courses offered by the IAAs serve to do more of the same and to compound the problem. The result has been massive wastage of funds, including wastage by the DCs who can least afford it, without establishing works/systems which will solve the problem. The problem is farther compounded by the lack, in the IAA programs, of meaningful post-construction monitoring evaluations to check actual on performance.

One example of these very many problems is the use of rapid sand filters for community water supply. The IAA program has helped financed hundreds if not thousands of these plants in the DCs and the process continues on and on, despite the fact that the plants commonly produce effluents of from 5 to 10 ppm turbidity (compared to design standard of 0.1 ppm), hence the plants actually do little good. The situation is similar for virtually all types of sanitary engineering and other types of infrastructure and also to preparation of Environmental Impact Assessments.

The purpose of the proposed paper is to describe and document this story, to recommend the preparation of meaningful guidelines manuals with terms of reference, including costs, and to recommend the feasible institutional approach—who should prepare them.

NEXT GENERATION MODELING APPROACHES FOR FATE AND TRANSPORT IN FLUVIAL SYSTEMS.
by: J. Russell Manson (mansoj@rpi.edu), Rensselaer Polytechnic Institute, Troy, NY 12180. Steve G. Wallis (steve@civil.hw.ac.uk), Heriot-Watt University, Edinburgh, EH14 4AS, Scotland.

The environmental modeling community is increasingly being required to produce efficient, accurate and reliable models of environmental systems. A recent review article [Thomann, 1998] concludes that the interpretation of model output and model quality control (mass balances, numerical accuracy, physical realism) will assume an increased importance in coming years due to the economic and political consequences of making a 'wrong' environmental policy decision. Larger environmental systems are now of interest at watershed, national and even global geographical scales. This increases the dimensionality, size and time scales for simulation. Model complexities are also spiraling upwards as our better understanding of more complex ecosystems and bio-chemical interactions becomes formulated mathematically [Thomann, 1998; Somlyódy et al, 1998]. For example, the coupling of chemical equilibrium models with those for solute transport is one area that necessitates highly efficient numerical algorithms if solutions are to be returned within realistic timescales, [Runkel et al, 1996]. Deterministic model predictions are losing favor to the more intellectually honest practice of quoting solutions with corresponding uncertainties and model confidence limits. Indeed the complexity of environmental systems begs this approach [Steinberg et al, 1996]. For the non-linear and non-uniform systems encountered in real situations, this usually entails a Monte Carlo or some other multi-simulation based procedure, [Schnoor, 1996]. The computational resources that are required to do the many model runs, necessary to build the statistical database, often deter practicing engineers from this approach. Clearly improving model efficiency to the point where this practice would be feasible or even routine is highly desirable.

The most computationally efficient mechanistic models are those based on a closed form or exact solution to the equations describing the problem. Unfortunately, these exact solutions rarely exist for the complex non-uniform scenarios found in real world applications. Recourse is therefore necessary to a numerical model which, although in principle is capable of dealing with complex, non-linear environmental processes and interactions, is, nevertheless, subject to associated numerical errors. In this paper the authors present a numerical fate and transport model called DISCUS [Manson et al, 1995; Wallis et al, 1997] which allows the use of much larger timesteps than current fate and transport models yet which maintains numerical integrity (i.e. mass conservation, accuracy, physical realism). The model is based on a semi-Lagrangian approach, in contrast to most current models that are Eulerian in nature. By enabling model runs to be completed orders of magnitude faster than is currently possible, some of the issues described above can be addressed: the semi-Lagrangian modeling philosophy provides this possibility. The specific objectives of this poster are: to summarize the principles behind Eulerian and semi-Lagrangian modeling approaches; to summarize the DISCUS method for pure advection in steady, non-uniform flows; and to show how dispersion, simple reaction terms and inflow boundary conditions can be incorporated in the model. Results of numerical experiments demonstrate the efficacy of the approach and results from case studies demonstrate the suitability of the method for practical water quality modeling scenarios.

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ENHANCING THERMAL REACTIVATION FOR WATER TREATMENT SERVICE. *by: David W. Mazyck (dwm110@psu.edu) and Fred S. Cannon (fcannon@psu.edu) Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA 16802.*

Granular activated carbon (GAC) is commonly employed by water utilities to remove organic compounds, including synthetic, volatile and taste and odor-causing compounds. Moreover, GACs usage in water treatment may increase in order to curtail the discharge of disinfection by-products (DBPs) to meet new regulations imposed by the Environmental Protection Agency (EPA).

After GAC has exhausted its finite adsorption capacity, a common practice is to reactivate and return the GAC back to service. However, during thermal reactivation calcium, which accumulated from complexing with natural organic matter (NOM), acts catalytically by increasing gasification reactions during oxidation by 3 to 25 times as compared to uncatalyzed oxidation. Because of calcium catalysis, the micropores are widened to mesopores and it is the micropores that constitute at least 90 % of the total surface area within virgin GAC. Moreover, the micropores are believed to be the most important for removing small organics from water. Thus, from this perspective, calcium catalysis can be perceived as detrimental to proper reactivation of GAC.

The objective of this research has been to tailor thermal reactivation of spent GAC to overcome calcium catalysis and micropore destruction. We hypothesized that we could diminish calcium catalysis effects by first steam-curing the spent GAC at a relatively low temperature (620 – 700 K) and then ramping its temperature up to elevated levels (1000 – 1170 K) in a nitrogen environment that would exclude the CO₂ gas species that could interact with calcium to catalytically gasify the GAC.

Pore volume distribution measurements using the density functional theory (DFT) revealed that this strategy increased the pore volume between 5.4 and 32 Å when compared to its virgin counterpart, or when compared to spent GACs that were conventionally reactivated. The steam curing/pyrolysis approach also achieved the same micropore volume as its virgin counterpart, and also more pores between 5.4 to 100 Å in width. Based on these results, we hypothesize that this reactivated carbon could serve better in water treatment as compared to virgin carbon.

Often GAC is employed at water treatment plants without much consideration as to how it works or how other treatment processes enhance or suppress the adsorption process. Moreover, the same GAC is often used at water treatment plants in different parts of the country, without considering the water influent characteristics. For example, these water characteristics can vary based upon the influence from industry, agriculture or different weather patterns, but a “generic” carbon is often employed and expected to remove organics from these diverse waters. Therefore, it seems appropriate that GAC should be activated or tailored to ensure that harmful organics are being removed. Depending upon the activation environment (steam or CO₂), the micropore volume can be dictated. Moreover, the surface chemistry of an activated carbon can be tailored to favor adsorption of organics such as taste and odor-causing compounds. With the EPA’s regulations becoming more and more stringent and new contaminants being added to the priority pollutant lists, it appears that there is research required to understand how to tailor activated carbons to remove target compounds.

TOTAL INORGANIC NITROGEN (TIN) DOWN TO CLEAN LAKE LEVELS. *by: Alan H. Molof, Technical Adviser, Samsung Engineering Company Ltd. (SECL) USA R&D Center, Englewood Cliffs, NJ and Associate Professor at Polytechnic University in Brooklyn, NY and Sungtai Kim, Branch Manager, SECL USA R&D Center, Englewood Cliffs, NJ.*

For a truly sustainable water environment, wastewater treatment must function at a very high performance level. Effluent nitrogen levels set at 8 mg/l are not leading to a sustainable water environment. A new process has been introduced which can meet the high performance requirements for a sustainable water environment by reducing the TIN (sum of ammonia, nitrite and nitrate nitrogen) to 0.05 mg/l which matches clean lake nitrogen levels. This process was developed in the laboratory, and field tested on a pilot plant basis.

To achieve this TIN level, wastewater treatment consisted of simply anoxic, aerated and settling tanks. The actual configuration of these process units consisted of a field primary settling tank followed by a pilot plant activated sludge in the MLE (Modified Ludzack-Ettinger) mode. The activated sludge tank had the first 20 percent as a non-aerated zone and the following 80 percent as an aerated zone followed by a settling zone. The settled sludge from the settling zone was returned to the non-aerated zone as was the MLSS in the final section of the aerated zone. Following the activated sludge MLE process was an add-on new pilot plant process termed the PENReP Process consisting of an anoxic zone followed by an aerated zone and a final settling zone. A volatile acid was added to the anoxic zone as sodium acetate. The settled sludge from the final settling zone was returned back to the anoxic zone and the settled effluent which was the effluent that tested at 0.05 mg/l TIN.

The field pilot plant results are from the Rockland County (NY) Sewer District No. 1 Wastewater Treatment Plant. The laboratory results were from Polytechnic University in Brooklyn, NY. The field pilot plant results are from a 3 month period from March 17 to June 11. The pilot plant flows were maintained constant for both the MLE activated sludge and the add-on PENReP Process.

The flow to the MLE activated sludge process was 20.4 m³/d (5400 gpd) with recycle from the settling tank at 50 percent and the recycle from the end of the aerated zone at 100 percent. The HRT based on Q was 1 hour in the non-aerated and 4 hours in the aerated zone.

The flow to the PENReP Process was 8.18 m³/d (2160 gpd) with a 1.5 recycle flow. The HRT based on (Q+Q_r) is 30 minutes for the anoxic zone, 45 minutes for the aeration zone and 60 minutes for the final settling zone. The final settling overflow rate was 22.49 m³/d/m² (551.6 gal/d/ft²). The average sludge blanket height in the final settling tank was about 11 percent of the side water depth.

The pilot plant MLE activated sludge results from the 3 month period averaged 2.69 mg/l for the ammonia nitrogen, 0.22 mg/l for nitrite nitrogen, 6.31 mg/l for the nitrate nitrogen and 9.22 mg/l for TIN. The high TIN was 14.4 and the low TIN was 5.8 mg/l.

The pilot plant PENReP Process results for this 3 month period averaged 0.16 mg/l for ammonia nitrogen, 0.02 mg/l for the nitrite nitrogen, 0.69 mg/l for the nitrate nitrogen and 0.87 mg/l for TIN. The high TIN was 4.19 mg/l and the low TIN was tested as zero.

ENVIRONMENTAL ENGINEERING CASE STUDIES FOR HIGHER-ORDER LEARNING. *by: Susan Morgan (smorgan@siue.edu), Campus Box 1800, Department of Civil Engineering, Southern Illinois University Edwardsville, Edwardsville, IL 62026-1800.*

While it is widely recognized that case studies are useful learning tools, they are not widely used in environmental engineering courses. There are many reasons for this discrepancy; however, one of the primary reasons is that complete environmental engineering case studies are not readily available and are time-consuming to research and write. While there are textbooks that purport to include case studies, these "case studies" tend to be descriptive examples or illustrations of a single concept or aspect of an incident rather than a comprehensive, detailed synopsis that can be used to promote critical thinking. While case studies are also examples, they go further; they present more complete details about several aspects of a problem or incident but leave questions for the students to answer and problems for them to solve. Case studies offer valuable opportunities for students to go beyond information gathering to synthesis, analysis, and evaluation—higher-order thinking skills.

In addition, case studies can incorporate issues (such as ethics, political feasibility, and social feasibility) that are difficult to cover in traditional assignments but are important in professional practice. Case studies offer opportunities for students to apply engineering concepts discussed and/or lectured on in the classroom to actual incidents. The students are forced to apply classroom material and, by doing so, learn its relevance as well as its limitations. Case studies can promote discussions in which students can improve their communication skills, which are often found lacking in engineers by employers. In addition, assignments can be structured to encourage teamwork, a skill that some students have trouble mastering but that is required in most professional work environments.

A grant from Southern Illinois University Edwardsville's Excellence in Undergraduate Education Program has provided funding to compile case studies of actual engineering projects in the St. Louis area. Projects pertinent to a junior-level introductory environmental engineering course as well as a senior-level hazardous waste management course will be the focus. The use of case studies in the introductory course is viewed as being especially valuable as this course may be the only course in which non-environmental engineers are exposed to aspects of environmental engineering that impact their fields. For example, structural engineers need to be cognizant of the need to design for energy and water conservation and to specify materials that promote sustainability but that do not adversely impact indoor air quality. Transportation engineers need to be cognizant of the need to take into account noise impacts as well as wetland issues when choosing construction materials and route locations.

Through the project, summaries and assignments will be developed for students while more detailed information, including actual project decisions and outcomes, will be developed for instructors. The methodology used to synthesize and evaluate the case studies as well as the format of the final case studies will be discussed. Case studies developed during the project will be used as examples.

ANALYSIS AND DESIGN OF A SUSTAINABLE DRAINAGE AND WATER SUPPLY SYSTEM FOR NEW ORLEANS. by: *H. Myers* (hmyers@mailhost.tcs.tulane.edu), *L. Steinberg* (lauras@mailhost.tcs.tulane.edu) and *G. Boyd* (gboyd@mailhost.tcs.tulane.edu), Department of Civil and Environmental Engineering, Tulane University, New Orleans, Louisiana 70118.

In this study, we apply the basic tenets of sustainability to an analysis of the sustainability of the drainage system and potable water treatment system of the City of New Orleans. As a city below sea level, and bordered by the Mississippi River on the south and east and by the 24-mile diameter Lake Pontchartrain on the north, New Orleans has unique drainage problems. These problems are exacerbated by New Orleans' location within the United States' hurricane zone. As a result of these conditions, New Orleans must pump most of its drainage water (approximately 90 million gallons per year) out of drainage canals and into Lake Pontchartrain. The environmental, energy, and economic costs of this pumping are discussed in this paper, and lead to an examination of more sustainable methods for stormwater drainage. In addition, we discuss the use of roof cisterns to collect rainwater to reduce urban flooding potential and for use as a non-potable water source. We also evaluate advantages, disadvantages, and viability of redirecting stormwater into the city water treatment plant. Our proposed infrastructure strategy for the City of New Orleans offers several advantages with respect to sustainability including the following: (1) reduced pollutant loading into Lake Pontchartrain; (2) reduced power costs associated with pumping raw water from the Mississippi River into the water treatment plant and discharge pumping of stormwater into Lake Pontchartrain; and (3) reduced risk of urban flooding by redirecting stormwater via cisterns for use as nonpotable water.

SIMULTANEOUS IN SITU VISUALIZATION OF BACTERIAL IDENTITY AND POLYPHOSPHATE ACCUMULATION IN ACTIVATED SLUDGE. by: *D.R. Noguera* (noguera@engr.wisc.edu), *C.-H. Hung* (chung1@students.wisc.edu), and *J.M. Regan* (jmregan@students.wisc.edu), 1415 Engineering Drive, Department of Civil and Environmental Engineering, University of Wisconsin, Madison, WI 53706.

The full-scale implementation of enhanced biological phosphorus removal (EBPR) processes has been successful, even though the key phosphate-accumulating (poly-P) bacteria have not been fully identified. The inability to isolate and identify a prevalent poly-P organism is due to the biases introduced by culturing and isolation methods and the difficulty to link molecular identification methods with phenotypic characteristics such as accumulation of polymeric materials. It is also feasible that the ability to accumulate polyphosphate is a widespread characteristic and thus there is not a single type of organism that can be labeled as the main poly-P bacteria in wastewater treatment. Current methods for in situ detection and enumeration of poly-P bacteria rely on the staining of polyphosphate granules, a characteristic that does not provide information on the identity of the organisms. On the other hand, phylogenetic analysis of the poly-P bacteria population in EBPR processes has often relied on either lab-scale enrichments or oligonucleotide probes specific for known poly-P bacteria. Neither of these methodologies provides a comprehensive evaluation of the actual poly-P population in a treatment plant. A better approach to study the diversity of poly-P bacteria in EBPR processes requires a culture-independent methodology to separate poly-P bacteria from nonpoly-P bacteria, followed by phylogenetic analyses of the poly-P fraction of the population. We have developed such a method based on the differences in density between poly-P and nonpoly-P bacteria.

Samples from an activated sludge system achieving biological phosphorus removal were collected, mechanically dispersed, and centrifuged in a Percoll density gradient. Bacteria that accumulated polyphosphate granules, determined by the fluorescence emission shift of DAPI, preferentially occupied two regions within the centrifuged tube. A first region corresponded to dense cells that accumulated at the bottom of the tube, while a second region, at the top of the tube, corresponded to less dense poly-P bacteria. Combined, these highly concentrated fractions of poly-P bacteria accounted for about 8% of the total microbial mass in the original activated sludge samples. Furthermore, phosphorus-to-protein ratios on different sections of the centrifuged tube confirmed the presence of poly-P cells in the regions detected by fluorescence. Phylogenetic analyses of the poly-P populations separated by centrifugation are currently underway. This separation methodology is a key step toward the direct identification of the most important poly-P microorganisms in activated sludge, without the bias introduced by culture-dependent methods.

QUANTIFYING GROWTH OF ACINETOBACTER SPECIES IN ACTIVATED SLUDGE WASTEWATER TREATMENT SYSTEMS USING MOLECULAR SIGNATURE METHODS. by D.B. Oerther (oerther@uiuc.edu) and L. Raskin (lraskin@uiuc.edu), Department of Civil & Environmental Engineering, University of Illinois, 205 North Mathews Avenue, Urbana, IL 61801.

New environmental legislation encourages the wastewater treatment community to improve existing wastewater treatment technologies while minimizing cost. One approach used to optimize the performance of existing wastewater treatment facilities and improve the design of additional wastewater treatment facilities is the development of mechanistic models of wastewater treatment. For example, to remove nutrients (i.e., nitrogen and phosphorous) from municipal wastewater, the operation of conventional activated sludge (AS) systems must be modified significantly. Mechanistic models of AS wastewater treatment, such as Activated Sludge Model No.'s 1 and 2^[11 and 12] are often used to predict the performance of conventional AS systems that are converted into nutrient removal systems.

To fully implement mechanistic models of AS wastewater treatment, experimental measurements of biomass concentration and growth rate are necessary¹³. Quantitative hybridizations with oligonucleotide probes targeting rRNA have been used to identify and enumerate microorganisms in AS wastewater treatment systems¹⁴. In addition to quantifying biomass concentrations [i.e.¹⁵], rRNA-based methods can be used to directly measure *in situ* microbial growth rates³. Recently, we developed rRNA-based methods to measure the *in situ* microbial growth rate of *Acinetobacter* species in AS^[16 and 17]. Our approach relies upon quantifying the relationship between the intracellular levels of rRNA and specific growth rate. Under balanced growth conditions (i.e. in chemostat), the levels of intracellular RNA are proportional to growth rate from growth rates of 1 h⁻¹ to 1 d⁻¹. Since mature rRNA is the major component of intracellular RNA, quantification of intracellular mature rRNA can be used to infer specific growth rates (for a discussion, see¹⁸). Recently, we quantified the relationship between intracellular mature rRNA and growth rate for a pure culture of *A. calcoaceticus*. Subsequently, we used this relationship to infer the specific growth rate of *Acinetobacter* species in laboratory-scale and a full-scale AS system⁶.

In addition to measuring net *in situ* growth rate under steady-state conditions, we have developed molecular methods to infer the specific growth rate of microorganisms under transient growth conditions (i.e. feast and famine conditions)⁸. Results from quantitative hybridizations with oligonucleotide probes targeting precursor-rRNA can be a good indicator of transient microbial growth (for a discussion see¹⁹). Therefore, we designed and experimentally characterized an oligonucleotide probe that targets a sequence within the precursor-rRNA of *Acinetobacter* species⁷. Subsequently, hybridizations of samples removed from laboratory- and full-scale AS wastewater treatment systems suggested that *Acinetobacter* species transiently experienced periods of rapid growth when return activated sludge (RAS) was placed in contact with fresh influent wastewater.

The results of our work targeting *Acinetobacter* species in AS wastewater treatment systems suggest that molecular methods can be used to quantify both microbial population abundance (using probes targeting mature rRNA) as well as growth rate and physiology (using probes targeting mature rRNA as well as precursor-rRNA) in AS. As previously discussed, these approaches should prove valuable for the calibration and validation of mechanistic models of AS wastewater treatment³.

¹¹ Henze, M., et al., *Activated Sludge Model No. 1*, 1987, London, IAWQ.

¹² Henze, M., et al., *Activated Sludge Model No. 2*, 1985, London, IAWQ.

¹³ Oerther, D.B., et al., *Wat. Sci. Tech.*, 1999, **39**: 11-20.

¹⁴ Amann, R.H., et al., *FEMS Microbiol. Ecol.*, 1998, **25**:205-215.

¹⁵ de los Reyes, F.R., et al., *Wat. Sci. Tech.*, 1998, **37**:485-493.

¹⁶ Oerther, D.B. and L. Raskin, in: *Proceedings of WEFTEC, 1999*, Alexandria, WEF.

¹⁷ Oerther, D.B., et al., *Appl. Environ. Microbiol.*, 1999, submitted.

¹⁸ DeLong, E.F., et al., *Science*, 1989, **243**:1360-1363.

¹⁹ Cangelosi, G.A. and W.H. Brabant, *J. Bact.*, 1997, **179**:4457-4463.

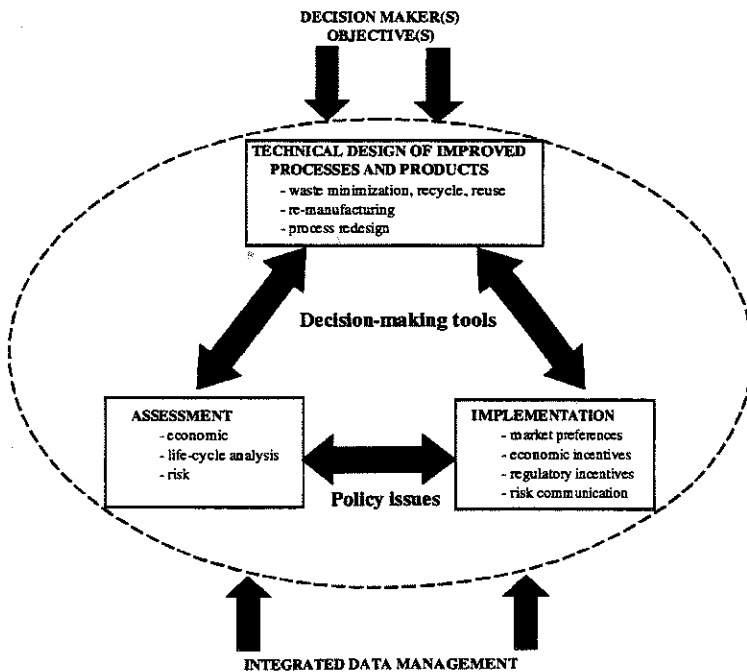
A NEW PARADIGM FOR DOCTORAL RESEARCH IN ENVIRONMENTAL MANUFACTURING MANAGEMENT. by: *Susan E. Powers* (sep@clarkson.edu) and *Thomas L. Theis* (theist@clarkson.edu) W.J. Rowley Laboratories, Clarkson University, Potsdam NY 13699-5710.

Clarkson University has recently established an integrated education and research program on Environmental Manufacturing Management (EvMM) which has as its focus the redesign of products, processes, systems, and organizations to balance industrial manufacturing activities with environmental stewardship. This program is currently funded through corporate sponsorships and the National Science Foundation under its Integrated Graduate Education, Research and Training (IGERT) program. The overall goal of the EvMM program is to couple the technical training graduate students typically receive and research they conduct at the doctoral level with extensive exposure to the environmental, ethical, economic, policy and communication aspects required to make positive changes towards sustainable manufacturing processes.

Traditional approaches to doctoral studies emphasize development and demonstration of expertise in a narrow topic of research, involving only that coursework that is germane to the topic, and is conducted under the guidance of a single mentor. Although a certain broadened knowledge of the field in which the topic is placed may be gained, the bridging to other disciplines is not intentionally encouraged. Advanced studies in the field of environmental engineering and science began to change this approach, with the need to incorporate concepts from the sciences, but now even these interdisciplinary areas are being challenged for further extension. In many ways the EvMM program is reflective of change which is already occurring in the marketplace. Interdisciplinary teams of faculty mentor the research activities of students teams who become engaged in environmental issues that are of interest to our industrial partners. The concept of each student having multiple mentors who direct his or her research in will enable each student to combine skills from the fields of engineering, the "hard" sciences, social sciences, and managerial and rhetorical fields to conduct research in appropriately defined industrial problems.

Research conducted by the multidisciplinary EvMM teams relies heavily on a systems approach to solving problems. This requires that the boundaries of the manufacturing facility include environmental control technologies, waste emissions, and environmental impacts. This approach is fundamentally different from system definition practices during the “firefighting” era of environmental engineering when treating emissions was the sole consideration. Although there are numerous ways to characterize problems within a systems framework, a systems approach works best when technical and economic factors are quantified, and multiple environmental,

managerial, ethical and regulatory constraints are incorporated into the analysis. As such, it is ideally suited for the conduct of multidisciplinary research. The multidisciplinary teams are tackling each problem from the perspective of four research thrust areas that are used to explore joint relationships and form a basis for framing research problems and questions to be investigated. These areas include 1) Technical Design of Improved Processes and Products, 2) Assessment Tools for EvMM, 3) Implementation of EvMM Practices, and 4) Integrated Environmental Data Management Systems. The figure to the left illustrates the relationships among these four areas.



MODELING THE IMPACT OF WATER QUALITY PARAMETERS ON WATERBORNE PATHOGENS IN RECREATIONAL WATERS. by: *T. Remington*, Department of Geography and Environmental Engineering, *M. Butkus* (bm8375@exmail.usma.edu), Department of Geography and Environmental Engineering, *M. Kelley* (bm3913@exmail.usma.edu), Department of Geography and Environmental Engineering, *J. Marin* (dj7900@exmail.usma.edu) Department of Electrical Engineering and Computer Science, and *M. Labare* (mm7983@exmail.usma.edu), Department of Chemistry, United States Military Academy, West Point, NY 10996.

High concentrations of pathogenic microorganisms, in lakes used for recreational purposes, can pose a serious threat to human health. Often times sampling techniques are both inadequate and inaccurate and do not indicate the true pathogen concentration in the recreational water. Development of standards, for recreational water use, is confounded by the multitude of parameters that impact the waterborne concentration of pathogenic microorganisms. Models that can predict changes in the concentration of waterborne indicator organisms may improve our understanding of the impact of these parameters and provide some utility in improving sampling protocols. Water quality data from recreational waters in the West Point, New York area and rainfall data from a rain gauge in Black Rock Forest, New York, were collected and analyzed using several models including statistical and neural network models. Results will be presented.

INFORMATION TECHNOLOGY FOR PRODUCT LIFECYCLE MANAGEMENT. *by: Donna M. Riley (dmriley@princeton.edu) and Valerie M. Thomas (vmthomas@princeton.edu), H212 Engineering Quadrangle, Center for Energy and Environmental Studies Princeton University, Princeton, NJ 08544.*

Management of the use and disposal of products is a fundamental issue in environmental policy. Although there has been significant progress in recycling of materials such as paper, aluminum, and steel in recent years, there has been little progress in the management of discarded consumer products. Information technology has the potential to make lifecycle management of consumer products both easier and more economical by addressing two key obstacles: product information loss and inefficiencies in second-hand markets. In addition to enhancing manufacturers' product stewardship programs, product management systems could benefit consumers by maintaining product value and making re-sale easier.

The concept of product self-management, in which a product manages its own transition into re-use or recycle markets, provides a new aspect for sustainable product design. Technologies ranging from bar codes to state-of-the art radio-frequency transponders allow product information and lifecycle management instructions to be embedded in the product itself.

Existing applications are evaluated, including on-line secondary markets and electronic tagging systems. Ongoing demonstration projects include a GIS-based Web-searchable database of local garage sales, a UPC-based system for reuse of household chemical products, and improvements to the online Recyclables Exchange at the Chicago Board of Trade.

DECENTRALIZED WASTEWATER MANAGEMENT FOR A SUSTAINABLE ENVIRONMENT. by: *L. Ruppe* (lmruppe@ucdavis.edu), *J. Darby* (jdarby@ucdavis.edu), and *G. Tchobanoglous* (gtchobanoglous@ucdavis.edu), Department of Civil and Environmental Engineering, University of California at Davis, One Shields Avenue, Davis, CA 95616.

The Clean Water Act of 1972 required municipalities to treat domestic wastewater to national water quality standards. Federal funds were authorized for the construction of large wastewater treatment plants and it was envisioned that all households would eventually be connected to these centralized plants. During the 1990's, however, the percentage of households connected to centralized plants reached a plateau at approximately 75 percent. It is not cost effective to construct sanitary sewer lines to all residences; the remaining twenty-five percent of United States households rely on decentralized or onsite wastewater treatment systems to treat wastewater prior to subsurface or surface disposal. Due to improper design, unsuitable site conditions, and lack of management, conventional onsite systems frequently fail and become a direct source of contaminants to nearby surface water and groundwater. These failures are of particular concern in rural areas for which groundwater supplies up to 90 percent of the water used and is often consumed untreated. It is these rural areas that are generally served by decentralized wastewater treatment systems.

A new model is needed to guide the sustainable development of unsewered areas and prevent problems before they become widespread. Much work must be done to define the structure and function of decentralized and onsite wastewater management in the twenty-first century. Research needs comprise three distinct areas: technology, management, and education.

Technology

Existing technology must continue to be improved and new methods of treatment developed. Researchers must identify critical design constraints. To what extent should size reduction and efficiency be counterbalanced by cost effectiveness and ease of operation and maintenance? How important is energy efficiency? Under what conditions will effluent recycling be advantageous? The linkage of system design to the assimilative capacity of the receiving environment is critical. Remote sensing applications should be developed.

Management

Some communities have begun moving toward onsite wastewater treatment as a household function that is overseen or more actively managed by the local community. To ensure an adequate level of wastewater treatment, thereby safeguarding an environment that will sustain the entire community, decentralized wastewater management districts have been formed. How should the structure of the management district reflect the unique characteristics of the community? Should the district be a public or private entity? What will be the funding mechanism? Will effluent quality standards be enforced or will technology based treatment be required? How might these be enforced? What are the best means to ensure proper design, construction and operation of onsite wastewater treatment systems? Mechanisms by which these functions can be implemented include treatment system inventory, system design and installation, plan review and construction inspections, periodic system inspections, water quality monitoring, enforcement, and education.

Education

Homeowners will need to become educated providers of wastewater treatment services. Engineers, scientists, and public health officials, to name a few, can provide the scientific basis upon which governments, schools, citizens groups, and homebuilders can base their educational efforts. Professionals in such disciplines as psychology, economics, and education will provide valuable insight into the mechanisms by which homeowners can be groomed to feel themselves as stakeholders in the proper functioning of their onsite system. What level of involvement should the homeowner assume? What are the most effective means by which to ensure active participation?

It is reasonable to believe that future technological developments and refinements will make use of onsite management systems feasible for all homes, with the resulting consequence that conventional gravity sewers may become obsolete and centralized wastewater treatment facilities may evolve into decentralized wastewater management centers for onsite wastewater system information collection and control.

BIOAEROSOL DISTRIBUTION PATTERNS ADJACENT TO TWO SWINE-GROWING-FINISHING HOUSED CONFINEMENT UNITS IN THE AMERICAN MIDWEST. by: P.V. Scarpino (pscarpin@uceng.uc.edu) and H. Quinn, Department of Civil and Environmental Engineering, The University of Cincinnati, Cincinnati, OH 45221-0071.

The presence of microbes in the air environment inside of housed confinement swine-production facilities used in modern animal husbandry has been well documented (Elliott et al., 1976; Clark et al., 1983; Crook et al., 1991; Wathes, 1995). Concern has been raised about the possible health effects of airborne microbes on both the swine and agricultural worker. The purpose of this study was to determine the presence of microbes from two swine-growing-finishing facilities in downwind areas around such operations. A series of bioaerosol studies were conducted around two Midwestern swine-growing-finishing operations that assessed microbial (bacteria and fungi) numbers and types released in air made at one of the facilities. Antibiotics in animal feed promotes animal growth, improved the efficiency of feed conversion to body weight, and may affect disease prophylaxis among the confined microbes in dosed animals, and their subsequent impact on human health.

Neighbors in close proximity to these operations complained of serious odors emanating from the facilities, personal discomfort due to the odors, loss of sleep, possible allergic manifestations, and respiratory difficulties.

Six-stage Andersen bioaerosol samplers were used to recover bacterial and fungal aerosols at sampling sites in the vicinity of the swine growing operations. Plate Count Agar (PCA) for bacterial and Mold Inhibitory Agar for fungal recoveries were used. Subcultures using the replica plate procedure were made of the PCA master plates using selective media for staphylococci, streptococci, and coliforms. In one swine operation studied, isolated staphylococci were tested for their sensitivity to antibiotics. Recoveries of total Colony Forming Units (CFU) of microbes (fungi and bacteria) at levels of $10^3/\text{m}^3$ of air was used as an indicator of possible danger to nearby inhabitants.

Swine-Production Facility I

About $1430 \text{ CFU}/\text{m}^3$ of air total microbes were found downwind of the swine operation; $930 \text{ CFU}/\text{m}^3$ air at a site downwind of the swine confinement barn and a recently manured field; and ca. $1870 \text{ CFU}/\text{m}^3$ of air in a nearby residence. The residence had 1130 CFU of molds/ m^3 of air alone in the inside air. Many of the staphylococcal isolates from the air near the swine barn were antibiotic-resistant. No *Klebsiella*, *Salmonella*, or *Shigella* bacteria were recovered at any of the sampling sites, and just an occasional coliform and *Streptococcus* were detected. Air fungi identified included species of *Alternaria*, *Aspergillus*, *Monilia*, *Mucor*, *Penicillium*, and *Rhizopus*.

Swine-Production Facility II

Three separate studies were made over a seven-month period. The first study was done in the fall, and showed in the morning at two different sampling stations a few hundred yards away from the swine-production facility recoveries of 388 and $1303 \text{ CFU}/\text{m}^3$ of air for the bacteria, and 978 and $1600 \text{ CFU}/\text{m}^3$ of air for the fungi. The afternoon levels downwind of the facility were 370 and $1614 \text{ CFU}/\text{m}^3$ of air for the bacteria, and 763 and $2567 \text{ CFU}/\text{m}^3$ of air for the fungi. Significant levels of staphylococci and fungi were also found in the nearby residences. All of the staphylococci isolated were coagulase-positive. The area was again sampled in the spring and later at the beginning of summer. In the spring sampling, low bacterial and fungal levels were observed, while in early summer high numbers of aerosolized staphylococci at one downhill station constituted 54% of the total bacteria recovered downwind of the facility.

Animal confinement facilities should be sited with consideration of the location of human habitation. The use of antibiotics in animal feed should be reviewed to minimize the development of antibiotic-resistant bacteria.

DEVELOPMENT OF SPECTROELECTROCHEMICAL TOOLS FOR IN SITU CHARACTERIZATION OF SURFACE REACTIVITY. by: Michelle M. Scherer¹ (michelle-scherer@uiowa.edu) and Vicki H. Grassian² (vicki-grassian@uiowa.edu), ¹Department of Civil and Environmental Engineering, 2130 Seamans Center, ²Department of Chemistry, 244 Iowa Advanced Technologies Laboratory, The University of Iowa, Iowa City, IA 52242.

Reactivity at the mineral-water interface is often inferred from macroscopic measurements of solution phase speciation. Although a great deal has been learned about surface reactivity with this approach (i.e., the pioneering work of Stumm and coworkers to use surface complexation to describe reactivity), future advances depend on our ability to use molecular-level information to discern *surface* speciation.

We are currently collaborating to apply in-situ electrochemical and spectroscopic techniques to study the role of surface speciation in redox reactions at the mineral-water interface. Electrochemistry provides a powerful tool for studying surface redox reactions as evidenced by our recent work employing an electrochemical cell to study the reduction of chlorinated solvents by iron metal¹. Spectroscopy, specifically Fourier Transform Infrared Spectroscopy (FTir), provides information on the vibrational states of molecules sorbed to a surface which allows characterization of surface speciation. Recent applications of FTir include the photocatalyzed oxidation of volatile organic compounds (VOCs)².

The integration of these electrochemical and spectroscopic tools (i.e., spectroelectrochemistry) to study reactions at environmental interfaces requires an interdisciplinary approach involving spectroscopic, electrochemical, and environmental expertise. We will present our progress in combining these techniques to study redox reactions in complex heterogeneous systems and provide an overview of the potential applications of these techniques.

Electrochemical models to describe relationship between potential and current. Interfacial chemistry of complex particulate surfaces in fluids is poorly understood. Combine with in situ characterization of chemical structure FTir transmission spectra Reaction mechanisms at oxide-water interfaces Attenuated total reflectance (ATR)

Our approach to unraveling the chemistry of these decomposition reactions on powdered metal oxides samples is to do careful surface science studies even though these surfaces are poorly characterized compared to single crystal surfaces studied under ultrahigh vacuum. However, understanding the chemistry that occurs on these high surface area metal oxide catalysts is perhaps more practical for actually developing methods and better catalysts for these reactions. In order for catalytic processes to be commercialized or to be widely used, it is necessary to understand at some level the reaction mechanism and even more importantly it is necessary to identify pathways that lead to catalyst deactivation. Characterizing intermediate species in the reaction, allows us to propose a reaction mechanism and possible deactivation mechanisms. The experimental approach used in our studies primarily involves the use of infrared spectroscopy to investigate surface reactions as well as mass spectrometry to monitor gas-phase reactants and products. Other analytical techniques will be used for catalyst characterization as the role of structure in some of these reactions is being investigated.

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REACTIVITY OF IRON MINERALS IN NATURAL AND ENGINEERED SYSTEMS. by: M.M. Scherer (michelle-scherer@uiowa.edu), A.G. Williams and M.J. Alowitz, Department of Civil and Environmental Engineering, 2130 Seamans Center, The University of Iowa, Iowa City, IA 52242.

There is growing interest in the reactivity and catalytic activity of iron mineral surfaces because of their potential to control the fate of contaminants in both natural and engineered systems¹. Recently, reduction by reduced iron minerals, such as green rusts (GRs) has emerged as a possible transformation pathway in soils, sediments, and groundwater treatment systems (i.e., Fe⁰ permeable reactive barriers). The significance of this pathway relative to competing transformation reactions, however, is still unclear. Although there is evidence that reduced iron minerals can abiotically transform contaminants on rapid time scales^{2 and 3}, little is known about the mechanisms and kinetics of these reactions in natural and engineered systems.

We are investigating the reduction of several contaminants by iron minerals, including green rusts, goethite, magnetite, and akaganeite. Green rust minerals appear to be the most reactive however, there is some evidence that the presence of adsorbed Fe(II) may significantly enhance the reactivity of the other minerals⁴. The insight derived from these investigations will provide an improved basis for predicting the fate of contaminants in sediments and aquifers and assessing the significance of reduced iron minerals in the remediation performance of Fe⁰ permeable reactive barriers.

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² Haderlein, S.B. and K. Pecher, *Pollutant Reduction in Heterogeneous Fe(II)/Fe(III) Systems*, in *Mineral-Water Interfacial Reactions: Kinetics and Mechanisms*, T. Grundal and D. Sparks, Editors. 1998, American Chemical Society. p. 342-357.

³ Erbs, M., H.C.B. Hansen, and C.E. Olsen, Reductive Dechlorination of Carbon Tetrachloride Using Iron(II) Iron(III) Hydroxide Sulfate (green rust). *Environmental Science and Technology*, 1999. 33: p. 307-311.

⁴ Klausen, J., S.P. Trüber, S.B. Haderlein, and R.P. Schwarzenback, Reduction of Substituted Nitrobenzenes by Fe(II) in Aqueous Mineral Suspensions. *Environmental Science & Technology*, 1995. 29(9): p. 2396-2404.

PREPARATION AND CHARACTERIZATION OF MAGNETICALLY ACTIVE POLYMERIC PARTICLES (MAPP) FOR ENHANCED SEPARATION IN COMPLEX ENVIRONMENTAL SYSTEMS. by: *Arup K. SenGupta* (arup.sengupta@lehigh.edu) and *K. Kodama* Department of Civil and Environmental Engineering and Earth and Environmental Science, 13 E. Packer Avenue, Lehigh University, Bethlehem, PA 18015.

In a flowing stream or river, it is often imperative to monitor the presence of environmentally regulated dissolved compounds in order to assess the extent of contamination and also, identify the possible source of contamination for forensic purpose. Ideally, the technique should be a passive one which avoids continuous sample collections and analyses.

In many large fresh water lakes, phosphates are released from the lake sediments with the onset of summer into the hypolimnion. The phosphates gradually diffuse into the epilimnion resulting in eutrophication. The rate of phosphate release depends on the phosphorus content of the lake sediment. A prior knowledge of a location with high phosphorus content of the lake sediment will be immensely helpful in controlling eutrophication.

Many secondary wastewater treatment plants are resorting to land application of their biosolids. However, in spite of the best pre-treatment practices, regulated compounds, namely, pesticides, heavy metals, metalloids, synthetic organic compounds, etc., occasionally appear in the influent and corrective actions (addition of powdered activated carbon, ferric chloride, alum, etc.) are taken primarily to ensure that treated water quality comply with prevailing regulations. Consequently, the biosolids are now inseparably mixed with other contaminants-laden solid phases, thus rendering them often questionable for land or agricultural applications.

The foregoing environmental problems, as diverse as they may appear, can be greatly resolved by using Magnetically Active Polymeric Particles (MAPP). While the polymeric particles can be tailored to improve sorption affinity for a specific class of contaminants, incorporation of magnetic activity (ferro- or para magnetism) allows their retrieval from complex environmental matrix such as biosolids, lake or river sediments or a large storage tank containing a viscous radioactive liquid. While the technology of magnetic separation of solid particles through use of permanent or electromagnets has come of age in mining and ore beneficiation industry, the preparation and characterization of MAPP for enhanced environmental separation is virtually unexplored.

Ideally, MAPP should be durable, non-biodegradable, highly selective toward target contaminants and amenable to regeneration and reuse without any loss in magnetic activity after prolonged usage. The technique of imparting magnetic activity into a polymer particle (measured as magnetic susceptibility) needs to be fine tuned so that different polymer particles may attain different magnetic activities allowing efficient downstream separation by varying the strength of the magnetic field. Particle sizes and magnetic activity require to be optimized so that MAPP remain dispersed in the liquid phase and exhibit high sorption kinetics.

Collaboration between the geology and environmental engineering groups at Lehigh University during the last eighteen months has resulted in the preparation and characterization of several magnetically active polymeric sorbents. X-ray diffractograms have identified stable magnetite nano-crystals within the gel phase of the polymer particles with high affinities toward phosphates and arsenic oxyanions. The magnetic activity measured through susceptibility meters remained unchanged after fifteen sorption/desorption cycles. The future course of inter-disciplinary research and an array of possible applications of MAPP benefiting complex environmental separation will be presented.

TURBULENCE, STRATIFICATION AND RESIDUAL FLOWS IN ESTUARINE AND COASTAL ECOSYSTEMS. by: Mark T. Stacey (mstacey@socrates.berkeley.edu), 631 Davis Hall, Department of Civil and Environmental Engineering, University of California-Berkeley, Berkeley, CA 94720-1710 and T.M. Powell (zackp@socrates.berkeley.edu), VLSB 3060, Department of Integrative Biology, University of California-Berkeley, Berkeley, CA 94720-3140.

Urbanized coastal habitats and estuarine ecosystems are placed under extreme stress from the large human populations which live in contact with them. Examples include the introduction of toxic chemicals, such as heavy metals from wastewater discharges, and loading perturbations, such as the increase in nutrients leading to an outbreak of *Pfiesteria* in Chesapeake Bay. In spite of these stresses, estuarine ecosystems remain critical biological communities because they are regions of high primary productivity, act as nursery grounds for certain species of fish, and provide thoroughfares for anadromous species.

In these bodies of water, tidal flows, winds and waves interact with the density variations imposed by river flows to produce an extremely complex hydrodynamic environment. When there are density variations, the water column has a tendency to stratify. Stratification, however, is offset by mixing in the water column. This mixing can be produced from a variety of sources: tidal flows, winds, surface waves, or interactions of internal waves. The level of stratification is then determined by the balance between the production of mixing from these sources and the maintenance of stratification by density forcing.

The levels of stratification and mixing which result from this interaction is one component which determines the health of the ecosystem. In the estuarine environment, the timing and magnitude of stratification has a direct link to blooms of phytoplankton. Stratification and mixing on the tidal timescale is also an important component in determining residual circulation. Residual flows set the transport and dispersion of larval fish, and are therefore important in determining whether young fish are delivered to the proper nursery grounds to mature. Moreover, residual flows are one signal used by anadromous species to find their way through the estuary – alterations to these flows may have resulted in problems with migrating species in San Francisco Bay.

Environmental engineers and scientists are in the unique position to be able to address these issues from a multidisciplinary angle – bringing expertise from the hydrodynamic, biological, and chemical fields. In developing a hydrodynamic model, the proper parameterization of turbulent mixing is necessary if the model is going to accurately predict the level of stratification, and hence the residual circulation. The oceanographic community is beginning to realize the importance of these small-scale physical processes to the modeling of large-scale transport and dispersion. In estuarine and near-coastal environments, the impact of turbulent mixing is even more direct and pronounced.

Finally, as technology evolves and our ability to observe hydrodynamic phenomena (and coupled biological and geo-chemical features) quantitatively in these energetic estuarine and coastal environments, inverse modeling and data assimilation will have an increasingly important role in understanding the flows—for both parameter and boundary condition estimation. It is important for us, as environmental engineers and scientists, to be involved with the development of this important new field. The application of these techniques is becoming widespread in the oceanographic literature and similar benefits may be gained by applying them to the smaller-scale flows in the near-coastal environment.

BIODEGRADATION OF 1-NAPHTHOL IN THE PRESENCE OF DISSOLVED HUMIC ACID. *by: M. Tuntoolavest (munruk@psu.edu) and W.D. Burgos (bburgos@psu.edu), 212 Sackett Engineering Building, Department of Civil & Environmental Engineering, The Pennsylvania State University, University Park, PA 16802.*

Previous research on the impact of dissolved humic substances on the biodegradation of organic contaminants has produced apparently contradictory results. The presence of humics have been shown to increase, decrease, or have no effect on the rate of degradation of aromatic contaminants. Humics have also been shown to increase or decrease the extent of degradation of aromatic contaminants. The objectives of this research were to study the impact of a purified A horizon forest soil humic acid on the biodegradation of 1-naphthol in batch reactors under conditions of controlled pH, ionic strength and bacterial numbers to better understand these processes.

A naphthalene-enrichment mixed culture and a 1-naphthol-degrading pure culture (isolated from the mixed culture) were both tested. A "specific activity" test was developed to ensure that relatively equal amounts of viable organisms were added with either culture. All experiments were performed under nongrowth conditions by excluding nitrogen from the reactor solutions. The sorption of 1-naphthol to dissolved humic acid was measured using an equilibrium dialysis technique and allowing 7 d for equilibrium to establish. Results showed that in a 10 mM LiCl background electrolyte with constant 1-naphthol and humic acid concentrations, sorption reached a plateau above pH 8. These results were used to select the pH of the biodegradation experiments (pH 8.1 ± 0.1 , phosphate buffer; ionic strength equivalent to 10 mM LiCl) and the length of the ^{14}C -1-naphthol-humic acid pre-equilibration (7 to 10 d) to ensure significant sorption would occur. Initial 1-naphthol concentrations were varied between 0.16 and 21.3 mg L^{-1} and humic acid concentrations were 0, 10 or 65 mg C L^{-1} . The rate and extent of 1-naphthol biodegradation were measured as contaminant loss from solution (by both HPLC and LSC) and $^{14}\text{CO}_2$ evolution over a 3 d period.

A zero-order 1-naphthol biodegradation rate measured over the initial 24 hours was used to evaluate the impact of the humic acid. For either the mixed or pure-cultures, no significant difference in biodegradation rates were caused by the presence of humic acid. Also, no significant difference in biodegradation rates for the two cultures (for identical test conditions) was observed. However, the extent of degradation was significantly affected by the presence of humic acid. For both cultures at low initial 1-naphthol concentrations, sorption of 1-naphthol, or soluble intermediates, to humic acid reduced the extent of biodegradation. For the mixed culture at high initial 1-naphthol concentrations, the extent of 1-naphthol biodegradation was enhanced in the presence of humic acid. We believe these results demonstrate that at low 1-naphthol-to-humic acid ratios sorption can reduce bioavailability, while at high 1-naphthol-to-humic acid ratios sorption can reduce the "free" 1-naphthol concentration below a level that would otherwise be harmful to the bacteria, therefore allowing further biodegradation to occur.

ADSORPTION OF AZO DYES ON ORGANOPHILIC CLAYS. by: A. Uribe (uribea@email.uc.edu) and M. J. Kramer (kramermk@email.uc.edu), P.L. Bishop (pbishop@uceng.uc.edu), 741 Bladwin Hall, Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH 45221-0071.

Organophilic clays have been increasingly used as adsorbents of organic compounds from water solutions²⁰. Azo dyes as a general class of organic dyes can be removed from aqueous phases by means of adsorption onto organo-clays. Development of the adsorption capacity of organophilic clays for distinct dyes is a primary objective of this study. Structural Activity Relationships (SAR) between adsorption and dye structure can be developed from isotherm data collected. The salient motifs of the dye structure can be modified, from which we can correlate adsorption relationships. Utilizing the X-ray Diffraction (XRD) technique, spatial determination of dye adsorption can be found.

Mono-azo and Poly-azo dyes were utilized to develop a SAR for quaternary alkyl ammonium substituted clays. Adsorption capacities from individual and mixed dye solutions were calculated from isotherm data. Correlations from adsorption capacity and chemical structure will be used in the development of SAR for azo dyes.

Mono and Poly-azo compounds with common core structures form the basis of our SAR. Chemical substitutes on the aromatic cores are selected on the basis of their potential interaction with adsorbent surfaces.

Sorbed species into the organic phase of the modified clay have an important role in the expansion of the clay. Reported expansion coefficients for alkyl ammonium substituted clays range from 10% up to >50%²¹. XRD data was used to determine the expansion coefficient of the organo-clay once the adsorption process reached equilibrium; comparative analysis of the dye structure versus the expansion coefficient are given.

Chemical behavior and bondage structures were interpreted using FT-IR spectra obtained from some of the samples. Desorption processes under varying pH conditions were studied. Recovery of azo dyes from desorption processing was analyzed as a possible means of purification and reuse.

²⁰ Dentel, S.K., Bottero, J.Y., Khatib, K., Demougeot, H., Duguet, J.P., and Anselme C., 1995. Sorption of tannic acid, phenol and 2,4,5-trichlorophenol on organoclays. *Wat. Res.* 29, 5, 1273-1280.

²¹ Zhao, H, Jaynes, W.F., and Vance G.F., 1996. Sorption of the ionizable organic compound, Dicamba (2,6-Dichloro-2-methoxy benzoic acid), by organo-clays, *Chemosphere*, 33, 10, 2089-2100.

MODELING AND MEASURING BIOGEOCHEMICAL KINETIC EXPERIMENTS: SYSTEM CONSISTENCY, DATA NEEDS AND RATE FORMULATION. *by: G.T. Yeh (gty2@psu.edu) and W.D. Burgos (wburgos@psu.edu), 212 Sackett Engineering Building, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA 16802.*

Numerous issues need to be addressed before a mechanistic-based reactive biogeochemical model can justifiably claim to be superior to more widely employed "ad hoc" biogeochemical models. The most important issues among others are: (1) the assessment of minimum data needs of experiments required for the verification of experimental hypotheses, (2) the assessment of system consistency associated with reaction hypotheses, and (3) the formulation of reaction processes and the determination of reaction parameters. The central issue in biogeochemical modeling experiments is the formulation of r_i (the production/degradation rate of i -th species) and the determination of parameters associated with it. There may be two general means of formulating r_i : ad hoc and reaction-based formulations. In an ad hoc formulation, the production/degradation rate is simply obtained with empirical functions. The problem with an ad hoc approach is that it will result in an inadequate parametrization in which the reaction parameters are not "true" constants; thus they are only applicable to the exact experimental conditions tested.

Reaction-based formulations should be taken if we are to obtain "true" constants broadly applicable to diverse biogeochemical conditions. This poster focuses on reactive biogeochemical modeling methods, issues, and data needs. We show that (1) to assess system consistency, data needs, and equilibrium assumptions, and to facilitate numerical integrations, the set of ordinary differential equations governing the evolution of biogeochemical species should be decomposed into three subsets of equations: mass action equations, kinetic-variable equations, and mass conservation equations; (2) equilibrium constants for all linearly independent "fast" equilibrium reactions can be determined one reaction by one reaction; (3) reaction rate constants (parameters) for those "slow" kinetic reactions that are linearly dependent on equilibrium reactions are irrelevant to the problem; (4) rate constants for a Kinetic reaction that is linearly independent of other kinetic reactions can be determined based on only one curve of species concentration-vs-time; and (5) rate constants for those kinetic reactions that are linearly dependent on each other must be determined simultaneously based on a number of curves of concentration-vs-time that are exactly equal to the number of those reactions.

Two demonstrative examples of geochemical and biogeochemical reactive systems are used to illustrate the idea of assessing system consistency and minimum data needs for reaction-based modeling. The first example considers the metal adsorption to ferric oxide, while the second example considers the bioreduction of ferric oxide. These examples highlight the need for simple "model" systems to study biogeochemical reactions because the inclusion of additional species will involve several more reactions and usually always increase the minimum number of species concentrations that must be measured. In the first example, more than the minimum number of species concentrations could be directly measured for the initial conceptualization of the geochemical reactions. As additional reactions and species were added to that system, the data needs exceeded the number of (easily) measurable species. Either additional surface analytical techniques were required, or the experimental design needed to be altered to minimize the number of surface species present. In the second example, less than the minimum number of species concentrations could be directly measured for the initial conceptualization of the biogeochemical reactions. For that case the conceptualized reactions and species had to be reduced, or additional surface analytical techniques were required. Both of these examples are useful in evaluating data needs for measuring biogeochemical reactions, and demonstrate iterative refinement between the specification of a reactive system and the experimental design.

NOVEL ENVIRONMENTAL TECHNOLOGIES DRIVEN BY ELECTRIC AND MAGNETIC FIELDS.
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Novel environmental technologies based on electric and magnetic fields are presented. An electrohydrodynamic method is used to form microbubbles of a gas in a liquid, and thereby increase the interfacial area for mass transfer. Based on this approach, an electro-ozonation method is discussed and enhanced ozonation rates for phenol and methylene blue are demonstrated. It is also shown that by using a strong electric field, there is no need for ozone. Oxidative radicals formed in oxygen under corona-discharge conditions destroy organic pollutants in water at the same rate as ozone. The use of electric fields in (i) mixing of both miscible and immiscible fluids, (ii) liquid-liquid extraction, (iii) distillation, (iv) electro-sorption of metal ions, and (v) materials processing are demonstrated. Magnetic fields are also used to separate paramagnetic, super-paramagnetic, and diamagnetic particles from aqueous suspensions. Magnetic flocculation and filtration phenomena are presented and their applications in environmental separations are discussed.

MICROSENSORS AS NOVEL ANALYTICAL TOOLS FOR COMPLEX ENVIRONMENTAL SYSTEMS. by: *Tong Yu* (yut@email.uc.edu) and *Paul L. Bishop* (pbishop@boss.cee.uc.edu), Department of Civil and Environmental Engineering, University of Alberta, Edmonton, AB, Canada T6G 2G7; Department of Civil and Environmental Engineering, University of Cincinnati, Cincinnati, OH 45221-0071.

Research Scope

Microsensors consist of microelectrodes, micro-biosensors and fiber-optic microsensors. Their tip diameters are typically from 1 to 50 μm . These microsensors have been developed primarily in analytical chemistry and aquatic sciences. They can be used to measure O_2 , H_2 , N_2O , H_2S , CO_2 , pH, NH_4^+ , NO_3^- , NO_2^- , Cl^- , Ca^{2+} , S^{2-} , S_6 , Fe^{2+} , Mn^{2+} , CH_4 , redox potential, glucose, and dissolved organic carbon. Microsensors are effective analytical tools for studies of complex environmental systems. Their tiny tips and high spatial resolution enable us to directly measure these chemical species in micro-environment. The early efforts to introduce the microsensor techniques into environmental biofilm studies have produced very encouraging results.

The research scope at this frontier includes (1) the study and development of the microsensor techniques for environmental engineering and sciences and (2) the application of the microsensor techniques to the studies of complex environmental systems.

Impact

The microsensor techniques, both applied alone and combined with the molecular biology tools, can significantly improve our understanding of the complex systems in different environmental research areas. Our improved understanding will ultimately lead to rational optimization of environmental engineering processes and to a sustainable environment.

Long-Range Goals

The long-range research goals are the follows: (1) Introduce currently available microsensor techniques into environmental engineering and sciences. The current and potential application areas include studies in marine/lake sediments, microbial mats, biofilms, activated sludge, biofouling, biocorrosion, drinking water disinfection, soil remediation, and vegetation/plantation(?). An example is the combination of the microsensors with the molecular probes for studies of complex microbial systems. (2) Develop new and better microsensors for the special needs of environmental studies. One example is the fiber-optic microsensors and micro-biosensors targeted at environmentally-significant organic molecules. The other example is microsensors with improved selectivity, stability and response time. (3) Modify the microsensor techniques for special environmental applications. To use microsensors for *in situ* measurement and to develop "easy-to-use" microsensors and microsensor-array for direct measurement in the field are of special interest to environmental researchers.

Role Of Environmental Engineers And Scientists

To reach the first goal, environmental engineers/scientists need to learn the currently available microsensor techniques and then to apply them to their environmental research. To reach the second goal, environmental engineers/scientist should provide the requirements as users and rely on the expertise of the analytical chemists on the development of new microsensors. To reach the third goal, environmental engineers/scientists have to work with scientists who have expertise in microsensor techniques side-by-side in interdisciplinary teams.

Immediate Steps

The following immediate steps can be taken to address this research need: (1) Increase the communication and interaction between environmental engineers/scientists (the users) and scientists with expertise in microsensor techniques (the suppliers). (2) Encourage environmental engineers/scientists to learn different microsensor techniques and to apply them to the above mentioned environmental research areas. (3) Encourage collaborative research on the microsensor techniques between environmental engineers/scientists and analytical chemists as members of interdisciplinary research teams.