Water Resources Center

Annual Technical Report

FY 1999

Introduction

The Water Resource Problems of Delaware Delaware has more than 2,509 miles of rivers and streams, and 2,954 acres of lakes and ponds that have been classified using the federal Clean Water Act's rating system of designated uses (such as drinking water supply, swimming, fishing, etc.). Delaware has promulgated surface water quality standards which are designed to protect the designated uses of each classified water body in the State. While Delaware's rivers and streams generally meet the standards for their designated uses, the Department of Natural Resources and Environmental Control (DNREC) has found that 79% do not support the swimming use and 62% do not support the fish and wildlife uses. The major causes of non-attainment of designated uses of Delaware's water resources are high levels of pathogenic bacteria, nutrient over-enrichment, toxics, and degradation of physical stream habitat. The majority of the water quality standard violations are due to nonpoint source poution impacts. Bacteria concentrations above the level considered acceptable for primary conract recreation are found in 79% of Delaware's rivers and streams, 40% of ponds and lakes and 16% of estuarine waters (excluding the Delaware River and Bay). Safe shellfish harvesting and consumption is also adversely impacted by high bacteria levels in many of Delaware's estuarine and tidal waters. Nutrient over-enrichment of Delaware's water bodies is due to soil erosion, failing septic systems, and nutrient losses from land application of manure and fertilizer. Lowered dissolved oxygen levels and nuisance plant growth result from excess nutrients in Delaware's waterbodies. Toxics, such as Polychlorinated Biphenyls (PCB's), dioxin, chlorinated benzenes and pesticides persist in the environment and accumulate in the flesh of fish. Several rivers and streams in Delaware, as well as the Delaware Bay, have fish consumption advisories due to toxics. Finally, physical habitat of 87% of Delaware's nontidal perennial streams is degraded due to several factors including increases in impervious surfaces as a result of urban land uses in the Piedmont, and stream channelization to improve drainage on agricultural lands in the Coastal Plain. Physically degraded stream habitats generally have decreased shade, less channel stability, and a reduction in runoff filtering vegetation. Results of degradation of physical stream habitat include reduced aquatic life diversity and violations of water quality standards for dissolved oxygen and temperature. Ground water in Delaware is impacted by nitrate contamination, particularly in the agricultural areas of Kent and Sussex counties. High nitrate levels in underground sources of drinking water are a potential health concern, as well as a source of nutrients to surface water. Synthetic organic compounds, such as cleaning solvents and degreasers have been detected in Delaware's gound water, primarily due to leaking underground strorage tanks, landfills, septic systems, chemical spills and leaks and abandoned hazardous waste sites. Elevated dissolved iron concentrations in well water and salt water intrusion are also ground water concerns for the State. The protection of the quality and quantity of the State's aquifers is a key concern, particularly given the fact that reliance on ground water for drinking water supplies has been increasing in Delaware. Priority areas for overall water quality and quantity research and implementation in Delaware include: enhanced management and control of stormwater runoff, erosion and sediment, a better understanding of the sources, transport, fate and remediation of toxics, comprehensive management of agricultural nutrients and sources of pathogenic bacteria, increased understanding of the response of aquatic systems to specific pollutants, identification and protection of key aquifer recharge areas, better managment of water supply and demand (including the financing of water supply infrastructures), treatment and disposal of on-site sewage, protection and restoration of wetlands and better understanding and

prevention of saltwater intrusion to potable water supplies. Due to the development pressures in northern Delaware and the coastal resort areas, attention to these issues is essential to protect the State's water supply. Delaware Water Resources Center Program Goals and Priorities The primary goal of the Delaware Water Resources Center is to support research that will provide solutions to the State's priority water problems. A secondary goal is to serve as a source of information to water researchers, decision makers, natural resource protection agency personnel and to the public through technology transfer projects. A third goal is to promote the training and education of future water scientists and engineers.

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin
Project Number	B-01
Start Date	03/01/1996
End Date	02/28/1999
Research Category	Water Quality
Focus Category #1	Hydrology
Focus Category #2	Water Quality
Focus Category #3	Models
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Carmine C. Balascio	Associate Professor	University of Delaware	01
Gerald Kauffman	Research Associate	University of Delaware	02

Problem and Research Objectives

Section 303(d) of the 1972 Federal Clean Water Act (CWA), as amended, requires States to develop a list of water bodies that need additional pollution reduction beyond that provided by the application of existing conventional controls. These waters are referred to as "Water Quality Limited". States are required to establish Total Maximum Daily Load s (TMDLs) for water quality limited segments of water bodies. A TMDL establishes the maximum amount of pollutants a waterbed can receive without

violating water quality standards, thereby allowing use goals such as swimming, fishing and drinking water supply to be met. Delaware is establishing pollutant load reduction targets to meet water quality standards in priority water bodies of the State. TMDLs are currently pursued for high priority waters in the State which have the most severe water quality problems, such as the Christina River Basin. The primary objective of the subject project was to obtain flow and water quality data for the Christina River Basin. The data is being used to calibrate the hydrology and water quality model HSPF. The calibration requires a number of different storm types, spread throughout the different seasons of the year. Some parameters require calibration with low intensity, long duration rainfall. Others are more sensitive to high intensity, short duration events. With a permanent sampling station installed it will be possible to gather data for a full range of storms in addition to dry period flow data, which is valuable for continuous simulation model calibration. The HSPF model will be used to calculate the TMDL allocations for the Christina River Basin. The project is part of a large interstate effort between Delaware and Pennsylvania to quantify existing and allowable pollutant loadings from point and non-point sources to the Christina River. The full TMDL process will determine the pollutants causing water quality impairments, identify maximum permissible loading capacities for water quality limited segments of the Christina River, and for each relevant pollutant, assign load allocations to each of the different sources, point and nonpoint, in the watershed

Methodology

A sampling station was constructed, equipment and a communications system was installed and tested. An ISCO integrated flow meter and storm sampler was used at the USGS gage site. Flow and water quality data for six large frontal storm systems were collected over the course of the year.

Principal Findings and Significance

The DWRC funded objectives of the project have been met, namely to construct a permanent sampling station in the Christina River Basin, and collect flow and water quality data for several storm events over the course of a year. Synthesis, reduction and analysis of the collected data is now underway. To address the problems of some gaps in the data, University investigators are working on techniques for synthesizing required rainfall inputs, which will be available this summer in a paper entitled, "Multiquadric Equations, Kriging and Rainfall Estimation". Once the data is adequately prepared, the USGS will use the data to calibrate the HSPF model. Full calibration of the model is expected by the Spring of 2001. The model will be used to calculate TMDL allocations for the Christina River Basin and project findings will be used as a guide for other watersheds in the Mid-Atlantic Region.

Descriptors

Title: Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin Project Number: B-01 Start Date: March 1996 End Date: February 1999 Investigators: Carmine C. Balascio, Department of Bioresources Engineering, University of Delaware Gerald Kauffman, Water Resources Agency for New Castle County Focus Categories: WQL Congressional District: Delaware-at large Descriptors: Water Quality, Hydrologic Processes, Water Quantity, Water Quality Modeling

Articles in Refereed Scientific Journals

Balascio, C.C. , D.J. Palmeri, and H. Gao. 1998. "Use of a genetic algorithm and multi-objective programing for calibration of a hydrologic model" in TRANSACTIONS of the ASAE, 41(3), Minneapolis, MN, pages: 615-619. Balascio, C.C. 1999. " The characteristics of multi quadric

equations and other surface-fitting techniques for rainfall interpolation and estimation" in preparation for submittal to ASCE Journal of Hydrologic Engineering.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Geochemistry, Geostatistics and Hydrology of Phosphorus Losses in Agricultural Drainage: Developing Improved Phosphorus Management Practices for Surface Water Protection
Project Number	C-02
Start Date	09/01/1996
End Date	08/01/1999
Research Category	Water Quality
Focus Category #1	Hydrology
Focus Category #2	Agriculture
Focus Category #3	Non Point Pollution
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
James Thomas Sims	Professor	University of Delaware	01
Donald Lewis Sparks	Professor	University of Delaware	02
Alan Scott Andres	Research Associate	University of Delaware	03

Problem and Research Objectives

The overall goal of this research project is to better understand the processes controlling the release and transport of P from high P agricultural cropland to surface water. The study integrates basic and applied soil chemical experiments on the fate and release of soil P with landscape scale geostatistics and hydrologic modeling to provide a sensible, mechanistically sound foundation for agricultural P management. There are three specific research objectives of the project. The first objective is to develop a sound, fundamental understanding of the soil and geochemical processes that control the release of P to drainage waters and to surface runoff. Second, geostatistical analyses will be used to quantify the extent of P saturation of the agricultural cropland in Delaware's Inland Bays Watershed, site of a national estuary and many small locally important ponds and lakes. Finally, hydrologic modeling will be conducted to begin preliminary characterization of the flow paths of agricultural drainage waters and surface runoff from agricultural cropland in Delaware's Inland Bays Watershed. Ultimately the study should help identify areas where improved management practices for P should be focused in Delaware's Inland Bays Watershed. Furthermore, the integrated nature of the study should allow its application to many other areas in the Atlantic Coastal Plain faced with similar water quality problems.

Methodology

Residence time effects (<24 hours and >24 hours) on the kinetics of P adsorption/desorption at the ferrihydrite/water interface at pH=4, I=0.1M NaCl, and [P]o=1mM were evaluated. In addition a short-term (24 hour) desorption study under the same reaction conditions was studied using a stirred-flow apparatus. In-situ ATR-FTIR analysis was used to evaluate the mechanisms of P sorption and X-ray absorption. Near edge structure spectroscopy (XANES) was used to determine the nature of mineral formation following P adsorption by ferrihydrite. Work continued on modifying the hydrologic component of the FHANTM model for Delaware conditions. The model was modified based on specific information related to soil water holding capacity, site-specific data on soil erosion, and updated rainfall information. The P chemistry module in FHANTM has been modified to more appropriately reflect the chemistry of P in mid-Atlantic soils. We conducted P desorption studies that evaluated, for 23 soils, the effects of time, soil to water ratio, and initial desorbable P on P desorption. The information from these studies was then used to develop a predictive model that can be used to characterize P desorption based on readily measured soil properties.

Principal Findings and Significance

Adsorption kinetics for P were initially fast, resulting in 93% of the total adsorption completed within 6 hours, followed by a slow P uptake. Only approximately 5% of total adsorbed P was recovered after in a sample incubated for 2 days. The total P recovery decreases <1% with increasing aging time from 2 days to 10 months. Temperature dependent adsorption shows that the initial 15 minutes of reaction was diffusion rate-limited. The reaction between 6 hours and 360 hours was dependent on endothermic reaction, suggesting a predominantly chemically controlled reaction. In-situ ATR-FTIR analysis showed the formation of either protonated monodentate mononuclear or bidentate binuclear complexes of P at the loading level of 100-700uM g-1. The formation of iron phosphate precipitate (i.e., amorphous strengite) was observed using XANES spectroscopy, and the mineral formation was rapid (< 5 minutes) and enhanced with increasing time up to 48 hours. The hydrologic component of the FHANTM model has been modified for Delaware conditions. Testing of the hydrologic component of the model is underway. The P chemistry component of the FHANTM model has been improved

based on studies evaluating P desorption. Oxalate Fe and Al are the major soil components that will control P desorption. A predictive model that characterizes P desorption based on these soil properties has been developed and is now being validated.

Descriptors

Title: Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection Project Number: C-02 Start Date: September 1996 End Date: August 1999 Investigators: Dr. James Thomas Sims, Department of Plant and Soil Sciences, Dr. Donald L. Sparks, Department of Plant and Soil Sciences Scott Andres, Delaware Geological Survey University of Delaware, Newark, DE 19717-1303 Focus Categories: GW, WQL Congressional District: Delaware-at large Descriptors: Water Quality, Hydrology, Geochemistry, Animal Waste, Agricultural Drainage, Phosphorous

Articles in Refereed Scientific Journals

Journal Articles: Vadas, P. A. and J. T. Sims. 1999. Phosphorus sorption in manured Atlantic Coastal Plain soils under flooded and drained conditions. Journal of Environmental Quality 28:1870-1877. Pautler, M.C. and J. T. Sims. 2000. Relationships between soil test phosphorus, soluble phosphorus, and phosphorus saturation in Delaware soils. Soil Science Society of America Journal 64:765-773.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	The Effect of Biosurfactants on the Fate and Transport of Nonpolar Organic Contaminants in Porous Media
Project Number	C-03
Start Date	09/01/1997
End Date	08/01/1999
Research Category	Ground-water Flow and Transport
Focus Category #1	Groundwater
Focus Category #2	Solute Transport

Focus Category #3	Treatment
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Mark Radosevich	Associate Professor	University of Delaware	01
Yan Jin	Assistant Professor	University of Delaware	02
Daniel K. Cha	Assistant Professor	University of Delaware	03

Problem and Research Objectives

Biological degradation is widely accepted as the primary dissipation mechanism for most organic pollutants in the environment, but the activity of degrading microorganisms is dependent upon many factors including: contaminant uptake and bioavailability, concentration, toxicity, mobility, access to other nutrients, and activated enzymes. Mass transfer from sorbed or insoluble phases is often considered to be the rate-limiting step in biodegradation of organic contaminants because the compounds must be released to the aqueous phase prior to entering the microbial cell and subsequent intracellular transformation by the necessary catabolic enzymes. Evidence has emerged that is inconsistent with the assumption that only aqueous-phase contaminants are available for microbial attack (Crocker et al., 1995; Guerin and Boyd, 1992; Harms and Zehnder, 1995; Ortega-Calvo and Alexander, 1994; and Osswald et al., 1996). These studies propose that while some microorganisms are limited to aqueous-phase substrates, others may be better adapted for accessing contaminants which are sorbed to soil or partitioned into a NAPL. In any case, it is clear from recently reported research that the bioavailability of a contaminant is species-specific, and in many instances, not strictly limited to aqueous-phase substrates. Overcoming rate-limited mass transfer to enhance removal and degradation of pollutants has been the focus of many recent studies. The results of these investigations have shown that desorption, solubility, and mobility of hydrophobic contaminants can be enhanced through the addition of synthetic and biologically-produced surfactants that can lower the surface and interfacial tension of aqueous media (Jafvert et al., 1994; Noordman et al., 1998; Nam and Alexander, 1998a; Zhang and Miller, 1992, 1994, 1995, and 1997). While it is clear that biosurfactants can enhance hydrocarbon desorption and solubility, their effect on bioavailability and degradation are less straightforward. The addition of biosurfactant to soil-water systems has been shown to have conflicting effects on contaminant mineralization by different bacteria (Allen et al., 1999; and Stelmack et al., 1999). The presence of surfactants at a concentration equal to one-half the critical micelle concentration (CMC) inhibited the uptake and biodegradation of non-aqueous phase liquid (NAPL) extracts from creosote-contaminated soils presumably due to reduced bacterial adhesion to the NAPL-water interface (Stelmack et al., 1999). Another study by Allen et al. (1999) showed that the surfactant Triton X-100 had contrasting effects on PAH degradation by two PAH-degrading microorganisms. The presence of the surfactant enhanced mineralization of both naphthalene and phenanthrene (PHE) by Pseudomonas strain NCIMB 9816, but in equivalent systems inhibited the degradation of the same contaminants by Sphingomonas yanoikuyae (Allen et al., 1999). Other studies have implicated biosurfactants in the alteration of cell hydrophobicity causing cells to aggregate or form clusters and also the disruption of bacterial attachment to soil and artificial matrices (Herman et al., 1997; and Zhang and Miller, 1992). Clearly, the addition of surfactants to contaminated systems

can enhance the desorption and mobility of hydrophobic contaminants, but the increased aqueous concentrations do not necessarily result in concomitant bioavailability enhancement (Stelmack et al., 1999). The primary goals of this study during the reporting period were to 1) investigate the differential bioavailability of phenanthrene to PHE-degrading bacteria (isolate P5-2 and P. strain R) in model aqueous and soil systems; 2) to assess potential cell-cell interactions between the PHE-degrading bacteria and a rhamnolipid-producing strain, Pseudomonas aeruginosa 9027; and 3) to determine the effect of added rhamnolipid biosurfactant on contaminant-soil and contaminant-microbe interactions in well defined soil microcosms. Three hypotheses were evaluated. We hypothesized that strain-specific bioavailability of sorbed PHE could be explained by cell attachment at the soil-water interface and/or the specific affinity of each strain for PHE. Second, we hypothesized that addition of surfactant would result in more rapid PHE mineralization for the strain with a higher specific affinity for PHE (P5-2) by increasing the soluble PHE concentration and inhibit PHE mineralization by the strain with a low specific affinity (P. strain R) for PHE by inhibiting cell attachment to the soil-water interface. Finally, we hypothesized that accelerated degradation in soils co-inoculated with PHE-degrading bacteria and a rhamnolipid-producing bacterium (summarized in previous annual report) resulted from in situ production of biosurfactant. To test this hypothesis, rhamnolipid was added in parallel experiments to enhance PHE dissolution and desorption and to evaluate its effects on PHE biodegradation in soils that were co-inoculated with various combinations of the test bacterial strains.

Methodology

To complete the objectives described above, a series of PHE-degradation experiments in model aqueous and soil batch and column systems inoculated with various combinations the test bacterial strains were conducted. PHE-degradation was monitored by measuring the production of 14CO2 from labeled PHE or via HPLC analyses. Sorption and release kinetics of PHE from solid matrices were evaluated in standard batch equilibration experiments with and without added surfactants. Work is also ongoing to develop a fluorescent in situ hybridization method to track time-resolved changes and spatial distributions of the test bacterial strains in co-inoculated systems. These experiments are based on strain-specific 16S rRNA probes that we have developed from sequence analysis of the three bacterial strains used in the degradation experiments.

Principal Findings and Significance

P. strain R was able to mineralize a greater portion of sorbed-PHE than strain P5-2 but in aqueous cultures the rate and extent of PHE-mineralization was greater in systems inoculated with isolate P5-2. In high organic matter soil (Fallsington sandy loam), where the sorption of PHE was the greatest, addition of rhamnolipid at 5 CMC increased PHE mineralization in systems inoculated with P. strain R. PHE mineralization in soils inoculated with P5-2 was low or undetectable and no consistent change in PHE degradation was observed when biosurfactant was added to these systems. Co-inoculation of Fallsington soil with the biosurfactant-producer did not affect PHE-mineralization by isolate P5-2, but significantly enhanced PHE-mineralization by P. strain R. Based on soil and aqueous degradation experiments, the enhancement of PHE-mineralization in co-inoculated systems could not be explained by P. aeruginosa-mediated PHE-degradation. The addition of rhamnolipid biosurfactant at concentrations above the CMC resulted in enhanced PHE-release from test soils. These results suggest that the PHE-degrading strains were able to access different pools of PHE in the soil and that the enhanced solubilization/release of PHE from soils resulting from the addition of biosurfactants does not result in enhanced bioavailability for some microorganisms. The results also demonstrated that bacteria with the catabolic potential to degrade sorbed hydrophobic contaminants could interact commensally with surfactant-producing strains by an unknown mechanism to hasten the

biodegradation of soil-bound, hazardous, organic pollutants. The results of this research clarify the species-specific effects of biosurfactants on cell-cell, cell-soil, and contaminant-soil interactions and will support the development of more efficient biological approaches to decontaminate soils polluted with hydrophobic organic chemicals.

Descriptors

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Chengwei Fang, Ph.D., Fall '99, Ph.D. Dissertation. Mechanisms of enhanced organic contaminant degradation in the grass rhizosphere. University of Delaware, Newark, DE Svetlana Wilson Fall '99 M.S. Thesis. Effect of biosurfactant and bacterial co-inoculation on phenanthrene fate and transport in soil: batch and column studies. University of Delaware, Newark, DE

Water Resources Research Institute Reports

Conference Proceedings

Chang, J.S., D.K. Cha, M. Radosevich, and Y.Jin. 1999. "Mineralization of phenanthrene in the presence of biosurfactants produced by Rhodococcus erythropolis". In Hazardous and Industrial Wastes, 31st Mid-Atlantic Industrial and HazardousWaste Conference Proceedings.

Other Publications

Information Transfer Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Delaware Water Resources Center Homepage
Description	The homepage provides information on current DWRC research projects, final reports, requests for proposals for grant funding, upcoming water resource conferences and links to other water resource sites.
Start Date	01/03/1996
End Date	01/03/2003
Type	Library And Database Services
Lead Institution	Water Resources Center

Principal Investigators

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Basic Project Information

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Category	**Data**
Title	Interstate Initiatives for Clean Water in the Christina River Basin
Description	Presentation on DWRC funded research project entitled: "Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin"
Start Date	06/17/1999
End Date	06/17/1999
Type	Conferences
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Carmine C. Balascio	Associate Professor	University of Delaware	01
Gerald Kauffman	Professional Staff	University of Delaware	01

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Basic Project Information	
Category	**Data**
Title	DWRC Graduate Fellowship and Undergraduate Internship Program
Description	The DWRC approved three new graduate fellowship research projects and eight new undergraduate internship research projects for funding this year. All eleven projects address water resource issues of concern to Delaware. The fellowship and internship program will help to fullfill one of the primary goals of the DWRC, which is to promote the training and education of future water scientists and engineers.
Start Date	11/15/1999
End Date	02/28/2001
Type	Publications
Lead Institution	Water Resources Center

Principal Investigators

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Basic Project Information	
Category	**Data**
Title	Delaware Water Resources Center (DWRC) Advisory Panel
Description	The DWRC Advisory Panel was expanded to include 16 representatives from numerous organizations in the State which have significant expertise and interest in water resource research, management and education. The panel responsibilities have been to provide peer review and ranking of research proposals, help plan the annual DWRC conference, promote the interaction of the DWRC with other agencies and advise the Director on State priority research focal areas and the best ways to accomplish the Center's mission.
Start Date	11/16/1999
End Date	11/16/2003
Type	Conferences
Lead Institution	Water Resources Center

Principal Investigators

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Basic Project Information

Basic Project Information	
Category	**Data**
Title	Annual Meeting of the Soil Science Society of America
Description	DWRC funded research presentations were made at the conference
Start Date	11/17/1999
End Date	11/18/1999
Type	Conferences
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Peter Vadas	Student	University of Delaware	01
Yuji Arai	Student	University of Delaware	02
Maria C. Pautler	Research Associate	University of Delaware	03
James Thomas Sims	Professor	University of Delaware	04
Donald Lewis Sparks	Professor	University of Delaware	05

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Water Resources Research Institute Reports

Conference Proceedings

Vadas, P.A., and J.T. Sims. 1999. Modifying the phosphorus component of the FHANTM2 model for use in Delaware soils. Annual Meeting of the Soil Science Society of America, Salt Lake City, Utah. Pautler, M.C., and J.T. Sims. 1999. Using agronomic soil tests to characterize phosphorus saturation in Atlantic Coastal Plain soils. Annual Meeting of the Soil Science Society of America, Salt Lake City, Utah. Arai, Y. and D. L. Sparks. 1999. Phosphorus fraction dynamics in amended soils. Annual Meeting of the Soil Science Society of America, Salt Lake City, Utah.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	General Meeting of the American Society for Microbiology
Description	Presentation on DWRC funded research. Title of presentation: The Influence of Cell-Cell-Interactions on Phenanthrene Degradation in Soils Co-inoculated with PHE-Degrading and Surfactant-Producing Bacteria
Start Date	01/03/2000
End Date	01/04/2000
Type	Conferences
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Stacy Dean	Student	University of Delaware	01
Yan Jin	Assistant Professor	University of Delaware	02
Daniel K. Cha	Assistant Professor	University of Delaware	03
Mark Radosevich	Associate Professor	University of Delaware	04

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Basic Project Information	
Category	**Data**
Title	Delaware Water Resources Center Water News
Description	A newsletter issued biannually by the Delaware Water Resources Center
Start Date	03/01/2000
End Date	10/01/2003
Type	Newsletter
Lead Institution	Water Resources Center

Principal Investigators

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Basic Project Information

Basic Project Information	
Category	**Data**
Title	Northeastern Branch of the American Society of Agronomy Meeting
Description	DWRC funded research presentation
Start Date	06/12/2000
End Date	06/15/2000
Type	Conferences
Lead Institution	University of Delaware

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Yuji Arai	Student	University of Delaware	01
Donald Lewis Sparks	Professor	University of Delaware	02

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Conference Proceedings

Arai, Y. and D. L. Sparks. 2000. Investigation of the residence time effect on phosphate adsorption/desorption mechanisms at the ferrihydrite/water interface using P XANES and ATR-FTIR. Northeastern branch of the American society of agronomy meeting, Newark, DE.

Other Publications

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	N/A	6	N/A	N/A	N/A
Masters	N/A	3	N/A	N/A	N/A
Ph.D.	N/A	4	N/A	N/A	N/A
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	N/A	13	N/A	N/A	N/A

Awards & Achievements

Peter A. Vadas: Received the Outstanding Graduate Student award from the Northeast Branch of the American Society of Agronomy and Soil Science Society of America for 1999-2000.

Publications from Prior Projects

Articles in Refereed Scientific Journals

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Dissertations

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