United States Department of Agriculture

National Institute of Food and Agriculture

Water and Watershed & Agricultural Water Science Programs Project Directors Meeting

Waterfront Centre
Washington D.C.
20024

February 2, 2011

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Research, Education, Extension

National Research Initiative/Agriculture and Food Research Initiative

Water and Watershed & Agricultural Water Science Programs Project Directors Meeting

United State Department of Agriculture
National Institute of Food and Agriculture
Washington D.C 20024

Welcome to the 2011 NRI/AFRI Projects Director Meeting

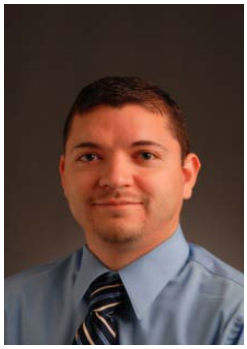
This year the Water and Watersheds program and the Agricultural Water Science Foundational Program meet jointly to share concepts, innovative methodologies, and successes. Our goal is to provide an opportunity for project directors to learn and engage in discussions that will improve your and our understanding of water issues in the evolving world of agriculture. At the same time this meeting will help enhance communication and interaction among NIFA staff and NRI/AFRI awardees. This meeting will assist NIFA staff in identifying success stories and outcomes resulting from sponsored research in these programs.

Awardees should benefit from the experiences of their colleagues and yield greater opportunity for successful completion of the NRI/AFRI award. Fostering communication among awardees, we feel, will result in better sharing of new information, and resources, and the development of new collaborations.

We are glad you are here. We hope that everyone who attends will be enriched and impressed by the exciting science, innovation, productivity of your fellow awardees. Thank you for coming!

Sincerely,

Jim Dobrowolski
National Program Leader
202-401-5016
jdobrowolski@nifa.usda.gov



Dewell D. Paez
Program Specialist
202-401-4141
dpaez@nifa.usda.gov

2011 Project Directors Meeting Agenda

February 2, 2011
Waterfront Centre
Washington D.C 20024
Room 1410 A-D

7:30 – 8:00 a.m. Poster set-up and continental breakfast

8:00 – 8:15 a.m. Welcome and Introductions - **Jim Dobrowolski, National Program Leader, Frank Boteler,** Assistant Director, Institute of Bioenergy, Climate, and Environment

8:15 – 9:45 a.m. **Poster Session I**

Influence of Soluble Organic Matter on Cryptosporidium Parvum Oocyst Mobility in Variable Charge Soils
Chittaranjan Ray - University of Hawaii, Honolulu

Use of Microarrays and Qpcr/Rt-Qpcr for Characterization of Viral Populations within Water Supplies Affected by Agricultural Activities
Fatimah Alhamlan (replacing Erik R. Coats) - University of Idaho, Moscow

Photochemical Disinfection of Pathogens: Influence of Extracellular Polymeric Substances on Bactericidal Capacity of Reactive Oxygen Species
David Cwiertny (replacing Sharon Walker) - The Regents of the University of California, Riverside

Quantification and Control of Bacterial Pathogens in Agricultural Watersheds
Philip Moore - USDA Agricultural Research Service, Fayetteville

Watershed Scale Assessment of a Karst Drainage Basin Using Microbial, Geospatial, and Geochemical Approaches
Alice Jones - Eastern Kentucky University, Richmond

The Influence of Subsurface Drainage on Watershed Stream Flow and Nitrate Load, and the Potential for Water Conservation
Laura Bowling - Purdue University, West Lafayette

Assessing Water Use and Water Quality Change with Respect to Large-Scale Expansion of Ethanol Feedstock Production in the United States
Burton C. English - University of Tennessee, Knoxville

Antibiotic Resistance, Gene Transfer, and the Horizontal Gene Pool of Agriculture-Associated Soils and Waters
Roderick I. Mackie - University of Illinois, Champaign

Predicting the Effects of Agricultural Practices on Waterborne Human Pathogens, Livestock Helminthes, and the Health of Rural Water-Bodies
Zachery Staley (replacing Jason Rohr) - University of South Florida, Tampa

A Hydro-Econometric Analysis of Producer Water use and Aquifer Hydrology in the Texas High Plain
Chenggang Wang - Texas Tech University, Lubbock

The Occurrence and Fate of Sex Hormones and their Conjugates in Animal Waste and Soil and Aquatic Environments
Xia Kang - Mississippi State University of Agriculture and Applied Sci., Mississippi State

Runoff Characteristics and Redox Control of Veterinary Antibiotics in Manure, Soil and Water
Jim J. Wang - Louisiana State University Agricultural Center, Baton Rouge

Dynamics of Hormone Loads and Attenuation in Ditches and Streams Draining Agricultural Fields Receiving Animal Manure Applications
Linda Lee - Purdue University, West Lafayette

Understanding Dynamics of Microbial Contaminant Fate and Transport in Rural and Agricultural Lands
Tamer Helmy (replacing Rachel T. Noble) - University of North Carolina at Chapel Hill, Morehead City

Investigating the Spread of Antimicrobial Resistance near Animal Facilities: Mechanisms of Extracellular DNA Transport and Transfer
Julie Zilles (replacing Helen Nguyen) - University of Illinois, Champaign

Surfactant-Facilitated Transport of Cryptosporidium Parvum in Soil
Christophe Darnault - University of Illinois at Chicago, Chicago

9:45 – 10:00 a.m. **Break**

10:00 – 12:00 p.m. **Oral Session I**

10:00 – 10:20 p.m. *Impact of Forest Treatments and Climate Change on Hydrologic Regimes: Assesssment of the Mechanisms that Affect Hydrologic Alteration*
Timothy E. Link - University of Idaho, Moscow

10:20 – 10:40 p.m. *Investigation of the Fate and Transport of Fecal Contamination Using Microbial Source Tracking*
Christopher C. Obropta - Rutgers University, New Brunswick

10:40– 11:00 p.m. *Salmonella and Shiga-Toxin Encoding Genes in Coastal Streams in Central California: Relation to Land Use*
Alexandria B. Boehm - Stanford University, Stanford

11:00– 11:20 p.m. *Survival and Transport of E. Coli O157:H7 and Salmonella Newport in Manure and Manured Soils*
Zhengxia Dou - University of Pennsylvania, Kennett Square

11:20– 11:40 p.m. *Fate of Motile Bacterial Pathogens in the Subsurface: Determining the Extent and Influence of Motility and Counter-Current Movement on Cell*
Jane Hill - University of Vermont and State Agricultural College, Burlington

11:40 – 12:00 p.m. *Fate and Transport of Pathogenic Microorganisms Originating From Livestock Manures Applied to Agricultural Lands*
Shane W. Rogers - United States Environmental Protection Agency

12:00 – 1:00 p.m. **Lunch on your own**

1:00 – 3:00 p.m. **Oral Session II**

1:00 – 1:20 p.m. *Assessment of Dairy Manure Management Practices to Reduce Pathogen Runoff Losses in Agricultural Watersheds*
Donald W. Meals - Stone Environmental, Inc., Montpelier, Vermont

1:20 – 1:40 p.m. *S. Typhimurium and E. Coli O157:H7 Transport Modeling for Agricultural Practices*
Gang Chen - Florida A&M University, Tallahassee

1:40 – 2:00 p.m. *Transport and Survival of Escherichia Coli within Soil Aggregates*
Sasha Kravchenko - Michigan State University, East Lansing

2:00 – 2:20 p.m. *Water Conservation in Forage Production Systems by Sorghum-Legume Intercropping in the Southern High Plains*
Sangamesh V. Angadi - New Mexico State University, Clovis

2:20 – 2:40 p.m. *Quantifying the Mechanisms of Pathogen Retention in Unsaturated Soils*
Yan Jin (replacing Steven L. Bryant) - The University of Texas, Austin

2:40 – 3:00 p.m. *Upper Sugar Creek Watershed, Ohio: A Model Watershed for Study of Pathogen Origin, Fate and Transport*
Richard Moore (replacing Warren A. Dick) - The Ohio State University, Wooster

3:00 – 3:20 p.m. *Assessing Farm-Source E. Coli and Salmonella Mobility to Water*
Tammo S. Steenhuis - Cornell University, Ithaca

3:20 – 3:30 p.m. **Break**

3:30 – 5:00 p.m. **Poster Session II**

Source, Fate and Transport of Cryptosporidium in A Rural Midwestern Watershed
John McEvoy - North Dakota State University, Fargo

Current Knowledge of Sources, Fate & Transport of Rural and Agricultural Watershed Pathogens: A National Synthesis Workshop
Dwight Bowman - Cornell University, Ithaca

Fate of Antibiotics in Poultry Litter before and After Application to Grasslands
Ching-Hua Huang - Georgia Institute of Technology, Atlanta

Animal Manure-Derived Dissolved Organic Matter Affects Sorption and Transport of Veterinary Pharmaceuticals in Soils
Hui Li - Michigan State University, East Lansing

Persistence and Mobility of Estrogens in the Environment
Francis X. Casey - North Dakota State University, Fargo

Fate and Transport of Steroid Hormones and Veterinary Antibiotics Derived from Cattle Farms
Wei Zheng - University of Illinois, Champaign

Agricultural Water Security and In stream Flows for Endangered Salmonids in Coastal California's Watersheds
David Newburn - Texas Agricultural Experiment Station, College Station

Transport and Mitigation of Beef Cattle Veterinary Pharmaceuticals and Hormones in Surface and Sub-Surface Runoff from Grazed Watersheds
Edward P. Kolodziej (replacing Kenneth W. Tate) - University of California, Davis

Environmental Fate of Synthetic Growth Promoters Used in Animal Agriculture: Mechanistic Studies of Hormone Photolysis, Biodegradation and Soil Processes in Natural Systems
Edward P. Kolodziej - Board of Regents, NSHE, on behalf of UNR,Reno

Fate, Transport, and Changes in the Potency of Hormones, Antibiotics, and their Degradates at the Watershed Scale
Shreeram Inamdar - University of Delaware, Newark

Role of Directly Connected Macropores in Pathogen Transport to Subsurface Drainage
Garey A. Fox - Oklahoma State University, Stillwater

Managing the Risk of Cryptosporidium and Salmonella Spp. in Watersheds
Hussni O. Mohammed - Cornell University, Ithaca

Impact of Subsurface Drainage on Water Availability in the Red River Basin
Xinhua Jia - North Dakota State University, Fargo

Survival of Escherichia Coli on Soil Particle Surface in Opaeula Watershed of Oahu, Hawaii
Tao Yan - University of Hawaii, Honolulu

Payment Incentives Required for Irrigation Retirement Programs
Steven D. Shultz - University of Nebraska, Omaha

Human Health Risks from Animal Agriculture: Comparative Analysis of the Transmission of Multiple Zoonotic Pathogens in Mixed-Use Agricultural
Thomas Harter - University of California, Davis

Escherichia Coli and Cryptosporidium Occurrence, Transport, Fate and Reduction from Vermont Dairy Farm Point and Non Point Pollution Sources
Aleksandra Drizo - The University of Vermont and State Agricultural College, Burlington

Grazing Management Effects on Pathogen Loading of Midwestern Pasture Streams
James R. Russell - Iowa State University, Ames

5:00 p.m. **Adjourn**

Newly funded projects

Bioaccumulation of Endocrine Disrupting Compounds from Recycled Water in Edible Fruits and Vegetables
Patrick C. Wilson - University of Florida, Fort Pierce

Bioaccumulation of Antimicrobials by Vegetables and Fruits: Potential and Summary to Human Health and Environmental Fate
Dawn Reinhold - Michigan State University, East Lansing

Development of Drought Triggers for Agricultural Applications
Indrajeet Chaubey - Purdue University, West Lafayette

Accumulation of Antibiotic Resistant Salmonella in Lettuce after Irrigation using Recycled Water
Xu Li– University of Nebraska, Lincoln

Understanding Fate of PPCPs in Soil-Plant Systems Irrigated with Treated Wastewater
Jianying (Jay) Gan - University of California, Riverside

Bioaccumulation of Chemicals of Emerging Concern (CECs) in Food Crops from Reclaimed Water
Christopher P. Higgins - Colorado School of Mines, Golden

Drought Decision Making Tool for Agricultural Producers
Clyde Munster - Texas A&M University, College Station

Development of a High-Resolution Drought Trigger Tool (HiDrTT) for the United States
John Nielsen-Gammon - Texas A&M University, College Station

Investigation into Effect of Soil Moisture Depletion on Vegetable Crop Uptake of Microcontaminants under Recycled Water Irrigation
Chittaranjan Ray - University of Hawaii, Honolulu

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Poster Session I

2006-35102-17192

Influence of Soluble Organic Matter on *Cryptosporidium Parvum* Oocyst Mobility in Variable Charge Soils

Chittaranjan Ray, Water Resources Research Center, University of Hawaii at Manoa, Hawaii
Ronald W. Harvey, U.S. Geological Survey, Colorado
Jon Chorover, College of Agriculture and Life Sciences, University of Arizona, Arizona

Summary: The presence of *Cryptosporidium parvum* öocysts in source water has serious public health implications because of their high resistance to common chemical disinfectants such as chlorine. Currently, the USEPA requires all public water supplies that use surface water or ground water that is classified to be "under the influence of surface water" to remove 99.99% (4.0 log units) of *C. parvum* oocysts using sand filtration. However, achieving 4-log removal of Cryptosporidium can be problematic for older filtration plants. Because livestock animals are the major source of *C. parvum*, there is pressure on the agricultural community to develop better management practices that reduce numbers of this pathogen being introduced into source waters. Recent research in a number of laboratories has focused on the potential of particulate matter and biofilms to immobilize *C. parvum*. In particular, considerable research effort has focused on this pathogen's fate and transport in the fixed-charge soils that are typically found in temperate climates. However, vast areas of the southeastern United States, Hawaii, and Puerto Rico have soils predominantly having variable-charge surfaces. Lush vegetation and erodible soils contribute to the presence of dissolved organic matter and microscopic particulates in runoff; but no systematic studies have been conducted to examine the interaction of dissolved organic matter and particulates on the mobility of *C. parvum* oocysts in variable-charge soils.

The goals of our work were to address how *C. parvum* and model microspheres attach to tropical and temperate zone soils, how the dissolved organic matter affect transport in various soils, and how the natural clay particles affect aggregation.

Impact: Stakeholders include water utilities, local health departments, agricultural extension agents, and water treatment plant operators in areas where there are predominantly variable-charge soils and livestock manure can find its way to water supply sources. It was shown through our study that some agricultural soils from Hawaii can act as reservoirs of pathogens due to their high particulate organic matter content and can be source of contamination of surface water or shallow ground water. It was also found that dissolved organic carbon has no consistent effect in enhancing transport of *C. parvum* oocysts. Further we found that carboxylated microspheres are not reliable surrogates for *C. parvum* oocysts due to their disparate surface characteristics. The results of the our study are important in that it provides the first spectroscopic evidence for a molecular adhesion mechanism that goes beyond DLVO interactions, and provides a molecular bonding basis for the strong effects of metal oxides on pathogen retardation during transport.

2008-35102-04635

Use of Microarrays and QPCR/RT-QPCR for Characterization of Viral Populations within Water Supplies Affected by Agricultural Activities

Erik R. Coats, Civil Engineering, University of Idaho

Summary: We will develop and validate a microarray-based assay for screening agriculturally impacted waters for simultaneous detection of >1,500 viruses and bacteria. Water samples from a watershed potentially impacted by a dairy will be examined. This effort will result in development of a protocol to characterize viral populations in agriculturally impacted waters and addresses USDA's FY 2008 Program Priority to understand the sources, fate, and transport of pathogens, with an emphasis on E. coli and enteric viruses. Objectives are to produce a protocol to characterize viral populations and to understand the sources, fate, and transport of pathogens in agriculturally impacted waters. Milestones: Obtain water samples (quarters 1-5); Process samples: (quarters 1-6); Microarray hybridizations (quarters 2-7); Data analyses (quarters 2-8); qPCR/RT-qPCR analyses (quarters 5-8); Publications (quarters 4 and 8); Publish protocol (quarter 8). This research will produce new fundamental and applied knowledge, new methods and techniques, and a protocol for use of microarrays to characterize viral populations in agriculturally impacted waters. Results will be disseminated in peer-reviewed publications and on the Internet.

Impact: Host/Phage arrays results - Enteric viruses were detected with the highest signal intensity in both lagoons. - The following organisms were detected by PCR, and sequenced. Bovine enterovirus (AY831697.1), Phage cdtI (AB285204.1), Bacteriophage HK109 (AJ298550.1), Staphylococcus Phage MR11 (AB370268.1), Streptococcus thermophilus phage OBJ (in Lagoon 1 only), Salmonella phage mig-3 (AF020804), Salmonella enterica (FQ312003.1), Bacillus licheniformis (EU221362.1), Virgibacillus (AM237397.1), Bacillus 16S (HM061660.1), Clostridium 16S (AB539900.1), Bacillus Subtilis (AB542912.1), Escherichia coli (CP001969.1), Transmission Electron Microscopy (TEM) data - Viral-like particles were detected in each sample showing different morphology such as tailed, cubic, and filamentous. The TEM data supports the array results which indicate the presence of viruses in lagoon samples. We have been operating our novel 2-stage dairy manure anaerobic digestion process for approximately 12 months, and have determined that this unique method of serial extraction of resource (dairy manure fermentation followed by anaerobic digestion of the fermented residual manure) can produce comparable, if not more, biogas than a conventional single stage system receiving raw manure. Current estimates are that the UI 2-stage process can produce approximately 0.28 L of biogas per gram volatile solids load, while the conventional single-stage system produces approximately 0.24 L/(gVS-d). Such an outcome is impressive, considering that the highest value organic carbon is removed from the manure in the fermenter through production of volatile fatty acids (VFAs), with the VFAs routed away from the downstream AD to another commodity process. Investigations of this process will continue for the next 12 months of the project.

2008-35102-04659

Photochemical Disinfection of Agriculturally Introduced Pathogens: The Influence of Extracellular Polymeric Substances on the Bactericidal Capacity of Naturally Occurring Reactive Oxygen Species

Sharon L. Walker and David M. Cwiertny, Department of Chemical and Environmental Engineering, University of California, Riverside

Summary: Bacterial pathogens including *E. coli* are generally prevalent in surface waters near agricultural operations and their persistence poses a threat to the health of humans, livestock, and plants. An improved understanding of their natural attenuation mechanisms is necessary to predict their persistence and the risks associated with their occurrence in aquatic systems. The current work aims to determine the contribution of naturally occurring photochemical processes to the attenuation of bacterial pathogens. In particular, our study aims to identify the influence of common biological and aquatic chemical variables on the efficiency of indirect photochemical disinfection processes involving reactive oxygen species (ROS) such as hydroxyl radical ($^{\bullet}OH$) and singlet oxygen ($^1O_2$). We previously hypothesized that an important bacterial variable in ROS-mediated indirect photolysis is extracellular polymeric substances (EPS), a mixture of carbohydrate and protein polymers exuded by bacteria, because it will control the bacteria's ability to interact with ROS. To test this hypothesis, the kill rates of multiple strains of *E. coli* with varying degrees of EPS coating have been measured in batch photochemical systems using nitrate photolysis for $^{\bullet}OH$ production. Results from nitrate systems are being compared to rates of disinfection measured in more complex systems utilizing alternative routes for ROS production including photolysis of dissolved organic matter and photo-Fenton chemical processes with colloidal iron.

Impact: To date, experiments have revealed that $^{\bullet}OH$ is the most potent photochemically generated ROS for bacterial disinfection in surface waters. Rates of *E. coli* viability loss increase monotonically with exposure to increasing steady-state $^{\bullet}OH$ concentrations produced via nitrate photolysis. In contrast, exposure to other ROS including $^1O_2$ and hydrogen peroxide produced no viability loss over similar contact times. As such, studies have focused on bacterial and chemical variables influencing the bactericidal activity of $^{\bullet}OH$, as well as the fundamental processes responsible for $^{\bullet}OH$ production in sunlit surface waters. Contrary to our initial hypothesis, experiments have shown that the level of bacterial EPS exerts negligible influence on the bactericidal activity of $^{\bullet}OH$ in homogeneous systems. Notably, this result was observed for multiple *E. coli* strains, which all showed remarkably similar rates of viability loss in batch photochemical experiments despite inherent differences in their native EPS levels. Ongoing work is exploring the role that EPS plays in governing the interaction of *E. coli* with other species responsible for $^{\bullet}OH$ production including humic and fulvic acids and colloidal hematite because factors that promote bacteria interaction with these species would be expected to in turn promote viability loss. We are also exploring factors that may increase the potency of $^1O_2$ and hydrogen peroxide by examining whether ROS activity is enhanced when coupled with direct photochemical reaction pathways. Collectively, these fundamental insights will help farmers and regulatory agencies better predict pathogen persistence in agriculturally impacted surface waters, allowing improved management of water resources in the future, particularly with respect to the safe handling and reuse of agricultural runoff.

2008-35102-19192

Quantification and Control of Bacterial Pathogens in Agricultural Watersheds

Philip Moore, Poultry Production &Safety Research Unit ARS, Fayetteville, Arkansas

Summary: Science-based knowledge on the fate and transport of pathogens in mixed-land use watersheds is critically needed, allowing for identifying important sources and targeting areas of a watershed for remedial efforts in minimizing transport of contaminants. Development of remedial measures or BMP's will require a comprehensive understanding of the factors that influence pathogen survival and movement. This project will develop fundamental baseline data for understanding pathogen sources, fate and transport. Research will be conducted on both small plots and at the field scale. Rainfall simulations will be conducted on 72 small plots to evaluate the effects of time after manure application, type of manure, manure treatments, and weather on pathogen survival and runoff. We will also monitor pathogen runoff for two years from 28 small watersheds to determine effects of the following treatments on pathogen transport: 1) grazing/pasture management, 2) poultry litter application methods, 3) chemical treatment of litter, 4) runoff type (sub-surface flow vs. overland flow), 5) treating biosolids with water treatment residuals, and 6) different landscape positions and flow pathways. We will also assess the viability of using indicator organisms by conducting correlation studies with data obtained from the studies above to determine if E. coli or Enterococci counts are related to specific pathogens present in runoff water from fields fertilized with poultry and/or beef manure. This research could result in significant improvements in the sustainability of beef cattle and poultry farming operations through the development of cost-effective BMPs which reduce bacterial pathogen survival and/or transport in agricultural watersheds. The objectives of this project are to: (1) measure pathogen concentrations in poultry litter and cattle manure, (2) evaluate factors that affect pathogen runoff from poultry litter from small plots, (3) determine the impact of best management practices on pathogen runoff from pastures fertilized with poultry litter, and (4) correlate the numbers of indicator organisms to specific pathogens.

Impact: We will determine the factors that affect pathogen fate/transport from pastures and measure the effects of BMPs on reducing these losses. Small plot studies using rainfall simulators will be used to evaluate the effects of: 1) time after manure application; 2) type of manure (poultry, swine, beef, dairy and biosolids); 3) manure treatments (composting, chemical addition); and 4) weather (season/temperature) on pathogen runoff. II. We will determine the effect of land use, landscape position, and BMPs on pathogen transport from small watersheds by measuring the effect of the following treatments: 1) grazing/pasture management; 2) poultry litter application methods; 3) chemical treatment of poultry litter; 4) chemical treatment of biosolids, and 5) different landscape positions and flow pathways. We will assess the viability of using indicator organisms and microbe tracking tools at the watershed scale by: 1) conducting correlation studies with data obtained from the studies above to see if E. coli or other indicator counts are related to specific pathogens present in runoff water from fields fertilized with poultry and/or beef manure; and 2) evaluating the effectiveness, cost, and practicality of tracking tools used to investigate pathogen sources within watersheds.

2008-35102-19217

Watershed Scale Assessment of a Karst Drainage Basin Using Microbial, Geospatial, and Geochemical Approaches

Alice L. Jones, Eastern Kentucky University

Summary: The research project will facilitate the understanding of the sources, fate, and transport of pathogens in soil, surface and ground water, and irrigation systems of agricultural and rural watersheds to reduce these pathogens in the environment; thereby, providing safer water sources. The research project is critical in addressing the relevance of karst topography and its relative influence on surface/groundwater interaction and these affects on water quality. Karst topography is characterized by sinkholes, underground streams, and caverns. Once a karst area becomes polluted, it is generally very difficult to remediate based upon the unusual surface and subsurface features. The originality of the proposed research lies in combining the knowledge of the karst environment through tracking water movement using dye traces, implementation and effects of best management practices using organisms that serve as indicators of environments that are preferential for the flourishment of potential pathogenic organisms, to develop a management concept of approaching water quality issues in such unique and complex environmental systems. The combination of these aforementioned factors with nutrient analyses, fecal pathogen analysis, and GIS-generated maps will provide a detailed description of how and where pathogens move through a karst system and the subsequent development of an effective management plan to address the water quality of such watersheds.

Impact: A study conducted by Albright[1,2] and continued by Jones[3] sought to characterize a watershed and determine whether the influences of best management practices could be detected at the watershed scale. Albright monitored at 18 surface water and six groundwater sites for physical and chemical water quality parameters throughout the Brushy Creek watershed in southeastern Kentucky and then used GIS to compare areas of the watershed with high adoption of cattle BMPs with areas of sparse or non-adoption. The results indicated that there were no differences in water quality at the watershed scale that could be attributed to the presence or absence of the BMPs, and hypothesized that one reason was that the karstic nature of the watershed was not considered in the development of the BMP prescriptions. A follow-on study in progress by Jones[4] and slated for completion in the Spring of 2011 seeks to determine whether karstic groundwater-surface water interaction adequately explains why the cattle BMPs have had little effect on water quality by more completely characterizing the land- and hydrological conditions of the area, including land use characteristics, physical habitat assessment of riparian corridors, and censuses of fish and invertebrates. Preliminary results comparing areas of the watershed where groundwater-surface water interactions are suggest that groundwater is, in fact, a substantial conduit of nutrient and E. coli contaminants in the stream network.

[1]Albright, M. "Assessment of Agricultural Best Management Practices in the Brushy Creek Watershed" MS thesis Eastern Kentucky University 2007. Print

[2]Albright, M. 2007. "Assessment of Agricultural Best Management Practices in the Brushy Creek Watershed" . Eastern Kentucky Environmental Research Institute Report Summary Series RS07.005.

[3]Jones, A. Watershed scale assessment of a karst drainage basin using microbial, geospatial, and geochemical approaches. Contract no.: 2008-35102-19217.

[4]Jones, A. Watershed scale assessment of a karst drainage basin using microbial, geospatial, and geochemical approaches. Contract no.: 2008-35102-19217.

2008-35102-19259

The Influence of Subsurface Drainage on Streamflow and Nitrate Load and the Potential for Water Conservation

Laura Bowling, Dept. of Agronomy, Purdue University, IN

Summary: The project aims to address the hydrologic and water quality impacts of subsurface (tile) drainage in the Wabash River basin in Indiana. Large quantities of drain flow from intensively drained agricultural watersheds can significantly alter the daily and seasonal streamflow pattern and increase nitrate loads to receiving streams. Nitrate loading from agricultural lands of the Midwest has been shown to contribute to hypoxia and a severe reduction in fish populations in parts of the Gulf of Mexico. The main goals of the project are to i) quantify watershed subsurface drainage volumes through analysis of observed streamflow and associated datasets, ii) assess the observed influence of watershed subsurface drainage on the streamflow pattern in comparison to public perceptions, iii) quantify the nitrate load from subsurface drainage systems in the Wabash River basin, and iv) assess the potential for nitrate load reduction and water conservation in the Wabash River basin through implementation of DWM.

Impact: This ongoing work will benefit row-crop producers, researchers, policy makers and administrators. The quantification of subsurface drainage influence on streamflow pattern and watershed/regional nitrate load will assist policy makers in water resources planning and targeting watershed areas to reduce nitrate loading to major river systems in the Midwest and the Gulf of Mexico. A potential future impact is improved aquatic diversity in the Wabash River basin, through identification of the historic streamflow regime and strategies for restoring aspects of that regime. Our research on DWM will enhance farmer awareness regarding the potential of implementing DWM in order to reduce the nitrate load and conserve water, and will enable them to better decide if DWM is an appropriate conservation measure for their fields. This work is anticipated to increase the use of aerial image-derived maps of subsurface drains by farmers and conservation districts to enable better water management decisions at the field level. The potential subsurface drained area in Indiana was estimated to be 2.44 million ha, about 26% of Indiana geographic area. Methods to quantify the subsurface drainage contribution to streamflow using hydrograph separation and hydrologic models are currently being developed. The preliminary results indicate that as the extent of tile drained area increased, the frequency of high flow events and the stream flashiness tended to increase for smaller watersheds, through a reduction in base flow and an increase in fast response runoff. Our work on nitrate load reduction through DWM predicted a 51% reduction in drain flow and nitrate load in an agricultural watershed in west central Indiana that has a 46% tile drained area.

2009-35102-05009

Assessing Water Use and Water Quality Change with Respect to Large-Scale Expansion of Ethanol Feedstock Production in the United States

Burton C. English, Agricultural & Resources Economics University of Tennessee, Knoxville

Summary: The general research goals of this research are focused on two: (1) to identify and quantify the gross water use and water quality required at county and Agricultural Statistic District (ASD) levels to meet the anticipated amount of ethanol feedstock production (36 billion gallons of ethanol by 2022 with 21 billion gallons of ethanol from feedstock other than corn); (2) to identify policies that will enhance water quality and water conservation under these ethanol production goals and indicate and estimate the impacts of these potential national water policy tools. The objectives and research scope of this proposal address the second research priority stated in the FY2008 under the program 26.0 Water and Watersheds. The project will identify, evaluate, and incorporate producer management behaviors that have the potential to reduce projected water consumption and increase water conservation. The project will incorporate a national and regional economic and policy component with a water use model. It will incorporate traditional water demands and document water savings that might occur under alternative policies while still meeting the announced ethanol mandate. The proposed research aims to generate information about the production of dedicated bioenergy crops in lieu of competing crops uses, and demand for inputs including land and water resources. Via using simulations produced by linking a regional policy analysis model with a scaled-up agronomic model, this research are capable of providing timely information about the economic, environmental, agricultural water demand, and agricultural trade-offs under multiple policy scenarios including technical changes in bioenergy production, various production targets, conservation tillage practices, and agricultural polices as these relate to feedstock production. Results will supplement other information required by policy makers, stakeholders, public and private investors, and those that advise them with respect to understanding the complex changes anticipated by the growth of the bioenergy industry. At the same time, information will be relevant for understanding local level and regional constraints as they pertain to water quality, water and soil conservation, and community well-being.

Impact: This research will generate information about the production of dedicated bioenergy crops in lieu of competing crop uses, and demand for inputs including land and water resources. Results will help identify potential policies capable of enhancing water quantity and quality along with their potential impacts on the nation's agricultural sector. Findings will supplement other information required by policy makers, stakeholders, public and private investors, and their advisors with respect to understanding the complex changes anticipated by the growth of the bioenergy industry. At the same time, information will be relevant for understanding local level and regional constraints as they pertain to water quality, water and soil conservation, and community well-being.
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2009-035102-05021

Antibiotic Resistance, Gene Transfer, and the Horizontal Gene Pool of Agriculture-Associated Soils and Waters

Roderick I. Mackie, Department of Animal Sciences, Division of Nutritional Sciences and Institute of Genomic Biology, University of Illinois, Urbana, IL 61801

Summary: The use of antibiotics in livestock production is a ubiquitous practice. Swine, poultry and cattle production all use antibiotics for treatment and prevention of animal diseases, as well as for growth promotion. As such, water bodies in close proximity to animal operations are often at risk of contamination by manure and resistance genes. The project concerns fundamental examination of the microbial communities, antibiotic resistance genes and mobile gene pools that are associated with swine production facilities, and to evaluate if these contaminants impose a potential adverse risk to adjacent surface and groundwater bodies and ultimately to the well-being of environment, human and animals.

Impact: The regulatory bodies and scientific community are the major stakeholders of this work. The knowledge gained from this work would enable regulatory bodies to better monitor and assess the biotic and abiotic risk imposed by animal husbandry. Our work would help to enhance the long-range sustainability of U.S. agricultural systems by providing the data necessary for the proper assessment of microbial risk. This will subsequently allow for better design and implementation of informed management decisions about antibiotic usage in agriculture, treatment of animal waste, and the use of animal manure as fertilizer.

We utilized primers targeting at tetracycline resistance genes to establish the copy number of antibiotic resistance genes (TetQ and TetZ) in manure and groundwater sampled from different wells and source material. Our Q-PCR results showed that tetracycline resistance genes were present at barely detectable concentration in background wells. The highest abundance of tetracycline resistance genes were detected in a well, located downstream of the waste pit along the direction of groundwater flow. Our findings using 16S rRNA-based pyrosequencing showed that in the background wells, the microbial community was comprised predominantly of Proteobacteria (~95% of total microbial community). However, the microbial community in the groundwater with increasing contamination shifted towards increasing abundance of Firmicutes and Bacteroidetes (from ~2% to ~10%). In summary, our findings demonstrate an increase in the abundance of tetracycline resistance genes and a corresponding shift in the microbial community as proximity to contamination increases.

2009-35102-05043

Predicting the Effects of Agricultural Practices on Waterborne Human Pathogens, Livestock Helminthes, and the Health of Rural Water-Bodies

Zachery R. Staley, Valerie J. Harwood, Jason R. Rohr,
University of South Florida, Department of Integrative Biology, Tampa, FL

Summary: Livestock waste can harbor various zoonotic, waterborne pathogens that impact human health when they enter water bodies. Our preliminary work suggests that existing agrochemicals can enhance and diminish disease risk by killing pathogens or their intermediate hosts or by modifying the abundance of their food or predators. This suggests that producers could alter the type and timing of agrochemical applications, the layout of crops, and the location of livestock to improve human, livestock, and ecosystem health. The primary goal of the proposed research is to better understand the effects of agricultural practices on rural water quality, with emphases on the abundance of waterborne fecal indicator bacteria (E. coli, Enterococcus spp.) and actual zoonotic pathogens (E. coli O157:H7, Salmonella enterica serovar Typhimurium, human adenovirus). Our secondary goal is to use the knowledge resulting from this research to predict when and where these pathogens will be problematic and to develop management practices to reduce their abundance.

Impact: The stakeholders in this project are farmers and natural resources managers. Our results so far have shown that agrochemical treatments of fertilizer and atrazine increase fecal indicator bacteria (FIBs) densities. Our stakeholders could lessen the risk to human health by decoupling the use of agrochemicals from livestock waste, thereby limiting the opportunity for agrochemicals to positively influence the densities of bacteria and zoonotic pathogens. Also, coupling livestock waste with agrochemicals capable of killing pathogens would further reduce the risk to human health. To date, no new technology has been developed as a result of this project.

So far, we have conducted a study to investigate the impact of agrochemicals (fertilizer, atrazine, chlorothalonil, or malathion) on FIBs using complex mesocosms to simulate freshwater ecosystems at the community level. The results of this experiment showed significantly elevated densities of *E. coli* and enterococci in the sediment when fertilizer and/or atrazine were present, however, due to the complexity of these mesocosms, it was unclear whether these effects were the result of a direct mechanism of the agrochemicals or an indirect effect influencing predation, competition, parasitism, or altering the available food resources. To investigate whether these results were the product of direct effects, further experiments were conducted using simplified mesocosms containing only FIBs (*E. coli* and *Enterococcus faecalis*) and microbial pathogens (*E. coli* O157:H7, *S. enterica*, and adenovirus). No direct effect of any agrochemical treatment was found on any bacterial species, however a significant positive correlation was found between specific strains recovered from the sediment compared to the water column.

2009-65102-05481

A Hydro-Econometric Analysis of Producer Water Use and Aquifer Hydrology in the Texas High Plain

Chenggang Wang, Jeff Johnson, and Eduardo Segarra, Department of Agricultural and Applied Economics, Texas Tech University, Texas
Zhuping Sheng and James Bordovsky, Texas Agrilife Research, Texas A&M University System, Texas

Summary: In the semi arid Texas High Plains, groundwater in the Ogallala Aquifer is the lifeblood of the regional economy, and agricultural irrigation accounts for about 95 percent of total groundwater withdrawal. The most challenging problem facing the region is to find the best way of preserving the nonrenewable groundwater resource while maintaining regional economic growth to which the agricultural sector makes a significant contribution. The main goal of the project is to develop a policy assessment model for the Texas High Plains, in order that the impacts of water conservation policies can be soundly evaluated and better strategies developed to manage its groundwater resources.

Impact: The most prominent stakeholders of the project are agricultural producer groups, industrial, commercial, and institutional water users, environmental groups, municipal water authorities, federal and state natural resource conservation agencies. In particular, the project will enhance decision making by the region's water management body, the High Plains Underground Water Conservation District No. 1. The water district has recently voted for a 50/50 Management Goal, meaning that 50 percent of the volume of water in the Ogallala Aquifer in 2010 will have to remain in the aquifer in 50 years. The model developed by this project will enable us to evaluate the various policy measures proposed by stakeholders and find out the best approach to achieving that goal.

The final product of the project is a hydro-economic model for simulating future groundwater conditions under various management plans. The hydro-economic model is estimated and calibrated with over thirty years of historic data on groundwater levels and crop production across twelve Texas High Plains counties overlying the Ogallala Aquifer. The model accounts for the interactions of groundwater use behavior and aquifer hydrology, so that the impacts of policy injection, including the resulting change in groundwater use behavior, can be fully understood. It is anticipated that the research findings will provide decision-making guidelines for regional water stakeholders.

2009-65102-05923

The Occurrence and Fate of Sex Hormones and their Conjugates in Animal Waste and Soil and Aquatic Environments

Kang Xia and Kevin Armbrust
Mississippi State Chemical Laboratory, Mississippi State University, Mississippi
Mark Crenshaw
Department of Animal & Dairy Science, Mississippi State University, Mississippi

Summary: Input of hormones associated with manure from Concentrated Animal Feeding Operations (CAFOs) are of concern for both surface and groundwater quality, driving the need for data on factors influencing their input and subsequent fate in the environment.

The goals of this investigation are to: 1) monitor the occurrence of hormones and their metabolites in manure from animals at different life stages; 2) investigate how animal waste management practices affect the fate of hormones and metabolites in animal wastes through both laboratory and on-site studies; 3) determine the aquatic and terrestrial fate of hormones and their conjugates in laboratory studies.

Impact: Our stakeholders are operators of swine and poultry CAFOs, environmental policy decision makers, and the general public. We are currently collecting and analyzing manure from animals at different life stages and soil samples receiving animal waste application for various length of time. In a few months the data will be shared with operators of the CAFOs where samples were collected. The results will be synthesized and submitted to a peer-reviewed journal. Our stakeholders are operators of swine and poultry CAFOs, environmental policy decision makers, and the general public.

A new extraction technique was developed for analysis of hormones and their conjugates in animal waste. The technique was presented at a national meeting.
A new transformation pathway for hormones in the environment was reported.
Operators of swine and poultry CAFOs, environmental policy decision makers, and the general public have access to those reports.

Estrone, 17β-estradiol, and their conjugates were frequently detected in the chicken litter at levels ranging from low ng/g to several hundreds ng/g range. Those compounds were at similar levels in the hog manure sample. The levels of conjugated hormones in those samples were at similar or higher levels than free hormones, suggesting the importance of studying the fate and impact of hormone conjugates in the environment.

Fe(III)-saturated montmorillonite can polymerize hormones in the environment and, therefore, reducing it bioavailability. Potentially, Fe(III)-saturated montmorillonite can be used as additives in animal waste lagoon for hormone removal.

2009-65102-05975

Runoff Characteristics and Redox Control of Veterinary Antibiotics in Manure, Soil and Water

Jim J. Wang and Ron DeLaune
School of Plant, Environmental and Soil Sciences, Louisiana State University AgCenter

Summary: Application of animal manures to agricultural lands has caused concerns over the release of veterinary antibiotic compounds used in animal production into the environment. Various veterinary antibiotic compounds have been detected in water streams. This project investigates interactive behavior of antibiotic compounds in manure, soil and water. This information is essential for developing solutions aimed at controlling the risks associated with these compounds. Specific objectives for this year were to 1) determine the effects of commonly used manure chemicals on retention and degradation of tylosin, a macrolide-class antibiotic compound, and 2) evaluate the integrated effects of Eh-pH status on retention and degradation of tylosin in soil and water. Effects of alum, ferric chloride, red mud, and montmorillonite clay on tylosin mobility in chicken litter were assessed and these materials showed difference in reducing tylosin mobility. Three chicken manure-affected soils were evaluated for pH effect on tylosin adsorption and desorption characteristics. Interaction of tylosin with dairy lagoon sediments was investigated under different combined Eh and pH status. Both pH and redox were found to significantly influence tylosin behavior in soil and dairy lagoon sediments.

Impact: This study provides solid understanding on retention and degradation of tylosin in manure source, soil, and redox-sensitive aquatic systems. Interaction of tylosin with dairy lagoon sediments evaluated under different combined Eh and pH status demonstrated that the interaction between lagoon sediment and tylosin dictates the influence of redox and pH and the disappearance of tylosin from dairy lagoon slurry was generally quicker at relatively higher pH. In addition, experiment on leaching potential of tylosin in different soils indicated that tylosin was moderately mobile and were significantly influenced by organic matter content and soil pH. Montmorillonite clay was more effective than other commonly used manure chemicals in controlling the release of tylosin from the chicken litter. Part of the results was recently presented at the Soil Science Society of America Annual meeting (Jeong et al. 2010) and Louisiana animal waste research ACE group. It is expected that the information obtained from this project will help to develop management solutions that will minimize environmental risks associated with the release of antibiotics into soil and water through manure applications.

2009-65102-05995

Dynamics of Hormone Loads and Attenuation in Ditches and Streams Draining Agricultural Fields Receiving Animal Manure Applications

Linda S. Lee[1], Suresh C. Rao[1.2], and Nandita Basu[3]
Michael Mashtare[1], Stephen Sassman[1], Samuel Boland[3], and Natalia Loukinova[3]
[1]Purdue University, Department of Agronomy and [2]School of Civil Engineering
[3]University of Iowa, Civil and Environmental Engineering

Summary: Land application of manure and irrigation with annual-water derived lagoon effluent is currently based typically on crop nutrient and/or water needs. However, the increased density of animals within a given animal operation and transportation costs results in animal wastes being applied within a relatively small area, thus a potential concentrated source of synthetic and natural hormones as well as antimicrobials to the terrestrial ecosystem and potentially receiving waters. The role of animal waste-borne steroid hormones on ecosystem and human health is an emerging concern. Concentrations of hormones sufficient to invoke impacts on aquatic species have been detected in the ditch network receiving tile drainage and surface run off from fields fertilized with animal manure and associated lagoon effluent. However, the propagation of this hormone load into the watershed into which the ditch network flows is not well understood. Processes impacting the loads downstream must be sufficiently quantified in order to predict how much of a stream network may be impacted by a source region and to what magnitude.

Our overall goal is to evaluate persistence of hormones in ditch-stream networks and how they may propagate in the stream network by achieving the following four objectives: (1) Develop a "source function" module to predict the hormone mass available for transport to ditches via subsurface tile-drains or surface runoff; (2) Assess legacy hormone loads accumulated in ditches receiving tile drainage and runoff; (3) Assess in-stream biogeochemical processes attenuating hormones during transport; and (4) Predict and validate what hormone loads will be transported in the stream network beyond the source area.

Impact: A passive surface water flux meter is being developed and validated for a low cost and effective way to monitor propagation of hormones as well as other compounds through a watershed. Such information is necessary to assess the natural attenuation that may occur in water ways and ultimately decide what the limits of hormone loads to water ways may be acceptable. The information synthesized from the results of this project can be used by agriculture personnel to better manage their operations towards minimal impact on nearby waterways. Such information will also be helpful to regulatory agencies in their decisions regarding guidelines for the use of manure and associated wastes and under what scenarios regulations may need to be applied. Current results to date suggest that both overland flow during heavy rain events and effluent irrigation during summer months appear to play a dominant role in hormone-sediment accumulation due to preferential flow to tile drains regardless of antecedent soil moisture conditions. Water monitoring, source zone model validation, model refinement of transport downstream modeling, and lab studies for quantifying the biogeochemical process are currently in progress.

2008-35102-04640

Understanding Dynamics of Microbial Contaminant Fate and Transport in Rural and Agricultural Lands

Noble, R.T., Gonzalez, R.A., Conn, K.E., Institute of Marine Sciences, University of North Carolina at Chapel Hill, North Carolina

Summary: The Newport River Estuary (NRE) in eastern North Carolina is a large, tidally-flushed estuarine system that is on the USEPA 303(d) list of impaired waterbodies for fecal coliforms for high priority shellfish harvesting waters. Stormwater runoff is acknowledged as a major contributor of fecal contamination to the NRE. However, delivery and transport characteristics of non-point source fecal contamination stemming from the adjacent agricultural and rural lands are poorly studied. The main objective of this research is to understand the complex microbial contaminant fate and transport in stormwater runoff to the NRE from two topographically similar creeks with contrasting land uses. Ware Creek has low-density residential areas in closest proximity to receiving waters with some row-crop agriculture. Forested lands and row-crop agriculture dominate Oyster Creek. Both creeks flow into the NRE and, at the intersection, are commercially-relevant, economically-important shellfish harvesting beds.

Impact: We are characterizing the microbial contaminant signature in each creek during a range of storms using conventional and novel indicators with matching flow measurements, permitting determination of relative loading contributions. Four sampling locations in an upstream to downstream transect through each creek have been sampled over multiple storm events revealing extremely high variability, especially in relation to the magnitude of storms, antecedent rainfall, and storm intensity. Storm-induced fecal indicator bacteria loading into Ware Creek frequently ranged from 1 to 3 orders of magnitude higher than Oyster Creek. Instantaneous maximum *E. coli* loading estimates of 4.12×10^{10} and 3.4×10^{10} MPN/10 minutes where found for Ware and Oyster creeks, respectively. We are using quantitative polymerase chain reaction to test the usefulness of alternative indicators of fecal contamination, including two *Bacteroides spp.* assays. Human-associated *Bacteroides sp.* concentrations average 64 cells/100ml during dry conditions with a 43% detection frequency, while storm concentrations average 474 cells/100ml with a 66% detection frequency. From information generated during this project, simple models of fecal contamination delivery will be developed to aid federal and state regulators in restoration of the impaired waterbodies through identification of appropriate flow-considered best management practices.

2008-35102-19143

Investigating the Spread of Antimicrobial Resistance near Animal Facilities: Mechanisms of Extracellular DNA Transport and Transfer

H. Nguyen & J. L. Zilles, Department of Civil & Environmental Engineering, University of Illinois
Urbana-Champaign, Illinois

Summary: This project investigates the problem of dissemination of antimicrobial resistance near animal facilities. It focuses specifically on the transfer of adsorbed DNA, including resistance genes, into microorganisms in the environment. The effect of adsorbed antimicrobials on gene transfer is also being investigated. The main objectives of the project are: 1) to characterize the extent and mechanism of DNA adsorption to representative soil surfaces, 2) to identify relationships among environmental parameters, DNA adsorption, adsorbed antimicrobials, and the frequency of gene transfer for adsorbed DNA, and 3) to evaluate the frequency of gene transfer in soil columns and effluent water. Long-term goals include understanding and modeling the fate of antimicrobial resistance genes and identifying measures to minimize the spread of antimicrobial resistance.

Impact: Understanding gene transfer is important for assessing risks associated with land application of manure and identifying measures to minimize this risk, assessing the risks associated with genetically modified organisms, and predicting and maximizing bioremediation of contaminated sites. To date we have determined that solution ionic composition, NOM, and the antimicrobial oxytetracycline do not have a strong effect on gene transfer via natural transformation of the soil bacterium *Azotobacter vinelandii*. Solution ionic composition, including Ca^{2+} content, does affect the amount of DNA that is adsorbed and its conformation, and thereby indirectly influences its persistence and possible transformation. Dissolved natural organic matter (NOM, total organic matter from 0 to 100 mg/L) also interacts with DNA, with soil NOM depositing more on adsorbed DNA than aquatic NOM. Although not affecting the transformation frequency, a higher concentration of adsorbed oxytetracycline was required for inhibition of bacterial growth as compared to dissolved oxytetracycline. The major stakeholders for this project include both crop and animal agricultural sectors and the general public. This work provides a foundation for modeling gene transfer in the environment, by suggesting models focus on the amount of DNA adsorbed rather than its conformation or the surrounding solution chemistry.

2008-35102-19159

Surfactant-Facilitated Transport of *Cryptosporidium Parvum* in Soil

Christophe Darnault[1] and Astrid Jacobson[2]
[1]Department of Civil and Materials Engineering, University of Illinois at Chicago, IL
[2]Plants, Soils & Climate Department, Utah State University, Logan, UT

Summary: Our project addresses the contamination of soil and water resources by *Cryptosporidium parvum* resulting from land application of manure and use of surfactants in rural and agricultural watersheds. The main goals of our project are to understand the role of surfactants and vadose zone processes on the transport of *C. parvum* oocysts in soils. In particular, the effects of industrial, organic surfactants and humic substances on the deposition of *C. parvum* oocysts on soil particles and their mobility through structured and non-structured agricultural or range soils from Illinois and Utah are explored.

Impacts: Stakeholders are farmers, agricultural and environmental state and federal agencies, and drinking water public utilities. We use real-time polymerase chain reaction (PCR) to detect and count *C. parvum* in environmental soil and water samples. To crack the oocyst walls and extract their DNA, we used the method of consecutive freeze-thaw cycles and DNA purification kits. Primer and probe sets were selected using genbank and surveying publications. The minimum detection limit was established as $10^{\wedge 2}$ oocysts/mL. An enumeration curve (oocyst concentration vs. amplified curve number) was developed. For extraction of oocysts in soil samples, the method published by Zilberman et al. (2010) was adopted and we were able to detect oocysts. Several soil column experiments were run and collected water samples analyzed. The breakthrough curves and spatial distributions of *C. parvum* oocysts corresponding to each simulated transport scenario are being analyzed to characterize and compare their transport in natural soils. Our recent results seem to indicate that surfactants enhance the transport of *C. parvum* in soil by simultaneously impacting the hydraulic properties and retention mechanisms. Prior to using *C. parvum* in soil columns, we performed preliminary transport experiments using particles such as quantum dots and we demonstrated the coupled effects of solution chemistry and hydrodynamics on the mobility and transport of quantum dot nanomaterials in the vadose zone, highlighting their enhanced transport by surfactant, fast transport by preferential flow, retention at gas-water interfaces and the ripening phenomena.

Uyusur, B, C.J.G. Darnault, A., P. Snee, E. Koken, R. Jacobson and R.R. Wells (2010) Coupled Effects of Solution Chemistry and Hydrodynamics on the Mobility and Transport of Quantum Dot Nanomaterials in the Vadose Zone. *Journal of Contaminant Hydrology*, doi:10.1016/j.jconhyd.2010.09.013, 118: 184-198.
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Impact of Forest Treatments and Climate Change on Hydrologic Regimes: Assessment of the Mechanisms that Affect Hydrologic Alteration

Timothy E. Link, Enhao Du, John A. Gravelle, Jason A. Hubbart, Paul Koeniger, Diana Carson, Kari Friedrichs, Zion Klos, and Eric Herchmer, Department of Forest Ecology & Biogeosciences, University of Idaho, Moscow, ID

Summary: The effectiveness of best management practices for forestry under contemporary management regimes have not been assessed, however forest managers require this information in order to make appropriate decisions and to adapt management strategies to sustain aquatic ecosystem health. Furthermore, the combined impacts of timber harvest patterns and climate change on the hydrologic regime of the snowcover transition zone in the Pacific Northwest is poorly understood. An improved understanding of both the effects of landcover alterations and mechanisms that lead to hydrologic alteration is needed to ensure the sustainability of natural resources. The goals of this project are to assess the effects of contemporary forest management practices on flow volume, flow timing, stream temperature, stream radiation, sediment loads, nutrients, aquatic macroinvertebrates, and stream habitat. An additional goal is to evaluate how the hydrologic regimes in headwater catchments are likely to be altered under future land management and climate scenarios. The results are significant because they are transferable to other watershed systems, and the resulting modeling tools can be used to explore the potential impacts of alternative management strategies. This project relates directly to the USDA-CSREES Natural Resources and the Environment mission and program goals of: 1) Objectively predicting the effects of landcover and climate change on sustainable forestry, 2) Effectively managing natural resources, and 3) Minimizing degradation of ecosystems, soils and water resources.

Impact: Stakeholders for this project include natural resources scientists, natural resources management agencies (e.g. U. S. Forest Service, Soil & Water Conservation districts, etc.), forest products companies (e.g. Potlatch Corporation), policy making groups (e.g. Idaho Forest Practices Act Advisory Board), and water resources managers. The primary groups targeted to benefit indirectly from this work are rural resource-dependent and communities, and more generally the population of the western U. S. through improved natural resources management to balance timber production with environmental sustainability. This work has directly helped federal agencies (specifically the U. S. Forest Service) in the region that manage over 7.5 million acres of public land to make decisions based on sound scientific analyses. The primary new knowledge gained was that the Idaho Forest Practices Act effectively protects water quality and aquatic ecosystem health within the interior Pacific Northwest geologic setting under current climate conditions when 50% or less of the land surface is altered by clear or partial cut harvest. A large portion of this area is projected to shift from a snow-dominated to a rain-dominated hydrologic regime by the middle of the 21st century, and alterations of the flow regime due to land cover conversion are relatively minor in relation to the climate-driven changes posing distinct adaptation challenges for forest managers throughout the western conifer-dominated region.

2007-35102-18145

Investigation of the Fate and Transport of Fecal Contamination Using Microbial Source Tracking

Christopher C. Obropta, Environmental Sciences, Rutgers University, New Brunswick

Summary: Fecal contamination in receiving waters is often blamed on stationary, known sources such as dairy farms, even though there are several other potential sources. These other sources confound measurements and inhibit the ability to conduct any true source track down to determine the origin of the contamination. This project will use determine the fate and transport characteristics of bovine sources of fecal contamination and thus deterine the relative contributions of dairy operations to contamination in receiving waters.

The goal of this study is to investigate the fate and transport of fecal contamination in an agricultural watershed dominted by small dairy operations. The investigators will use a Microbial Source Tracking technique to isolate bovine fecal contamination and thus have the ability to determine the characteristics that determine it flow through the system. The resulting HSPF model created through this effort will accurately model the watershed-wide transport of fecal contamination released from the dairy farms and provide information necessary for mitigation of these releases. Additionally the fate and transport parameters determined through this study can be tranlated for other similar watershed experiencing similar problems.

Impact: This NRI project was completed in combination with a NJDEP funded watershed restoration effort. The report will be complete and submitted in January 2010. It will use the field sampling data to pinpoint sources of nutrient and bacterial contamination and proposed corrective efforts. It is anticipated that the model that is currently under construction will aid in this effort by contributing realistic estimates of the impact of dairy operations to bacterial contamination in small rural watersheds.

2007-35102-18139

Salmonella and Shiga-Toxin Encoding Genes in Coastal Streams in Central California: Relation to Land Use

Alexandria Boehm, Civil and Environmental Engineering,
Stanford University, CA

Summary: Coastal streams that run through agricultural watersheds are suspected to be major non-point sources of fecal bacteria and zoonotic pathogens including *Salmonella* and *E. coli* O157:H7 to coastal waters. However, very little work has been done to determine the relationship between land use and concentrations of these organisms in streams. The proposed work will augment our knowledge of how land use impacts concentrations of pathogens and fecal pollution in coastal streams. In particular, our work elucidates how watershed, physical, and biological factors control the presence and fate of fecal indicator bacteria, host-specific fecal markers from *Bacteroidales*, *Salmonella*, *E. coli* O157:H7, and the shiga-toxin gene in coastal streams of central California. Field studies were carried out in streams draining watersheds along the central California coast with diverse land use characteristics to pin-point how agricultural land use correlates to the prevalence of these organisms and their subsequent flux to the coastal ocean. Microcosm studies will explore how water chemistry, sunlight, and grazers impact the persistence of different *Salmonella* serotypes in stream water.

The work addresses the following research hypotheses: **R1** Streams draining primarily agricultural watersheds contain more waterborne fecal indicator bacteria, *Salmonella*, *E. coli* O157:H7, animal fecal markers in *Bacteroidales*, and shiga-toxin genes than streams draining watersheds that are primarily urban or forested. **R2** The persistence of *Salmonella* varies based on serotype, salinity and nutrient densities of stream water, and the concentration of grazers; sunlight is a major factor affecting the persistence of the organism.

Impact: Stakeholders include government agencies and NGOs involved in coastal and agricultural watershed management and policy. We have begun dissemination and more will be done in the coming year as results become finalized. We have done outreach with local farmers as well as with employees of Natural Resources Conservation Service in Half Moon Bay, CA and Santa Cruz, CA during a water quality management workshop and field tour in August 2009.

This grant was not focused on creating new technologies.

New knowledge was gained regarding the association between pathogens and land use. Fecal indicators and bacterial pathogens in 14 coastal waterbodies were quantified over 2 years. Indicators and pathogens were positively associated urban land covers. *E. coli* O157 occurrence was positively associated agricultural land cover. Of the 241 *Salmonella* isolates examined so far, 109 distinct PFGE profiles and 112 distinct sequence types (STs) were observed; this included 22 unique STs.
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2007-35102-1824

Survival and Transport of *E. coli* O157 and *Salmonella* Newport in Manure and Manured Soils

Zhengxia Dou[1], Shelley C. Rankin[1], Helen W. Aceto[1], John D. Toth[1], Jesse Vanderhoef[1], Charles F. Ramberg, Jr.[1], and Chitrita DebRoy[2]

[1] University of Pennsylvania, School of Veterinary Medicine
[2] Penn State University, *E. coli* Reference Center

Summary: After a number of recent, high-profile cases of human disease caused by pathogens from agricultural production entering the human food chain, it is widely recognized that a number of pathogens have established reservoirs in the food animal system. Our research program is using a combination of laboratory, field and on-farm monitoring studies to examine the survival and transport of two common zoonotic pathogens, *E. coli* O157:H7 and *Salmonella enterica* serovar Newport, and to investigate possible control strategies to limit their movement off-farm and into the environment.

We conducted a series of field trials using environmental sentinel chambers to follow the time course of pathogen deactivation in the soil of a dairy farm, in the dairy effluent lagoon, and in composted manure solids. Our laboratory studies are focused on 1) the effects of temperature on pathogen survival in dairy manure; 2) amendment of manure with two chemicals commonly used in dairy production, hydrated lime and alum, to see if manipulating pH could kill off or control *E. coli* and *Salmonella*; and 3) transport of pathogens in the soil-water system using leaching columns under simulated rainfall.

Impact: Results from our investigations are providing valuable information for dairy producers on means to control the survival and spread of zoonotic pathogens on-farm, and also benefit the general public by limiting the environmental movement of pathogens into the human food chain.

While *Salmonella* could survive for up to 14 months in environmental sentinel chambers in dairy farm soil, the most promising control strategies we found are composting manure solids (temperatures of 65°C generated in the pile killed all *E. coli* and *Salmonella* within 18 hrs), and pH adjustment of manure to under 4.0 to 4.2 using alum or adjusting pH to over 10.5 using hydrated lime. Both interventions completely eliminated the pathogens from dairy manure. Leaching column studies showed that the great majority of pathogens moved through soil in the first rainfall after application, suggesting controlling timing of field spreading of manure in dry weather periods if possible.

2007-35102-18262

Fate of Motile Bacterial Pathogens in the Subsurface: Determining the Extent and Influence of Motility and Counter-Current Movement on Cell

Jane Hill, University of Vermont and State Agricultural College

Summary: Little is known about how pathogenic (disease-causing) bacteria such as E. coli and Salmonella species contaminate our water and food supplies. The purpose of this study is to investigate how pathogenic bacteria - in particular, the ones that can swim - travel through the ground and in our irrigation pipes. Our experiments will be used to generate a model of bacterial transport which can be used to predict where bacteria travel.

The objectives are: 1. To determine the relative impact of Salmonella and E. coli motility upon cell adhesion, counter-current travel, and co-current transport under a range of environmentally-relevant chemistries and hydrodynamic conditions. 2. To develop a model to predict the transport of motile bacteria in porous media with applications in groundwater and irrigation systems.

In order to determine the impact of motility on the adhesion and transport of bacteria our experiments will be conducted at multiple physical scales. Specifically, we will investigate the macroscopic fate of bacterial cell suspensions in traditional packed bed columns, as well as the fate of individual bacteria using two novel microscopy-based, micromodel and microfluidic flow cell techniques. Furthermore, a model will be developed such that the relative importance of physicochemical and hydrodynamic forces acting on bacteria in the porous media can be quantified. The resulting two-dimensional particle tracking model will provide a theoretical basis for comparison to our experimental results.

Impact: Our focus has been the completion of the experimental portions of the project (microfluidic, packed bed column, and radial stagnation point flow systems) as well as the extension of the experimental results to theoretical predictions of bacterial transport at the micro and packed-bed scale. In brief, our results show: 1.Flagella presence for E. coli and Salmonella spp. increases the retention of bacteria in packed bed columns, 2.Non-motile strains can be transported further with the flow (laminar) than flagellated strains, and 3.Under laminar flow and in restrictive geometries, motile E. coli and Salmonella spp. arc out a parabola whose shape features are a function of shear (influential variables are bacterium velocity and bacterium shape). The outcomes of this project directly support the USDA CSREES strategic goal to expand research that addresses the measurement, transport and fate of agricultural pollutants in working land ecosystems.

2007-35102-18614

Fate and Transport of Pathogenic Microorganisms Originating From Livestock Manures Applied to Agricultural Lands

Rogers, Civil & Environmental Engineering, Clarkson University, NY
Orin Shanks, U.S. EPA, ORD, NRMRL, Cincinnati, OH

Summary: The potential for microorganisms from animal manures to contaminate water and spread disease has been known for over a century. Concentration of large numbers of animals in production units has led to a concomitant increase in the quantity of manure in relatively small areas. The microbial load in this manure can adversely affect water resources both from a water supply and recreational standpoint. Due to the difficulties in quantifying pathogens, indicators of fecal pollution, including coliform bacteria, fecal coliforms, *E. coli*, and/or Enterococci, have been monitored in lieu of overt pathogens for more than 100 years. Sufficient evidence exists to suggest that indicator organisms are not adequate to protect public health. This work seeks to increase knowledge of the fate and transport of pathogenic microorganisms in the environment as affected by different manure and soil management practices. The goals of the research are (1) develop in-depth data concerning the survival of pathogenic microorganisms from manure applied to soil under different management practices; (2) evaluate the movement of these organisms in overland runoff flow and through tile drainage water to receiving waters; and (3) evaluate the variability of genetic markers of fecal pollution from manures under different management practices. Improved understanding of management practice efficacy will reduce the load of pathogenic organisms reaching the environment. Targeted improvements in management practices will benefit producers and the public by focusing resources on the most productive activities.

Impact: Project activities have led to an improved understanding of the efficacy of nutrient-limited manure application, field drainage structures, and other BMPs for controlling runoff of fecal indicator bacteria, manure pathogens, and genetic markers for fecal pollution across a diverse range of operations. Knowledge gained through project activities is supporting decision making by producers, public health officials, and regulators to recommend improved management practices, and will inform emerging U.S. EPA water quality regulations. Quantitative assessment of antibiotic resistant fecal indicator bacteria in manure waste management systems, drainage structures, and nearby receiving streams from manure amended lands have also been performed, resulting in a large culture collection of antibiotic-resistant bacteria from CAFO production environments. Evaluation of the potential of emerging genetic markers for water quality investigations near livestock production areas and manure-amended lands are ongoing. Even so, the variability in persistence and decay of these genetic markers, cultivable fecal indicators, and bacterial pathogens in soils amended with manures at agronomic rates as a function of manure characteristics and environmental factors have been quantified. The results have been reported in the context of the utility of emerging genetic markers as indicators of water quality degradation and fecal source indicators following manure application to land. Other dissemination activities include several U.S. EPA and U.S. Geological Survey reports available on government websites and through online extension services, invited presentations to the SWCS Empire State Chapter, the North Carolina Water Resources Research Institute, the New York State Water Environment Federation, the US EPA, Office of Water and Office of Research and Development Seminar Series, 9 guest lectures at research universities, and 21 additional presentations at state, national, and international conferences. Two articles in peer reviewed scientific literature reporting results from this work have been accepted, four additional articles submitted, and four more are anticipated. The project has resulted in six M.S. and M.E. degrees in environmental engineering and sciences and four undergraduate research projects. These projects have resulted in four state- and national-level student research awards, including the second place Montgomery-Watson-Harza Consulting Engineers and Association of Environmental Engineering and Science Professors Master's Thesis Award in 2010.

Oral Session II

2006-35102-17197

Assessment of Dairy Manure Management Practices to Reduce Pathogen Runoff Losses from Agricultural Watersheds

Donald W. Meals, David C. Braun, and John P. Hanzas
Stone Environmental, Inc., Montpelier, VT

Summary: Runoff from land receiving livestock waste often delivers indicator bacteria and pathogens to surface waters, contributing to violations of water quality standards and a potential public health risk. Improved manure management practices are needed to reduce export of indicator bacteria and pathogens from land to surface waters. The research objectives are to quantify the occurrence of generic *E. coli*, *E. coli* O157:H7, *Salmonella*, *Cryptosporidium*, and *Giardia* in representative dairy manure in Vermont; characterize and compare pathogen and indicator organism losses in runoff from hayland and cornland receiving manure at the field scale; and document the effects of improved management on runoff losses of microorganisms. Levels of generic *E. coli* (10^4 to 10^6 MPN/g) in liquid dairy manure were consistent with literature values and were an order of magnitude lower in stored manure compared to fresh. No *E. coli* O157:H7 were detected, and low numbers of *Cryptosporidium* (<86 oocysts/g) and *Giardia* (<133 cysts/g) were observed only in occasional samples. Over the entire study period, no *E. coli* O157:H7 and very low numbers of *Cryptosporidium* ($\leq$5 oocysts/L), *Giardia* ($\leq$310 cysts/L), and *Salmonella* ($\leq$120 organisms/100 ml) were detected in field runoff. No significant association between generic *E. coli* and pathogens was observed in fresh or stored manure or in field runoff. Generic *E. coli* counts in runoff from corn fields (median 2800 MPN/100 mL) were similar to those in hay field runoff (median 3000 MPN/100 mL). Storm event runoff from corn fields (median 154 m^3) was significantly higher than hayland runoff (median 25 m^3); *E. coli* export from corn fields was significantly higher than that from hay fields. Prompt incorporation of applied manure on corn land significantly reduced event runoff compared to surface application. However, there was no significant difference in *E. coli* levels in runoff due to incorporation. Because of the runoff effect, there was a nonsignificant tendency for lower *E. coli* export due to manure incorporation. Higher grass height at manure application resulted in significantly higher event discharge, *E. coli* counts, and *E. coli* export from the treated hay field.

Impact: The pathogen content of dairy manure and field runoff in our study area was quite low. Our results confirmed that although significant reduction in indicator *E. coli* content of dairy manure occurs through manure storage, runoff from both silage corn and hay cropland still carries high levels of indicator *E. coli*. Prompt incorporation of manure on silage corn land can be recommended as a way to reduce microorganism losses because it may protect against microorganism wash-out in immediate major rainfall events, and because incorporation tends to reduce runoff and microorganism export in the long run. However, increased grass height on hayland led to significantly higher *E. coli* counts and export and cannot be recommended as a management practice. These results will be important in the continuing efforts to improve water quality in the Lake Champlain Basin and other regions where runoff from agricultural land impacts water quality.

2007-35102-18111

S. Typhimurium and *E. coli* O157:H7 Transport Modeling for Agricultural Practices

Gang Chen and Amy Chan Hilton
Civil and Environmental Engineering
Florida A&M University, Tallahassee, FL 32310

Summary: Animal waste is a valuable resource, which, when managed properly, can reduce the need for commercial fertilizer. Similarly, as a new recognized water resource, nutrient-rich reclaimed wastewater supplies not only water, but also plant nutrients (especially nitrogen and phosphorus) that can benefit agricultural production. When animal waste or reclaimed wastewater is used for land applications or agricultural irrigation, the major concern is the possible spreading of infectious agents or pathogenic organisms in the soil and the subsequent possibility of groundwater contamination once the infectious agents or pathogenic organisms pass through the vadose zone and reach the groundwater table.

Our major research interest concerns the impact of physiological growth stage and macro nutrient ratio on the fate and transport of *S. Typhimurium* and *E. coli* O157:H7 in the subsurface soil. We believe that the transport of *S. Typhimurium* and *E. coli* O157:H7 is controlled by their interactions with the surrounding environment, which are determined by their surface thermodynamic properties. This project seeks to provide operation strategies for animal waste land applications and reclaimed wastewater agricultural irrigation. Three major thrusts will be focused on this project: (1) *S. Typhimurium* and *E. coli* O157:H7 surface property characterization and interaction quantification under different physiological stage and macro nutrient ratio conditions, (2) *S. Typhimurium* and *E. coli* O157:H7 transport conceptual model development and validation, and (3) implementation of research discovery in field applications.

Impact: Our long-term goal is to provide guidelines for reclaimed wastewater large scale agricultural applications to avoid causing unintended harm to human and animal health and the environment. From this research, a pathogen transport model will be developed, which will provide a useful framework for administration to oversee and manage large scale animal waste land applications to protect the groundwater from being contaminated by the pathogens.

We incorporated *lux* genes into the model bacterial strains to trace their mobility, which can provide real-time observations of microbial activities. It is very useful as a research tool to quantify microbial activities.

Recent Publications:

1. Liu, J., Subramaniam, P., Martin, L., Grasel, P., Taylor, C. and Chen, G. (in press 2010). *E. coli* O157:H7 desorption by rhamnolipid biosurfactant in water-unsaturated porous media. *Journal of Adhesion Science and Technology*.
2. Chen, G., Subramanian, P. and Tawfiq, K. (2010). Bacterial deposition in unsaturated porous media as related to surface properties. *International Journal of Environmental Pollution*, *40*, 363 to 379.
3. Chen, G., Driks, A., Tawfiq, K., Mallozzi, M. and Patil, S. (2010). Bacillus anthracis and Bacillus subtilis spore surface properties and transport. *Colloids and Surfaces B: Biointerfaces*, *76*, 512 to 518.

2008-35102-04567

Transport and Survival of Escherichia Coli within Soil Aggregates

Kravchenko[a], J. Rose[ab], and A. Smucker[a], [a]Department of Crop and Soil Sciences, [b]Department of Fisheries and Wildlife, Michigan State University, Michigan

Summary: Without better understanding of the mechanisms associated with *E. coli* transport and survival in soil, the ability to minimize *E. coli* contamination of surface and ground waters will be limited. Soil matrix is a complex heterogeneous substrate with a wide range of variations in environmental settings existing at micro scales. These variations generate tremendous habitat diversity for soil microorganisms and affect their transport and survival. Last decade advances in X-ray computed microtomography (CMT) allow obtaining 3-dimentional images of soil interiors with resolutions of just a few microns. The goal of this project was to study the relationship between pore distributions and structures within soil aggregates assessed using CMT and *E. coli* distribution and transport in soils under different agricultural management practices. The project looked at the aggregates from the same soil type but under long-term (>18 years) differential land use and management settings at the NSF-funded Long Term Ecological Research experiment at Kellogg Biological Station. The land management practices that were considered are 1) conventionally plowed row crop agriculture (CT); 2) conservationally managed (no-till) row crop agriculture (NT); and 3) native vegetation on land with previous agricultural use (NS).

Impact: Project's stakeholders are the environment research community interested in micro-scale microbial fate and transport in soils. Two new methods for processing intact soil aggregates have been developed in the course of the project. First, we devised a set of techniques for cutting intact soil aggregates into geo-referenced slices and relating the experimental measurements conducted on the slices with the CMT image information. Second, a methodology has been developed and tested for conducting water flow, solute transport, and microbial transport experiments through the soil aggregates from coarse-textured soils with low aggregate stability. The proposed methods will be of interest to the soil, environment, and microbiology researchers working with intact soil samples and X-ray soil imaging.

We found that 18-20 years of contrasting management led to substantial differences in pore structures of soil aggregates. Aggregates from NS and NT management had more large connected pores located preferentially in the aggregate centers, while homogeneously spread medium-sized pores prevailed in CT aggregates. These differences manifested themselves in a greater flux of chemical solutes and *E.coli* through the NS aggregates, while *E.coli* retention was greater in the CT aggregates. The entire aggregates were easily accessible to *E.coli* in CT, while aggregate centers were less accessible in NT and NS aggregates. Pore structures played an important role in *E.coli* redistribution within the aggregates and in *E. coli* potential for reentering the water current during a water flow event.

2007-35102-18120

Water Conservation in Forage Production Systems by Sorghum-Legume Intercropping in the Southern High Plains

Sangamesh V. Angadi- Plant and Environmental Sciences, New Mexico State University, Las Cruces

Summary: New Mexico has been one of the fastest growing dairy states in the country, and the rate of dairy growth in West Texas also is increasing with animal density doubling in the last two years. To sustain the fast growing animal feeding operations in the region, new crops and cropping systems are needed to maintain quality forage production with less water use. This research will evaluate integrated forage systems (sorghum as a dominant crop and legume as a companion crop) for their ability to improve water use efficiency while producing high quality forage for ever expanding dairy and beef industries in the Southern High Plains.

The overall objective is to evaluate integrated forage systems (sorghum as a dominant crop and legume as a companion crop) for their ability to improve water use efficiency while producing high quality forage for ever expanding dairy and beef industries in the Southern High Plains. This will be achieved by: 1) Evaluating spatial arrangement of sorghum-legume intercropping systems for the Southern High Plains to produce high quality forage under irrigation; 2) Identifying a suitable shade tolerant legume for the region that facilitates the growth of a dominant cereal crop and improves its quality and productivity; 3) Evaluating intercropping systems under different deficit irrigation management to identify long term sustainability under reducing water resources; 4) Understanding resource use patterns and resource use efficiencies of component crops of the intercropping systems with special emphasis on water, radiation and nutrients; and 5) Extrapolate the research findings to a regional scale to evaluate the feasibility to adopt sorghum-legume intercropping systems and to estimate potential water savings using long-term climatic data for the Southern High Plains.

Impact: It is anticipated that this project will result in multiple benefits and will improve the sustainability of large dairy and beef industry in the stress prone semiarid regions of the country. The US agriculture is generally said to be legume poor systems. This study will increase the adoption of legumes in forage production systems. At the same time, the system is expected to conserve water, increase forage productivity and improve forage quality. The new intercropping system may also help in improving environmental sustainability of dairy industry in the region.

2007-35102-18162

Quantifying the Mechanisms of Pathogen Retention in Unsaturated Soils

Steven L. Bryant, The University of Texas, Austin

Summary: The source, transport and survival of pathogens ranging from viruses to Cryptosporidium and Salmonella affect groundwater quality in watersheds in agricultural and rural landscapes. The goal of this research is to improve our understanding of a fundamental mechanism of pathogen retention in the vadose zone. We seek to quantify two complementary modes of retention: accumulation at the air-water interface vs accumulation in the (small) volume of water associated with the air-water-solid contact line. Their relative contributions to retention are the subject of continuing debate. We also seek to quantify, experimentally and computationally, the geometry of air/water configurations confined in simple geometries and in granular materials

Impact: The method for quantifying the length of AWS contact line was applied to a small, computer-generated packing of equal spheres. Drainage and imbibition displacements were simulated with LSMPQS, and at each step the fluid configurations were analyzed for contact line length. An important outcome was the role of pendular rings of wetting phase at grain contacts. These rings make the main contribution to contact line length for water saturations below about 40%. Each ring creates two separate contact lines, one on each grain at the contact. Resolving individual rings is impossible with coarse grids, and estimates of contact line length will be too small by nearly a factor of two. Simulations suggest that the grid refinement of 0.04 grain radius or smaller is necessary. A remarkable result is that the AWS contact line length for granular material plotted versus water saturation shows little hysteresis between drainage and imbibition. (In contrast the interfacial area between air and water shows substantial hysteresis.) The reason is the competition between growth of pendular rings (which increases contact line length) and destruction of pendular rings (which creates menisci in pore throats with smaller contact line length) during imbibition. The new method was also applied to high-resolution X-ray computed tomography images of several sediments and sedimentary rocks. Simulations of drainage and imbibition in the images of rocks showed significant hysteresis in the contact line length, which is consistent with the much smaller number of pendular rings that formed. The computed dimensionless specific contact line length during showed little variation from simple model sediments (sphere packings) to sedimentary rocks, suggesting that a single curve might describe a wide range of natural materials for drainage. The specific contact line length during imbibition was also similar for the sedimentary rocks, the difference in curves being attributable to the difference in residual air saturation. This suggests that contact line length for natural materials could be correlated with a simple family of curves. The predictions of specific contact line length were validated using high-resolution images of the same materials when partially saturated. The images were acquired only at endpoints of drainage and imbibition. Excellent agreement was found at the imbibition endpoint in a bead pack when the simulation used the same coarse resolution as the image. Good agreement was also found at imbibition endpoint in a sandstone. The contact line measured at drainage endpoint in a dolomite is dominated by spurious contribution from wetting films held in roughness on the grain surfaces. Additional research is needed to distinguish this contribution from that of AWS, which is more relevant to colloid retention. This is the first quantification of contact line length ever reported for porous media. These results thus form the basis for new understanding of a variety of phenomena in unsaturated soils.

2007-35102-18217

Upper sugar Creek Watershed Ohio: A model Watershed for Study of Pathogen Origin, Fate and Transport

Warren A. Dick, School of Natural Resources The Ohio State University, Wooster

Summary: A risks associated with the introduction of enteric pathogens into water systems can only be assessed and managed when the sources and fates of the contaminants are identified. B.Increased community awareness and participation in the process of maintaining watershed sustainability are often linked to identifying management practices that positively impact water quality. A. This project examines the sources and fates of enteric pathogens introduced to headwater streams in an agricultural watershed. B. We will identify relationships between land management and the introduction of microbial pollutants into headwater streams in an agricultural watershed.

We will identify relationships between land management and the introduction of microbial pollutants into the headwaters of the Upper Sugar Creek, one of Ohio's most highly impaired watersheds. This watershed has a great diversity of land use and our working hypothesis is that associations between land use and bacterial contamination can be made and adaptive land management can be encouraged based on community knowledge and active participation in decision making. Toward these ends, three objectives have been formulated: (1) Associate land use patterns with bacterial contamination using a watershed sampling approach, (2) Conduct highly focused follow-up sampling to associate specific land management practices with host source diversity of fecal indicators, detection of select pathogens, and microbial indicator concentrations, and (3) Identify social and cultural keys to land management decisions that impact the potential for microbial contamination in headwater streams of the Upper Sugar Creek.

Impact: Our results suggest that water safety resources can be allocated to optimize the control of pathogenic bacteria in the stream water during summer and early fall. Also, although we found low numbers of O157 E. coli and Salmonella in water samples, many were contaminated at the concentration of approximately 1 colony/mL of unprocessed water. Under favorable growth conditions, this concentration could be a significant health concern to children, who are likely to interact with contaminated water sources. Additionally, measurable amounts of O157 and Salmonella at our water test sites indicate greater contamination closer to the bacterial source where they are less diluted. Currently the 27 counties that are part of the Muskingum Watershed are considering forming a joint board of soil and water conservation districts (SWCDs) for water quality trading that could eventually include bacteria loads. Understanding and defining the bacteria loads is crucial to the point that they could be traded. Specifically in Upper Sugar Creek, the work on pathogen transport is important because it is a high priority for the Upper Sugar Creek farmer partners.

Cornell University

2008-35102-04462

Assessing Farm-Source E. Coli and Salmonella Mobility to Water

Anthony G. Hay[1], Tammo S. Steenhuis[2], Brian K. Richards[2], Lorin Warnick[3], Larry Geohring[2],
[1]Department of Microbiology, [2]Department of Biological and Environmental Engineering,
[3]Department of Population Medicine and Diagnostic Sciences, Cornell University, NY

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Summary: Water quality concerns have led to increased focus on the environmental transport and fate of pathogenic microorganisms, including viruses, bacteria, and protozoa. Pathogenic microorganisms can move freely in hydrologic flow paths through soil, and pose serious risks to public health once they enter surface water bodies or groundwater wells. The goal of this project is to determine if *E. coli* and *Salmonella* isolated from hydrologic flow paths that lead to nearby water resources are more mobile than those isolated from surface sources. Given the importance of safe drinking and irrigation water to public health and food safety, it is important to understand the impact of subtle differences between pathogens on potential transport so that appropriate mitigation strategies can be put in place where needed. In this study carried out on several dairy farms in New York, bacteria isolated from surface sources (manure, bedding, wastewater, etc.) were compared with those isolated from drainage tile flow and groundwater through soil, and then assessed for mobility under controlled laboratory conditions. Microbiological and physicochemical characteristics were identified and correlated with motility and manure management practices to help develop potential best management practices (BMPs) to control highly mobile microorganisms.

Impact: Dairy farms - often found in close proximity with food crops - are an important source of human *Salmonella* and *E. coli* infections. Given the regional preponderance of dairy farms, the close proximity of farms and non-farm populations, the extensive spreading of manures, and the close hydrologic connection of many fields to water resources, conducting in this research in the Northeast USA is of particular importance both to dairy farms and to the general public. In this project over 2500 strains of *Salmonella* and *E. coli* were assessed for their ability to transport to water. From these findings, we have observed that the method of manure application to the fields appeared to minimize environmental stresses experienced by *E. coli*, which influenced the characteristics of *E. coli* populations transporting into the drainage water. These findings provide new insight into the how manure management practices influence the motility and potential of microbial pathogens to reach water sources. We will now seek to apply this understanding by designing and testing on-farm best management practices (BMPs) to minimize potential pathogen transport from infected dairy farms to nearby water resources. BMPs can be both structural (such as vegetated barriers to which microbes may attach or changing tile outflow configurations) and/or managerial (such as the timing and placement of manure applications).

Poster Session II

NDSU

2008-35102-19260

Source, Fate and Transport of Cryptosporidium in a Rural Midwestern Watershed

McEvoy, J.M.[a], Clark, M.E.[b], and Khan, E.[c]
[a]Veterinary and Microbiological Sciences, [b]Biological Sciences and [c]Civil Engineering
North Dakota State University, Fargo, ND, 58108

Summary: *Cryptosporidium* is a waterborne parasite that can survive many of the treatments used to decontaminate water. Understanding the sources and transport of *Cryptosporidium* in watersheds is necessary to reduce the number of waterborne outbreaks associated with this pathogen. Livestock have traditionally been blamed for the presence of Cryptosporidium in water but this is overly simplistic and other sources such as wildlife must also be assessed. Our goals are to determine the relationship between Cryptosporidium in wildlife and surface water, to determine the survival of Cryptosporidium in river sediment during winter, and to determine the effect of tile drainage in the transport of Cryptosporidium to surface water.

Impact: The stakeholders in this project include environmental regulators, water districts, water treatment plants, livestock producers, and public health officials. We have identified the host species for a number of Cryptosporidium genotypes that were previously reported in surface water and we have identified human pathogenic Cryptosporidium parvum and Cryptosporidium ubiquitum in both squirrels and voles. Together, these data expand our knowledge of the source and human health importance of cryptosporidia that are found in surface water. The Red River experienced major flooding during the spring thaw of 2009 and 2010. We collected water samples during these major flood events and determined that there was high prevalence of cattle adapted Cryptosporidium andersoni, indicating that cattle are a major source of water contamination of the Red River during spring flooding. Studies of Cryptosporidium transport in drain tiles and survival in sediment are ongoing.

2009-65102-05842

Current Knowledge of Sources, Fate & Transport of rural and Agricultural Watershed Pathogens: A National Synthesis Workshop

Dwight Bowman, Microbiology and Immunology, Cornell University

Summary: The purpose of this project is to summarize the current state of pathogens in rural and agricultural watersheds and to provide a written summary document that will present our current state of knowledge relative to the presence, transport, and fate of these pathogens. The project will look at viruses, bacterial, protozoans, and helminths. The will also be direct discussion of risk assessment methods and outcome analysis. It will include producers, stakeholders, government regulators, scientists, and industrial representatives. The work is being performed in knowledge based discussion groups and will be synthesized into one large published document.

The long-term goal of the project is to develop a printed document that will summarize the current state of knowledge relative to pathogens (viruses, bacteria, and protozoa) in rural and agricultural watersheds. The model document that would be emulated would be the 250-page document generated by the US-EPA and USDA Workshop (mentioned above), entitled "Contemporary Perspectives on Infectious Disease Agents in Sewage Sludge and Manure", 2001. The document developed in this workshop would contain specific sections devoted to manure pathogens (sampling, isolation, identification, inactivation, fate, transport, remediation, and trace-backs) as they relate to the industries of beef and dairy cattle, swine, and poultry (layer and broiler). The document would also include a section on methods of remediation and mitigation to inactivate pathogens in manure on farms or to prevent or minimize their spread into surrounding waters.

Impact: The workshop will be a four day event. All guests will stay on the Cornell Campus, and all meetings will be held at the College of Veterinary Medicine. The Workshop will consist of tours, lectures, a laboratory, breakout groups, small group presentations and the development of a consensus document. The document will be submitted to CREES for review within 4 months of the completion of the workshop.

2009-65102-05843

Fate of Antibiotics in Poultry Litter Before and After Application to Grasslands

Ching-Hua Huang[1], Spyros G. Pavlostathis[1], Miguel L. Cabrera[2] and Aaron Thompson[2]
[1] School of Civil & Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia; [2] Dept. of Crop and Soil Sciences, University of Georgia, Athens, Georgia

Summary: Persistent antibiotics in poultry litter may contaminate soil and water when the litter is applied to pastures as fertilizer. This project investigates mobilization of antibiotics from broiler litter and the fate of these contaminants in the soil-water environment through a combination of laboratory and field studies. The impact of litter management including stacking and aluminum sulfate addition on the fate and transport of antibiotics is also examined.

The project includes four specific objectives: 1) to investigate the sorption/desorption of antibiotics in boiler litter and in litter-amended soils and evaluate the impact of aluminum sulfate amendment; 2) to investigate the degradation of antibiotics during litter stacking and evaluate the impact of aluminum sulfate amendment; 3) to investigate the biotic and abiotic transformation of antibiotics under conditions relevant in water-litter-soil environments; and 4) to investigate the transport of antibiotics in runoff after litter application and evaluate the impact of aluminum sulfate amendment.

Impact: This project will lead to a better understanding of the environmental fate and transport of antibiotics from poultry litter land applications and the impact of litter management. The results will be useful for the farmers, poultry industry, and environmental scientists for the development of litter management strategies to mitigate potential adverse effects associated with antibiotic contaminants.

Progress is being made in analytical method development, field study analysis, and sorption/degradation evaluation. Preliminary studies have found the presence of ionophore and tetracycline antibiotics in poultry litter, soils and runoff, confirming the necessity of further investigating the fate and transport of these antibiotics from litter to the aquatic environment. Preliminary results also indicate strong interactions of ionophores and tetracyclines with different natural sorbents and transformation of these antibiotics under different environmental conditions. Further studies will aim to better understand these processes and the impact of litter management. Thus far, this project has trained two doctoral students and two visiting scientists on the analysis of antibiotics in complex matrices

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This project provides a database for media selection, a moisture sensor for long term monitoring, an automatic control system for biofilter operation, and a demonstration for low cost commercial biofilter construction.

2009-65102-05847

Animal Manure-Derived Dissolved Organic Matter Affects Sorption and Transport of Veterinary Pharmaceuticals in Soils

Hui Li, Crop and Soil Sciences Michigan State University, East Lansing

Summary: The overall objective is to understand the impacts of dissolved organic matter derived from land-applied animal manures on sorption and transport of veterinary pharmaceuticals in soils. Veterinary pharmaceuticals are commonly administered to animals for disease control and added into feeds at subtherapeutic levels to improve feeding efficiency. These utilizations have been identified as a primary pollution source of veterinary pharmaceuticals in soil and water. A large fraction of pharmaceuticals administered to livestock are excreted into manures, and the application of the manures as organic plant fertilizers interjects these pharmaceuticals into agricultural lands, where they are subsequently disseminated to the environment. There is a paucity of fundamental knowledge regarding the sorption and transport of manure-borne pharmaceuticals in soils. Such knowledge is required to assess the potential for exposure of at-risk populations. We hypothesize that the formation of DOM-pharmaceutical associations significantly influences pharmaceutical sorption to solid phases in soils, and results in facilitated transport in the environment. To examine this hypothesis, we propose the following objectives to systematically evaluate the effects of manure-derived DOM on sorption and transport of veterinary pharmaceuticals in soils: Objective 1. Screen representative veterinary pharmaceuticals for their propensities to bind to manure-derived DOM; this information will be used to define a subset of pharmaceuticals for detailed study. Objective 2. Quantify and rank the physicochemical factors determining the extent of DOM interactions with veterinary pharmaceuticals. Objective 3. Quantify the effects of manure-derived DOM on sorption of veterinary pharmaceuticals by soils. Objective 4. Quantify manure-derived DOM-facilitated transport of veterinary pharmaceuticals in soils. The output of this project will produce information that is critically needed to enable accurate environmental fate modeling and risk assessment of veterinary pharmaceuticals originating from land application of animal manure. Knowledge gained from this research will facilitate the development of objective scientifically-informed management practices to minimize the dissemination of veterinary pharmaceuticals in the environment resulting from agricultural production systems.

Impact: 1) We will screen representative veterinary pharmaceuticals for their propensities to bind to manure-derived DOM; this information will be used to define a subset of pharmaceuticals for detailed study. (2) We will quantify and rank the physicochemical factors, such as pH, ion type and concentrations, determining the extent of DOM interactions with veterinary pharmaceuticals. (3) We will conduct batch studies to quantify the effects of manure-derived DOM on sorption of veterinary pharmaceuticals by soils. (4) We will conduct column studies to quantify manure-derived DOM-facilitated transport of veterinary pharmaceuticals in soils.

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NDSU

2010-65102-20400

Persistence and Mobility of Estrogens In The Environment

Francis Casey[1], Xuelian Bai[1], Suman Shrestha[1], Heldur Hakk[2], Thomas, DeSutter[1]
[1] Department of Soil Science, North Dakota State University, Fargo
[2] Bioscience Research Lab. USDA-ARS, Fargo, ND

Summary: We are investigating how dissolved organic carbon (DOC) and colloidal organic carbon (COC) derived from swine manure affects the persistence and mobility of 17β-estradiol (E2) and two common E2 conjugates, sulfate (E2S) and glucuronide (E2G). Also, we are investigating how land-applied manure influences the fate and transport of estrogens through soil to tile drainage and whether estrogen detections are related to estrogen conjugates and/or DOC/COC.

Estradiol is released from animals and is potent to some aquatic species at part per trillion levels. Detections of E2 in surface waters have been associated with animal feeding operations and manure management. Estrogen conjugates are innocuous but can readily deconjugate to form potent free estrogenic compounds. Animals release estrogens from their body predominantly in the conjugate form because the soluble conjugates are more easily eliminated. However, the solubility of conjugates potentially increases their mobility in the environment. Additionally, free E2 is hydrophobic and will preferentially associate with DOC/COC. This association with DOC/COC can potentially enhance the mobility and persistence of E2 in the environment.

The overall goal of our project is to identify the mechanisms that facilitate the mobility and enhance the persistence of reproductive hormones in the environment. We believe that hormone conjugates and/or the association of hormones with DOC/COC causes them to persist longer and be more mobile in the environment. Our laboratory and field experiments are designed to identify and evaluate these potential fate and transport mechanisms.

Impact: To date we have completed some laboratory experiments with E2G and with E2 in the presence of DOC/COC. Results indicate that E2G is more mobile in soils compared to free E2, and can potentially result in greater than expected mobility and persistence of E2 in the environment. Dissolved and colloid organic carbon, derived from swine manure was also effective in enhancing the mobility and persistence of E2.

Our research findings can help develop techniques to manage animal manures, which can reduce the potential contribution of hormones to the environment. The stakeholders that would have interest in our project are those involved in the developing good management practices for animal operations. The basic information from this research may also be used to develop methods to treat wastewater, which is useful to the water treatment industry. Also, stakeholders who are involved in developing and maintaining clean water standards would have interest in our project.

We were successful in the synthesis of radiolabelled sulfate and glucuronide conjugates of E2.
The fate and transport processes of E2G in soil were identified for the first time. Also, the influence of swine manure-derived DOC/COC on the sorption and persistence of E2 was identified for the first time.

2010-65102-20403

Fate and Transport of Steroid Hormones and Veterinary Antibiotics Derived from Cattle Farms

Wei Zheng, University of Illinois, Champaign

Summary: The frequent occurrence of pharmaceutical and personal care products (PPCPs) such as hormones and antibiotics in water bodies is an emerging environmental issue in the United States. Animal farms, especially for CAFOs, have been identified as one of the most important sources for the release of animal hormones and veterinary antibiotics into the environment. Finding effective and sustainable strategies for reducing these contaminants and protecting water supplies is one of the most challenging tasks facing U.S. agriculture today. This project provides a unique effort to improve the understanding concerning the fate and transport of farm animal hormones and veterinary pharmaceuticals in soil, surface and ground water, and irrigation systems of agricultural and rural watersheds. Also, this project will assist in developing methodologies to identify contamination sources, assess CAFO systems, and develop feasible and sustainable management strategies to minimize the environmental loading of veterinary pharmaceuticals and animal hormones from CAFOs.

The goal of this project is to identify and quantify the environmental fate and transport of steroid hormones, veterinary antibiotics, and their metabolites released from concentrated animal feeding operations (CAFOs). It will help fulfill the USDA's long-term goal to minimize environmental contamination from veterinary pharmaceuticals and animal hormones in soil and water, and thereby protect and maintain valuable water supplies for agricultural irrigation and livestock production. The specific objectives of this proposal are to: (1) Identify and quantify the fundamental chemical, physical, and biological processes relevant to steroid hormones and veterinary antibiotics in the environment; (2) Assess a colloid-facilitated transport model for predicting the fate and transport of representative hormones and antibiotics in the environment; and (3) Validate proposed management strategies to minimize the load of hormone and antibiotic contaminants from CAFOs into the environment.

Impact: The research will involve a combination of laboratory, field, and numerical modeling experiments using representative steroid hormones and veterinary antibiotics as well as dairy and beef wastes. First, the analytical methods for steroid hormones, veterinary antibiotics, and their metabolites will be developed and optimized. Second, laboratory batch experiments will be conducted to elucidate fundamental chemical, physical, and biological processes and mechanisms of manure-associated steroid hormones and veterinary antibiotics derived from dairy and beef farms in the environment. Third, column experiments will be performed to demonstrate colloid-facilitated transport of selected hormones and antibiotics for model simulation. Fourth, the occurrence of steroid hormones and veterinary antibiotics in water bodies surrounding dairy and beef farms will be monitored.

2010-65102-20404

Agricultural Water Security and Instream Flows for Endangered Species in Coastal California's Watersheds

David Newburn, Department of Agricultural Economics, Texas A&M University, Texas
Nicholas Brozovic, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, Illinois
Ximing Cai, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Illinois
Adina Merenlender, Department of Environmental Science, Policy, and Management, University of California at Berkeley, California

Summary: In recent years, the need to maintain instream flows for endangered species has increased regulatory restrictions on surface water rights. This has created an incentive for agricultural producers that would have relied on appropriative surface water rights for onsite storage to shift to groundwater pumping. But groundwater pumping in the vicinity of small upland streams during the summer growing season may be detrimental to juvenile salmon. Hence, restrictions on agricultural water storage that have the intention of maintaining peak flows for adult fish migration may perversely shift water extraction to the seasonal drought period with a potentially larger impact on summer juvenile fish survivorship. In this project, we have three main objectives: (1) develop a spatial economic model to analyze the effect of the species listing on individual landowners and the demand for additional onsite storage; (2) employ a spatially explicit hydrologic model during the winter rainy season to assess bypass flows for adult fish migration; and (3) integrate the spatially explicit economic and hydrologic models to analyze proposed policy scenarios that allow additional onsite reservoirs while minimizing impacts to bypass flows for adult fish. The integrated policy analysis is implemented in coastal California, specifically the grape growing regions of Sonoma County.

Impact: This study is the first to analyze the heterogeneous effect of federal species listing on individual agricultural producer's joint water management and land use decisions. Our spatial economic results indicate that after species listing, vineyard development with onsite reservoir became significantly less likely, particularly in upland watersheds with seasonal streams. Additionally, the spatial economic model has been used to predict the likelihood of locations with additional demand for onsite storage. The spatial explicit hydrologic model has been developed that analyzes bypass flow with and without existing onsite reservoirs. This model has been presented to various stakeholders including the Sonoma County Water Agency, the California State Water Resource Control Board, and the Salmon Coalition. We are currently integrating the spatial economic predictions of onsite reservoirs with the hydrologic model in order to investigate which additional reservoirs would likely have the least impact on adult winter bypass flows.

2010-65102-20407

Transport and Mitigation of Beef Cattle Veterinary Pharmaceuticals and Hormones in Surface and Sub-Surface Runoff from Grazed Watersheds

Kenneth Tate, UC Davis
Edward Kolodziej, UN Reno
Sanjai Parikh, UC Davis
Anthony O'Geen, UC Davis
Edward Atwill, UC Davis

Summary: This project assesses transport and fate of veterinary pharmaceuticals and hormones commonly used in beef cattle. Sustainable cattle production depends upon cattle production practices that maintain clean water for irrigation of food crops, human consumption and recreation, and aquatic habitat for sensitive species. Project goals are to: 1) Evaluate the leaching, fate and transport of veterinary pharmaceuticals (Ivermectin, Oxytetracycline) and growth promoting steroids (17alpha-Trenbolone, 17beta-Trenbolone, Trendione, Melengestrol) utilized daily by thousands of cattle ranchers on millions of hectares of rangeland and irrigated pasture; and 2) Develop and extend management recommendations which reduce the transport of these pollutants in runoff.

Impact: Stakeholders for this project include grazing managers, ranchers, grazing and natural resources technical service providers, conservation communities, watershed organizations, and regulatory agency staff involved in the management of California's over 40 million acres of grazed watersheds. Our goal for impact is to extend the results of this project to increase stakeholder understanding of the potential risks associated with these pollutants, their fate and transport in grazed watersheds, and management options to mitigate transport and risk. The technology we are evaluating includes prescribed grazing management and vegetative filter strips. We are in the first year of this four year project. We have conducted preliminary field work required to optimize methods of cattle fecal and urine collection/analysis, treatment implementation and field water sample collection/analysis for rangeland and irrigated pasture studies required to achieve our objectives. Good progress has been made on the study goals. Experiments are underway to quantify the leachable mass of synthetic hormones from fecal pats using tray microcosms under irrigated and rainfall conditions. Two experiments have been conducted evaluating short term (1-24 hours) and longer term (1-5 days) leaching of synthetic hormones from fully submerged fecal pats (simulating maximum leaching during irrigated conditions). Follow-up studies will evaluate hormone and pharmaceutical leaching from fecal pats as a function of the surface area of the pat exposed to water. A simulated rainfall experiment was conducted to estimate the mass of trenbolone leached during actual rainfall events. These preliminary field and lab trials have prepared us to conduct field and lab experiments during the second year of this study, targeting both rainfall runoff and irrigation driven runoff and transport of these pollutants.

2010-65102-20425

Environmental Fate of Synthetic Growth Promoters Used in Animal Agriculture: Mechanistic Studies of Hormone Photolysis, Biodegradation and Soil Processes in Natural Systems

Edward P. Kolodziej,[1] David M. Cwiertny,[2] and Eric Marchand[1]
[1]Department of Civil and Environmental Engineering, University of Nevada, Reno, [2]Department of Chemical and Environmental Engineering, University of California, Riverside

Summary: Trenbolone acetate, melengestrol acetate and zeranol are the three synthetic growth promoters approved for use in animal agriculture, and studies demonstrate their presence in soils and surface water near animal agriculture operations. As these compounds are potent endocrine disrupting compounds, there is growing concern over their persistence in the environment and potential adverse effects on ecosystem health. However, details about their fate in surface water and soil systems remain limited.

This project examines the transformation and fate of synthetic growth promoters and their metabolites in surface water and soils. Using laboratory-scale experimental systems, we are determining rates and mechanisms of photoreaction, rates and extent of sorption on soils, biotransformation rates under aerobic and anaerobic conditions, and potential for mineral-promoted oxidation and hydrolysis. These experiments are designed to develop a thorough mechanistic and quantitative understanding of the fate of these compounds, with the ultimate objective that this data set will help to predict and mitigate the adverse impacts of animal agriculture on environmental quality and ecosystem health in receiving waters.

Impact: To date, the photolysis of all growth promoters and their major biological metabolites has been extensively investigated. Results indicate that the trenbolone (17α- and 17β-trenbolone and trendione) and melegenstrol (melengestrol acetate and melengestrol) family of compounds undergo rapid direct photolysis, with half-lives near 0.5-1 h using both natural and simulated sunlight in experiments. In contrast, zeranol and its metabolites (β-zearalanol and zearalanone) do not undergo direct photolysis but are susceptible to indirect photolysis routes involving reactive oxygen species (e.g., hydroxyl radical) generated from the photoreaction of dissolved organic matter. These results indicate that the synthetic estrogen zeranol and its metabolites are likely the most photo-resistent family of compounds in surface waters, although specific environmental persistence is dependent on aquatic conditions that influence these DOM-sensitized indirect photolysis reactions. Our results also suggest that the products from the direct photolysis of the trenbolone and melegenstrol family of compounds, which in some cases are photostable isomers of the parent compounds, are also likely to persist in surface waters and thus merit further investigation as constituents of concern. To investigate the effects of redox state on degradation of growth promoters and metabolites, a series of experiments using chemical redox buffers is underway. Studies indicate that up to 5 discrete buffered anaerobic (E_H = -100 to -500 mV) redox states can be achieved using titanium citrate and cysteine buffers. Ongoing studies are investigating biological activity and transformations under this range of redox states. Once complete, this data can more accurately predict the exposure risks associated with SGPMs, in turn providing a substantial step forward in the long-term improvement and sustainability of our agricultural and food systems.

2010-65102-20448

Fate, Transport, And Changes In The Potency Of Hormones, Antibiotics, And Their Degradates At The Watershed Scale

Shreeram Inamdar, PhD., Bioresources Engineering, University of Delaware, DE; Diana Aga, PhD., University at Buffalo, NY

Summary: Hormones and veterinary antibiotics could enter the environment due to land application of animal manure on agricultural landscapes. While their ecological risks are obvious, knowledge on the fate and transport of these compounds and their transformation products is limited at the watershed scale. Therefore, we address four important questions in this study: Q1: What are the relative amounts of parent and transformation byproducts of hormones and antibiotics in the watershed drainage and what are the transport mechanisms?, Q2: How do moisture and redox conditions in riparian wetlands influence the amounts and forms of hormones and antibiotics?, Q3: How do seasonal changes in moisture, temperature, and storm events influence the persistence and export of these contaminants?, and Q4: Do the endocrine disrupting potency of hormones and the antimicrobial effects of antibiotics change relative to their chemical compositions? The hormones that will be investigated include: Estrone (E1), Estradiol (E2β and E2α), Estriol (E3) and their sulfate and glucuronide conjugates; whereas the antibiotics targeted include chlortetracycline and sulfamethazine. This study is being conducted in an agricultural watershed on coastal plain soils in Delaware. Poultry litter is being applied to the fields at a rate of nine Mg/ha. Sampling and analyses is being performed for surface runoff, groundwater, soil, and runoff sediment following storm events and will be conducted over a 2-year period.

Impact: This project has just completed its very first year of study and hence results included here are preliminary. Eventually, results from this study will help farmers, state and natural resource conservationists, and federal scientists to better protect and manage water resources in agricultural settings subject to land-application of manure. Initial results suggest that the concentrations of estrogens and antibiotics in runoff waters are low (< 5ng/L). Among the estrogens, only Estrone (E1) and the conjugated forms of Estradiol (E2β-17S and E2β -3S) were detected. For antibiotics, only oxytetracycline and sulfamethazine were above the detection limits. At the watershed scale, concentrations or hormone and antibiotics were highest at the field-edge and then declined rapidly for downslope riparian locations. While no estrogens were found on runoff sediment, concentrations of some antibiotics were high for sediment (> 50ng/g). Hormones and antibiotics were not detected in groundwaters. Overall, preliminary results from this site suggest that typical levels of land-application of poultry manure may not pose a substantial threat in terms of release of hormones or antibiotics to runoff waters.

2007-35102-18242

Role of Directly Connected Macropores In Pathogen Transport To Subsurface Drainage

Garey A. Fox, Ph.D., Oklahoma State University; Ramesh Kanwar, Ph.D., Iowa State University; Robert Malone, Ph.D., USDA-ARS; Tom Moorman, Ph.D., USDA-ARS

Summary: The primary transport of fecal bacteria in soils occurs through macropores that bypass the soil's filtering and adsorptive mechanisms. Recent research indicates immediate breakthrough of solutes and contaminants in subsurface drainage by extraordinarily efficient transport through directly connected macropores. It is hypothesized that one of the primary reasons for field specific pathogen transport to subsurface drainage systems is related to the presence or absence of directly connected macropores that are "hydrologically" connected to subsurface drainage systems. Fox, Kanwar, Malone, and Moorman[1] investigated the role of biological macropores (i.e., biopores) in *E. coli* transport through soil and into artificial subsurface drainage. Their work included both laboratory column studies with artificial macropores and *E. coli* and tracer field experiments with rainfall simulation after liquid swine manure application[2,3].

Impact: Biopores in both laboratory and field experiments have been shown to consistently provide a mechanism for rapidly transporting *E. coli* into subsurface drains during flow events. Thus, liquid swine manure application preceding a rainfall event could be a source of pathogen pollution in tile and groundwater. Influential factors such as manure effluent concentration, sessile bacteria, presence of biopores, and soil dispersion under high manure effluent concentrations should be considered when modeling fecal bacteria transport in the environment. Once completed, an updated numerical model (Root Zone Water Quality Model) will serve as a prediction tool capable of simulating fecal bacteria transport in runoff and to subsurface drainage with and without biopores. This tool may be used by researchers, manure applicators, and regulators in determining best management practices for application of liquid swine manure.

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[1] Fox G.A., R. Kanwar, R. Malone, and T. Moorman. Role of directly connected macropores in pathogen transport to subsurface drainage. Contract no.: 2007-35102-18242.

[2] Fox, G.A., R. Kanwar, and R. Malone. 2008. Earthworms and E. coli: A Perilous Combination for Drain Flow Water Quality. *Resource* 15(6): 22-24.

[3] Guzman, J.A., G.A. Fox, R.W. Malone, and R. Kanwar. 2009. *E. coli* transport from surface-applied manure to subsurface drains through artificial biopores. *J. Environ. Qual.* 2009 38: 2412-2421.

2006-35102-17356

Managing the Risk of Cryptosporidium and Salmonella Spp. in Watershed

Hussni O Mohammed Population Medicine and Diagnostics Sciences Ithaca, New York

Summary: The protection of watersheds continues to be a major challenge since it impacts source and finished water quality. Our long-term goal is to maintain the safety of drinking water and sustain the agricultural viability in New York State watersheds. To this end we designed a multidisciplinary integrated research, education, and extension approach. The focus of the effort will be on the waterborne pathogens Cryptosporidium and Salmonella spp. Our studies are aimed towards identifying internal and external sources of these pathogens that contribute to the risk of their perpetuation on dairy farms. This knowledge will be used to control the effect of these sources, and hence reduces the load of the pathogens on water derived from agricultural watersheds. The proposed complementary epidemiologic studies are aimed towards ensuring a minimal output of zoonotic strains of these two pathogens from dairy farms in the Upper Susquehanna Watershed. We will first identify farms where these pathogens occur. Secondly, we will conduct an in depth ecological investigation to identify factors that lead to the introduction and on-farm transmission of these pathogens. Thirdly, we will develop models to understand the mechanism(s) by which these two pathogens are transmitted among animals in the watershed habitat. Finally, we will integrate the knowledge gained in these studies into extension and educational programs to closing the knowledge gap in microbial water quality. This knowledge will assist the stakeholders in making risk management decisions to prevent contamination of watersheds.

Impact: Our long-term objective is to preserve healthy habitats in watersheds, maintain the safety of drinking water, and sustain agricultural viability in New York State. This objective will be addressed by carrying out a series of complementary epidemiologic studies to ensure a minimal output of infectious agents from dairy farms in the Upper Susquehanna Watershed. The proposed studies will focus on the waterborne pathogens a protozoan and a bacterium, Cryptosporidium and Salmonella, respectively. The overall hypothesis to be addressed in this proposal is that there are several endogenous and exogenous sources of these pathogens that contribute to the risk of their perpetuation on dairy farms. Controlling these endogenous and exogenous sources will reduce the potential contribution of animal wastes to the degradation of water quality. We are proposing a systematic, integrated, and cost-effective approach to test this hypothesis. This hypothesis will be addressed through the following complementary specific aims: a) Identify dairy farms with varying risks of zoonotic genotypes of Cryptosporidium and Salmonella in the Upper Susquehanna Watershed in Delaware County, New York; b). Quantify the incidence of the zoonotic genotypes of these two pathogens on dairy farms to identify the sources, understand the ecology and dynamics of these infections, and describe the factors that lead to their perpetuation in these populations; c) Describe the mechanism by which each of the zoonotic strains of Cryptosporidium and Salmonella is perpetuated and transmitted among and across different animal species (wildlife and cattle) and between animal species and the environment to assess their fate; and d) Based on the information in Aims 1 through 3, design, in collaboration with the stakeholders, cost-effective strategies to control and manage the potential risk associated with the presence of bacteria and protozoan pathogens on dairy farms.

NDSU

2008-35102-19253

Impact of Subsurface Drainage on Water availability in the Red River Basin

Xinhua Jia, Civil, Agricultural & Geological Engineering North Dakota State University

Summary: A wet weather cycle in the Red River Basin region since 1993 has brought the ground water level closer to the soil surface in many areas. Subsurface drainage (SSD) can be an effective way to maintain crop production where shallow groundwater exists over a poorly drained soil or where soil salinity has elevated due to higher water tables. However, releasing drainage water into the Red River modifies the water balance and water quality (water availability), which, in turn, may disrupt the existing ecology and hydrological balance of the regional watershed and wetlands. Through this seed grant, we plan to use an existing test field to (1) conduct comprehensive measurements of the water mass balances of drained and undrained fields, with emphases on validation of evapotranspiration ET estimates by satellite-based remote sensing energy balance model using a suite of ground-based measurements, including eddy correlation, scintillometer, and soil water balance methods, and on their inter-comparison; (2) develop remote sensing algorithms for identifying fields with SSD installed; and (3) extend results from this seed grant project to a larger spatial scale, watershed or regional, preferably through a standard USDA NRI proposal. This study and potentially the future one are well aligned with one of the two USDA NRI Water/Watershed program's priorities - to identify, evaluate, and understand SSD that improves agricultural water conservation and crop production.

Impact: This project has compared the water availability (water balance and water quality) between a tile drained and undrained fields. The immediate outcome from this project has benefited the cooperative farmer who is involved in this project. Due to a better understanding of the water balance, he has learned how to use the water level and soil moisture change in the field to guide his conservation drainage process. He has become aware of using the sump pump to control drainage at a timely and precisely manner to conserve water for a higher crop yield. The water quality in the surface water has also been improved due to the time change of fertilizer application from fall to spring and reduced drainage water and nutrient amount from the field. The cooperative farmer stopped the sump pump for drainage on June 27, 2008, June 3, 2009, and May 24, 2010, so that less amount water and nutrient were left the field to the surface water system. For the research team, we were able to use sensors to guide the process, and a new method was developed to measure the drainage effluent through this project. The drainage conservation techniques developed from this project has been shared with the public and used by other farmers in the Red River Valley (RRV) region. A significant policy change has been enforced in ND and drainage permit is now required for new tile drainage installation. The research team has gained more knowledge about the impact of tile drainage on the Red River Flood from the water balance point of view. New research project on snow hydrology has been started. It is expected that more farmers and public will adopt the technology for a better nutrient management plan incorporated in the water management plan. The results from this project will affect the RRV area and anywhere drainage is practiced.

2009-35102-05212

Survival of *Escherichia coli* on Soil Particle Surface in Opaeula Watershed of Oahu, Hawaii

Tao Yan, Department of Civil and Environmental Engineering, University of Hawaii at Manoa, Hawaii

Summary: The survival of *Escherichia coli* in agricultural soils can affect water bacteriological quality and confounds monitoring efforts. To understand *E. coli*'s survival in soil environments, it is important to taken into consideration the enormous genetic diversity of *E. coli* in natural environments and their different survival behaviors on soil particle surface than in water.

The overall goal of this project is to understand how different environmental *E. coli* strains survive on soil particles surfaces. Specific research objectives are to (1) determine the genetic diversity of environmental *E. coli* isolates collected from soil and water in Opaeula and other Hawaii watersheds, (2) to compare the survival of environmental *E. coli* among themselves and with the common lab K12 strain on quartz sand surface under various environmental stresses, and (3) to identify genetic elements and phenotypic characteristics contributing to the survival of *E. coli* in soil environments.

So far, about 1,000 soil and water *E. coli* isolates were obtained from the Opaeula and two other Hawaii watersheds. The *E. coli* isolates were DNA fingerprinted by rep-PCR and enormous genetic diversity was found among the isolates. The concentration levels of *E. coli* were found to vary in the watersheds depending on adjacent land use patterns, with higher abundance levels observed in urban areas than in agricultural and forest regions.

Impact: Upon completion, the project will improve our understanding of *E. coli* survival in soil environments. In particular, major environmental factors that affect *E. coli* survival in soil environments will be identified, which can help farmers to develop best management practices to reduce the abundance of *E. coli* in agricultural soil environments.

Publications:

1.Dustin K. Goto and Tao Yan (2010). Genotypic Diversity of Escherichia coli in the Water and Soil of Tropical Watersheds in Hawaii. *Applied and Environmental Microbiology*. Submitted.

2.Dustin K. Goto and Tao Yan (2010). Effects of Land Uses on Fecal Indicator Bacteria in the Water and Soil of a Tropical Watershed. *Environmental Monitoring and Assessment*. Submitted.

2007-35102-18234

Payment Incentives Required for Irrigation Retirements Programs

Steven D. Shultz, University of Nebraska, Omaha

Summary: Irrigation must be reduced by 100,000 acre-feet in the Republican watershed in southwestern Nebraska to comply with the recent settlement of a U.S. Supreme Court case (Kansas v. Nebraska and Colorado.) This study will estimate incentives required by landowners to permanently retire irrigation rights in the Republican watershed in order to quantify estimate potential irrigation retirement costs across the entire watershed.

Impact:. This project has demonstrated an approach to accurately and objectively quantify the market value of irrigation through hedonic price modeling of agricultural land sales across and Upper Great Plains watershed that relies on groundwater based irrigation. It has also been demonstrated that irrigation values vary substantially across the Republican watershed indicating that the use of a single (average irrigation value) across a watershed is misleading and inaccurate. As well based on an analysis of 27 retired parcels (2,400 acres) of land whose irrigation rights were retired in 2006 as part of a joint USDA/State/Natural Resource District) it is now known that 1) Retired irrigation parcels were markedly smaller and more irregularly shaped than nearby non-retired irrigated parcels, and they had higher slopes and lower soil rating for plant growth. In other words, they were less suitable for irrigation than non-retired parcels. 2) On aver rage land owners required premiums of 184 to retire their irrigation rights The characteristics of these parcels were estimated with a range of observed premiums from 11% to 925%. Change in Actions Irrigation retirement programs in the Republican Watershed have recently been placed on hold due to state lawsuit regarding the legality of how proposed irrigation retirement programs are to be funded and an ongoing Federal lawsuit between Kansas and Nebraska regarding water rights in the Watershed. However, stakeholders from the region (state legislators, natural resource district managers, and agricultural producers) are aware of this research regarding market values for irrigation and it is expected that when irrigation retirement programs in the Watershed are resumed, that retirement program details will be influenced by the research results of this project. However in the nearby (adjacent) Central Platte Watershed irrigation retirement programs are being undertaken by both natural resource districts and environmental organizations and it appears that these entities have benefited from the research results of this project. In particular they are not using a single (average) irrigation value across the entire watershed, and they appear to paying lower premiums for irrigation rights than observed in the Republican watershed (and quantified by this study). Finally, it is contended that his research has educated and influenced state policy makers with regards to the use of hedonic price modeling to quantify irrigation values as the approach has been incorporated into a research project quantifying the value of irrigation in the nearby Niobrara Watershed where an in-stream flow request for recreation is not being evaluated. In particular, many of the methodologies used in the Niobrara Basin project are the same as those used in the USDA-NRI project (the mapping and hedonic price modeling of agricultural land sales). The USDA-NRI project has therefore already had a positive impact in the state of Nebraska. Changes in conditions: Non Yet to report.

2008-35102-18733

Human Health Risks from Animal Agriculture: Comparitive Analysis of Transmission of Multiple Zoonotic Pathogens in Mixed-Used Agricultural

Thomas Harter, Land, Air and Water Resources University of California, Davis

Summary: The prevalence of some waterborne pathogens has prompted water districts, food safety agencies, and regulatory agencies to include animal agriculture and wastewater treatment plants in their list of possible adulterating water sources during outbreak investigations. This study is designed to understand similarities and differences in the occurrence, fate, and transport of key zoonotic pathogens and several indicator organisms in soil water, groundwater, and surface water at the field- and catchment-scale; and to provide a conceptual framework for the quantitative assessment of pathogen transport in the surface water groundwater continuum. We evaluate the environmental transmission of Cryptosporidium, Campylobacter, E. coli O157:H7, and Salmonella, as well as the indicator organisms Enterococcus spp. and Bacteroidales in animal production areas and in cropping systems irrigated with waters containing animal or human waste. This project begins to evaluate whether our current understanding of lab-scale processes can be scaled to the field- and catchment-scale. With multidisciplinary expertise in microbiology, veterinary medicine, and hydrology, the project team combines the strength of empirical work at various scales in agricultural systems with the need to understand transport processes based on first scientific principles. The knowledge gained will be critical to better assess and delineate the potential impacts of cattle grazing, confined animal agriculture (dairy), and municipal effluent application in cropping systems on surface water and groundwater quality.

Impact: A major outcome of this project is the new understanding that we developed on the filtration and transport behavior of pathogens; furthermore, our work has produced pioneering data on the farm scale occurrence and transport of other pathogens on confined animal facilities. One manuscript has been submitted, three manuscripts are in preparation. Our field, laboratory, and theoretical work has been presented to regulatory agency personnel, industry stakeholders, consultants, and environmental stakeholders, which are using the information to shape policy regarding the regulation and monitoring of animal feeding operations.

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2008-35102-19222

Escherichia Coli and Cryptosporidium Occurrence, Transport, Fate and Reduction from Vermont Dairy Far, Point and Non Point Pollution Sources

Aleksandra Drizo, Plant and Soil Sciences, The Unviversity of Vermont and State Agricultural College

Summary: The purpose of this research is to quantify dairy farm pathogens Escherichia coli (E. coli) and Cryptosporidium parvum (C. parvum) in barnyard and milking operations wastewater and in feed bunk and farm ditch runoff generated during precipitation events, and to assess a novel steel slag filter technology for reducing these organisms from point and non-point dairy farm effluents in a cold northern climate. In addition, the effects of water quality parameters, such as phosphorus, suspended solids, and organic matter concentrations, on E. coli and C. parvum occurrence, transport and survival rates in dairy farm effluents and runoff will be evaluated. The objectives will be achieved by long-term monitoring (24 months) of E. coli and C. parvum occurrence in pollution sources and pathways, and after steel slag filter treatment, on two dairy farms in Vermont. Knowledge of the E.coli and C. parvum occurrence and transport, and in particular, the effects of water quality parameters on their fate and quantity in dairy farm point and non-point pollution sources, will significantly contribute to efforts aimed at controlling and eliminating these pathogens. The project will also test the efficacy of EAF steel slag filters as a practical and cost effective technology for pathogen reduction with potential for implementation in water quality policy practices.

Impact: All samples collected at the UVM Dairy Farm and analyzed at the UVM Entomology Research Laboratory contained E. coli ranging from 3 x 10e3 to as high as 5.9 x 10e7 per 1ml. Bacteria content revealed significant seasonal variation, suggesting that E.coli is strongly affected by temperature fluctuations as well as farm practices (e.g. differences in the quantities of germicidal chemicals used during winter and summer months). Parasitic coccidian species were not detected in any of the farm wastewater samples, and therefore we concluded that animals at the UVM Paul Miller Dairy Farm are free from coccidian infection. Investigations on the ability of steel slag to reduce Cryptosporidium species from wastewater using Nosema genus microspordia showed that small columns (0.2 and 0.3 m height, containing 0.5 and 0.75 kg steel slag) decreased number of parasites 154 and 818 times, respectively. This finding is extremely important as it represents first investigations on the ability of steel slag to reduce Cryptosporidium species from wastewater. Another important finding was discovery of numerous protozoa from genus Coleps (Ciliatea, Gymnostomatida, Colepidae) on the surfaces of steel slag samples taken from the filter that had been treating dairy effluent for over 800 days. Two steel slag filters connecting in series, volume of 4 m3 and operating at the hydraulic residence time (HRT) of 6 days each, achieved remarkable E.coli reduction efficiency averaging 92% over a 325 days period. When the efficiency reduced to 40% on day 350, filters were drained and left to rest for a period of 5 weeks. Similarly to phenomena of P rejuvenation observed to occur in slag filters, after 5 weeks of resting, filters regained their full capacity to reduce E.coli, and operated at the average efficiency of 73% for another 100 days. Colum experiment confirmed that efficiency in E.coli reduction via steel slag filters is affected by the HRT. Comparison of slag filters performance at 4, 6, 8 and 12 hours HRT over a period of 60 days showed that E.coli efficiency increased from an average 49 (at 4 h HRT) to 92% (at 12 h HRT). The experiments to date enabled us to confirm steel slag filters efficiency and gain new understanding of the potential reduction mechanisms of E.coli reduction via steel slag filter technology. Perhaps the 3 most important findings in terms of expanding the current knowledge are: 1) the first results demonstrating that steel slag could be efficient in Cryptosporidium species reduction; 2) the discovery of the protozoa species (Coleps) on steel slag surfaces, as future research will be directed towards further understanding of their role in E.coli reduction and 3) the investigation of the impacts of various filter operating HRTs on E.coli reduction performances, which allowed us to further develop steel slag filters for treatment of pollution from diffuse sources.

2007-35102-18115

Grazing Management Effects on Pathogen Loading of Midwestern Pasture Streams

James R. Russell, Dept. of Animal Science, and Steven M. Ensley and Kyoung-Jin Yoon, Dept. of Veterinary Diagnostic and Production Animal Medicine, Iowa State University

Summary: Previous research has shown that allowing grazing cattle uncontrolled access to pasture streams increases concentrations of fecal coliform bacteria in the water, implying risks of loading of these water sources with enteric pathogens that may be present in cattle feces. The extent of this risk may be controlled by grazing management practices that limit the proportion of time that cattle are in or near the pasture streams. Furthermore, while the presence of fecal coliforms in a water source indicates fecal contamination, that contamination may be from other animal species and may not relate to the pathogen loading. The long-term goal of this project was to quantify the effect of grazing management practices that alter the distribution of beef cattle grazing near pasture streams on loading of specific intestinal pathogens in Midwestern surface water resources. Specific goals of the project were to: 1) Quantify grazing management effects on loading of surface water resources with fecal bacteria and specific pathogens from manure deposition in Midwestern pastures; 2) Measure grazing management effects on transport of specific intestinal pathogens in precipitation surface runoff from stream banks; 3) Evaluate the effects of botanical composition, grazing management, and climatic conditions on distribution and defecation patterns of cattle grazing in Midwestern pastures; and 4) Develop a model assessing the risk of intestinal pathogen loading of Midwestern pasture streams.

Impact: The primary stakeholders in this project are beef cow-calf producers in the Rathbun Lake watershed in south central Iowa as well as the rest of the Midwest and the agency and extension personnel who consult and advise these producers. This project has made the stakeholders aware of diverse sources of fecal bacteria and enteric viruses present in pasture streams that could infect their animals. In addition, the stakeholders understand that, while infrequent, the risks of pathogen loading could be reduced by health management practices to minimize shedding of pathogens and grazing management practices like rotational grazing that reduce pathogen loading from direct deposition of feces in the streams and in precipitation runoff from bare ground adjacent to the streams by reducing the proportion of time that cattle are in or near the streams. This project has provided the knowledge that: 1) Incidences of enteric viruses in pasture streams are not related to the concentrations of total coliforms and do not differ between up- or downstream sites on streams in pastures stocked at densities common to south central Iowa; 2) Shedding of *E. coli* O157:H7 and the enteric viruses by grazing cattle is infrequent, but is the primary factor controlling the risks of pathogen loading of pasture streams; 3) Maintaining vegetative cover along pasture streams will reduce the risk of pathogen loading of pasture streams in precipitation runoff; 4) Restricting grazing cattle access of pasture streams to stabilized crossings or through rotational grazing will reduce the risk of pathogen loading of pasture streams by reducing direct fecal deposition in streams and maintaining vegetated cover on stream banks; and 5) The best management practices to limit pathogen loading pasture streams by altering the temporal\spatial distribution of grazing cattle will be depend on pasture size and shape.

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2011-67019-21119

Bioaccumulation of Endocrine Disrupting Compounds from Recycled Water in Edible Fruits and Vegetables

Patrick C. Wilson, Indian River Research and Education Center University of Florida, Gainesville

Summary: Billions of gallons of sewage treatment plant effluents from domestic and industrial areas are discharged back into surface water sources or injected into deep wells. Use of this recycled waste water as an irrigation source for agricultural food production could significantly reduce stresses on groundwater resources used for potable water. However, recycled municipal waste water has some characteristics, particularly the presence of estrogenic hormones and chemicals that many render it hazardous for this application. Concern exists over the potential for bioaccumulation of estrogenic compounds, estrogen mimics, and some pharmaceutical compounds in edible fruit and vegetables irrigated using recycled municipal waste water. Estrogenic hormones are involved in many biological functions, including development, puberty, behavior, gametogenesis, and integrated sexual function. Exposure to exogenous sources of estrogenic chemicals (endocrine disrupting compounds, EDCs) can result in many negative impacts, including loss of reproductive potential and activation of some cancers. While information is available regarding EDC presence in sewage plant effluents and receiving water bodies, no information is available regarding potential transfer of those constituents to edible portions of fruits and vegetables receiving irrigation water from these sources. The purpose of this project is to establish a clear understanding of the fate and potential bioaccumulation of EDCs within the edible portion of crop plants. Various techniques will measure these compounds within plant fruits, leaves, stems, and roots. This information will be useful for predicting bioconcentration potential, potential dietary intake, and risks to human health.

Impact: Too early for to report impacts.

2011-67019-20026

MICHIGAN STATE UNIVERSITY

Bioaccumulation of Antimicrobials by Vegetables and Fruits: Potential And Relevance To Human Health And Environmental Fate

Dawn Reinhold (Biosystems and Agricultural Engineering), Alison Cupples (Civil and Environmental Engineering), and Hui Li (Crop and Soil Science); Michigan State University

Summary: The sustainability of food crops depends on increasingly scarce irrigation water. Current discharge of treated municipal wastewaters into surface waters introduces organic pollutants at concentrations reported to adversely impact freshwater ecosystems. Irrigation of crops with treated municipal wastewater may provide a sustainable solution to water quantity demands while providing additional treatment for organic pollutants; however, the same chemical constituents that can adversely impact aquatic ecosystems have the potential to bioaccumulate in foods. Antimicrobials, specifically triclocarban and triclosan, are commonly used in consumer goods and persist through wastewater treatment. Studies have documented ecosystem and human health risks associated with consumption of antimicrobials, including endocrine disruption and decreased rates of reproduction. Recent research by the PD has indicated that pumpkin and zucchini can bioaccumulate µg per g concentrations of antimicrobials from land-applied biosolids. To promote sustainable and safe utilization of municipal wastewaters for irrigation, research is needed to understand fate of antimicrobials in fields and fully characterize bioaccumulation of antimicrobials. The *overall aim of the proposed research* is to comprehensively assess the bioaccumulation of antimicrobials by common vegetables and fruits and to determine the relevance of bioaccumulation of antimicrobials from irrigated waters to human health risk and environmental fate. Our objectives are to: (1) Quantify the potential of food crops to bioaccumulate antimicrobials, (2) Quantify and model fate of antimicrobials in vegetated soil columns, and (3) Compare the health risk due to bioaccumulation of antimicrobials from irrigation with treated wastewaters with that from other routes of exposure.

Impact: Too early to report impacts.

2011-67019-21122

Development of Drought Triggers for Agricultural Applications

Indrajeet Chaubey, Departments of Agricultural and Biological Engineering, and Earth and Atmospheric Sciences, Purdue University
Rao S. Govindaraju, School of Civil Engineering, Purdue University
Nanduri Krishna Kumar, International Center for Water Resources Management, Central State University
Devadatta Niyogi, Departments of Agronomy, and Earth and Atmospheric Sciences, Purdue University
Carol X. Song, Rosen Center for Advanced Computing, Purdue University

Summary: Identifying drought triggers and providing spatio-temporal information on anticipated water deficits is crucial for both food and energy security. To establish reliable drought triggers and water deficits over various space-time horizons, we propose two types of graphical models - (a) directed graphical models (homogeneous hidden Markov models) for capturing time dependence, and (b) undirected graphical models (Markov random fields) for preserving spatial dependence in the data. The models will be trained adaptively in the Bayesian framework. The probabilistic basis of these models will facilitate informed drought response decisions by quantifying uncertainty in drought states and projected deficits, that can be used for quantifying drought risks and impacts.

A major objective of the proposal is first to develop a spatio-temporal probabilistic model for characterizing droughts from historical measurements of precipitation, temperature (surrogate for evapotranspiration), soil moisture and streamflow. This will allow us to investigate the stated hypothesis over the study region comprising of two major agriculture-dominated watersheds in the Midwest - Upper Mississippi River Basin (UMRB) and Ohio River Basin (ORB). We will develop a methodology that will enable us to compute a probability-based overall water deficit index from multiple drought-related quantities (or indices). By deploying copulas, we will construct joint distributions of hydrological variables that will preserve marginal distributions of relevant quantities along with their spatial and temporal inter-dependence. The joint distribution will provide an objective description of the overall deficit status. Subsequently, we will develop hidden Markov models to capture spatio-temporal aspects of droughts. This model will lead to the development of practical drought triggers and project water deficits that can be used for decision making purposes.

Impact: This project will start January 1, 2011. We do not have any result from this project to report at this point.

2011-67019-20052

Accumulation of Antibiotic Resistant *Salmonella* in Lettuce after Irrigation using Recycled Water

Xu Li[1], Daniel Snow[2], Laurie Hodges[3], and Shannon Bartelt-Hunt[1]
[1]Department of Civil Engineering, [2]School of Natural Resources, and [3]Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE

Summary: Recycled water from municipal and agricultural sources is often used as an alternative to supplement increasingly scarce fresh water sources for irrigation of food crops. Due to limitations in treatment methods, recycled water often contains trace level contaminants, such as antibiotics, metals, and pathogens. During irrigation these chemical and microbial constituents are introduced to cropland, where they can either be degraded, or persist and accumulate in soil. Among the persistent constituents are antibiotic resistant pathogens (ABR pathogens) and antibiotics. Pathogens can acquire antibiotic resistance genes (ABR genes) both in recycled water prior to irrigation and in soil after exposure to antibiotics introduced to soil during irrigation. ABR pathogens can gain rapid and widespread entry to food crops, colonize internally, and become endophytes. Endophytic pathogens, such as ABR *Salmonella*, cannot be eliminated during washing and pose a food safety concern of consuming vegetables that are eaten raw. Currently, little is known about the fate of ABR *Salmonella* in soil or their accumulation in fresh vegetables after irrigation using recycled water. This knowledge is critical in predicting the public health impacts of fresh vegetables irrigated using recycled water.

The main goal of the project is to understand and minimize the accumulation of ABR pathogens in vegetables irrigated using recycled water. The central hypothesis is that accumulation of ABR pathogens occurs in vegetables that are irrigated with recycled water, and the accumulation is positively correlated with the abundance of ABR pathogens in the rhizosphere. Three supporting research objectives have been established: 1) determine the fate of ABR *Salmonella* in soil after irrigation using recycled water, 2) quantify the accumulation of ABR *Salmonella* in lettuce, and 3) develop best management practices to minimize ABR *Salmonella* accumulation in lettuce.

Impact: The stakeholders are farmers that grow food crops as well as food processing companies that use fresh food crops in their products. Expected impacts include the assessment on the potential risk of using recycled water to irrigate food crops that are eaten raw and the development of best management practice to minimize such risk.

It's too early to report impacts

2011-67019-21120

Understanding Fate of PPCPs in Soil-Plant Systems Irrigated with Treated Wastewater

Jay Gan, and Jiri Simunek, Department of Environmental Sciences, University of California, Riverside, CA 92521

Summary: In arid and semi-arid regions (e.g., American Southwest), municipal treated wastewater may become an important water source to augment agricultural irrigation, thus enhancing the long-term sustainability of agriculture that is currently impacted by water scarcity due to urbanization, droughts, and climate changes. An emerging threshold issue to this reuse, however, is the potential transfer and accumulation of trace contaminants such as pharmaceutical and personal products (PPCPs) from the recycled water to edible plant tissues. At present, our collective knowledge on this topic is essentially blank. The main goal of this project is to evaluate the bioaccumulation of PPCPs by common vegetables and strawberry that are irrigated exclusively with treated wastewater. We will carry out greenhouse hydroponic experiments to characterize the uptake and translocation of PPCPs by using 14C-labeled compounds, and quantify levels of PPCPs in the edible tissues of lettuce, cabbage, bell pepper, tomato, carrot, parsley, radish, and strawberry in field plots irrigated solely with treated wastewater. In addition, we will investigate fate processes in soil that affect the availability of PPCPs for plant uptake, and evaluate the leaching risk of PPCPs through field monitoring and numerical simulation. This project will provide the much needed baseline information on the potential occurrence of PPCPs in fresh produces from reuse of wastewater. The study findings will be of great value to future efforts for understanding the human toxicological significance of potential PPCP occurrence in food sources, and for developing options that promote the safe use of treated wastewater in agriculture.

Impact: Outcomes of this project will provide the much needed baseline information for reuse of treated wastewater for agricultural irrigation. This information may be used by a range of stakeholders including various agricultural commodities, the general public and consumers, sanitation districts and water districts, and state and federal regulatory agencies involved in the regulation of food safety as well as environmental/water quality. The knowledge gained from this project is expected to promote the safe and beneficial reuse of treated wastewater and contribute to the sustainability of U.S. agriculture.

2011-67019-21118

Bioaccumulation of Chemicals of Emerging Concern In Food Crops From Reclaimed Water

Christopher P. Higgins, Eric R.V. Dickenson, Jörg E. Drewes
Environmental Science and Engineering Division
Colorado School of Mines
George O'Connor
University of Florida
James Crook
Consultant, Massachusetts

Summary: In light of increasing water scarcity, additional pressures are being placed on the appropriate and efficient use of available water resources, including reclaimed water. One potential use of reclaimed water is in agriculture, though concerns exist about the potential for uptake of chemical contaminants into food crops destined for human consumption. This proposed project will evaluate the potential for bioaccumulation of contaminants of emerging concern (CECs) from reclaimed water into food crops. In particular, the bioaccumulation of CECs such as pharmaceuticals, personal care products, and perfluorochemicals into plants will be assessed in a series of field and laboratory-based studies. The goal of this study is to conduct an in-depth evaluation of the potential bioaccumulation of CECs into food crops from reclaimed water.

A field study will be conducted at an agricultural site that has been using reclaimed water for food crop irrigation for several decades. The concentrations of CECs in the crops, soil, and the reclaimed water will be measured and compared to a control site irrigated with well water. The dose-dependent bioaccumulation of CECs will also be assessed in laboratory-based studies with reclaimed water fortified with CECs. Subsequent studies will examine the effect of soil organic matter and cumulative use of reclaimed water. To ensure comparability of results, at least two of the cultivars grown in the greenhouse studies will be identical to those used in the field. The validity of existing models for predicting CEC accumulation will be assessed, and potential improvements identified. To further validate the results of the laboratory studies, controlled field studies will be conducted over two growing seasons using crops, soil, and reclaimed water similar to that used in the greenhouse studies

Impact: This study will provide both a fundamental understanding as to the potential uptake of CECs into food crops as well as practical knowledge as to the extent to which this is occurring under field conditions. Stakeholders for this project include farmers interested in or already using reclaimed water for crop irrigation and federal, state, and municipal authorities responsible for the use and distribution of reclaimed water. The results of this study will inform these stakeholders and decision-makers as to the potential risks associated with the use of reclaimed water in agriculture.

Drought Decision Making Tool for Agricultural Producers

Clyde Munster, Biological and Agricultural Engineering, Texas A&M University, College Station

Summary: The effective use of water by agricultural producers during drought conditions is the water problem addressed by this project.

The main goal of this project is to develop an Early Warning System / Decision Making (EWS/DM) tool based on science-based, field derived threshold values of drought indicators for specific crops. The EWS/DM tool will have three integrated components; 1) a drought forecast program, 2) a hydrologic forecast model, 3) in-field crop stress monitoring program. This EWS/DM tool will give agricultural producers hydrologic forecasts for impending droughts and allow them to make appropriate responses regarging water use to maximize production and minimize risk.

Impact: The primary stakeholders are the broad spectrum of agricultural producers involved in food, feed, fiber and bioenergy production. Secondary stakeholders are regional water managers from federal, state, county, and city agencies. This project was just funded in November, 2010, and therefore there has not had an impact on our stakeholders yet.

The project has just started so no new technologies have been developed yet.

2011-67019-20042

Development of a High-Resolution Drought Trigger Tool (HiDrTT) for the United States

John Nielsen-Gammon, Atmospherics Sciences, Texas A&M University, College Station

Summary: For drought triggers and decision-making, there is an unmet need for drought assessment information at the local (sub-county) scale. A daily precipitation analysis produced by the National Weather Service could potentially serve as input to a drought trigger tool, but the analysis includes long-term biases due to radar calibration and other issues that detrimentally affect the estimates of drought severity. This project will develop a reliable technique for calibrating the daily precipitation analysis to minimize biases in estimates of accumulated precipitation, perform a statistical analysis of the historical precipitation record so that the precipitation analyses can be converted to drought index information, create a web-based delivery system for the drought index information so that the products can be tested and evaluated in different parts of the United States, and estimate the effectiveness and benefit of the drought index information. The project, collaboration between investigators at Texas A&M University, North Carolina State University, and Purdue University, will lay the ground work for nationwide drought monitoring at the local scale. The long-range benefit to agriculture of this project will be to improve the resiliency of agriculture through more accurate drought response decisions and more precise identification and relief for agricultural producers suffering under drought. These drought tools will enable location-specific decision-making designed to reduce the risk of loss or of more serious water restrictions at a later date.

Impact: Too early to report impact.

2011-67020-20057

Investigation into Effect of Soil Moisture Depletion on Vegetable Crop Uptake of Microcontaminants under Recycled Water Irrigation

Chittaranjan Ray, Water Resources Research Center, University of Hawaii at Manoa, Hawaii
Clinton Williams, U.S. Arid Lands Agricultural Research Center
Philip Moravcik, Water Resources Research Center, University of Hawaii at Manoa, Hawaii

Summary: Use of treated wastewater is common in United States and many parts of the world. Pharmaceuticals and Personal Care Products (PPCPs) are ubiquitous in treated effluent. The main water problem addressed in this project is the safety of use of treated wastewater for crop irrigation. The main question that needs to be answered: will these PPCPs be accumulated in vegetable crops that are eaten raw? If so, how would the soil moisture depletion in soil affect accumulation of PPCPs in these vegetable crops?

PPCPs used for personal health or cosmetic reasons comprise a diverse collection of thousands of chemicals, including prescription and over-the-counter drugs, perfumes, fragrances, and cosmetics. Considerable quantities of these end up in our cities' wastewater treatment plants and some are extremely refractory, making their way even through modern wastewater treatment plants. Analytical advances have improved our ability to detect and quantify these chemicals at extremely low levels, and considerable attention is now being focused on the effects these chemicals in the environment may have on human health. There is concern in the regulatory and scientific community that many of these chemicals (including actual human hormones) may have subtle effects on the human endocrine system when ingested in extremely low concentrations over the long term. In addition to the actual human hormones excreted by populations there are many PPCPs with the potential to disrupt endocrine functioning. Given the extreme potency of hormones' effects on human health it is feasible that long-term exposure to even very low doses of hormones and chemicals that interfere with hormonal functioning will cause health effects. While negative health effects have yet to be conclusively demonstrated from this exposure, the possibility is one that is increasingly of concern to environmental scientists and epidemiologists. Our study will help to resolve emerging concerns about the long term safety of utilizing effluent for the irrigation of crops eaten fresh. Greater latitude in the use of wastewater for crop irrigation will help to strengthen the nation's food security, particularly in areas with limited fresh waters.

Impact: Stakeholders include water utilities, local health departments, agricultural extension agents, farmers, and water treatment plant operators in areas where municipal sewage effluent is used for irrigation of crops eaten uncooked. The findings of this study will show which crops are most likely to accumulate PPCPs and how the moisture regimes in soil affect uptake of these chemicals.

Grant Reporting Suggestions

A requirement for NIFA grantees is to report on an annual basis the progress and accomplishments of their project. Once the project has come to an end it is also a requirement to submit a final termination report. This report should cover the entire period of the award.

NIFA relies on you, the grantee, to generate and report the outcomes and impacts of your project from NIFA investments in research, education and extension. Better quality information from NIFA awardees will mean higher quality outcomes and impacts reports that will lead to better program management and to tracking the success of the grant programs.

When writing your final termination reports please keep in mind the following points. If some of the points don't fit within the CRIS reporting system, additional material can be sent to the National Program Leader.

- Outputs are things you do, such as: activities, events, services, products, people reached. Outputs help link what you do with the project impact. Outcomes /Impacts answer the question "What happened as a result of my project"? It creates a change in knowledge, actions or conditions.

- Outcomes/Impacts sometimes are seen in a long-term and not during the period of the grant. We encourage the submissions of these outcomes. They can be directly sent via e-mail to the National Program Leader. This information may include but not limited to: published manuscripts, presentations, developed workshops, press releases, news releases, significant findings, newly developed technology, people benefited from the project and other communications that are critical for the success of our program.

- If you have knowledge of publications that were cited as a result of your projects, please include this information as well.

- If your project didn't go as expected, we would like to know the circumstances that created change or failure. If you had to do it over again, what would you have done differently in your project during the funding period?

- What were the major challenges you or your organization faced during the grant period?

Appropriate Acknowledgment of Your Award

The Agriculture and Food Research Initiative (AFRI), formerly the National Research Initiative (NRI), plays an essential role in fulfilling the mission of the National Institute of Food and Agriculture. Proper acknowledgment of your USDA-NIFA-AFRI funding in published manuscripts, presentations, press releases, and other communications is critical for the success of our agency's programs. This includes proper acknowledgment of the program and agency, as well as that of the Department and grant number.

We expect you to use the following language to acknowledge NIFA support, as appropriate:

"This project was supported by Agriculture and Food Research Initiative Competitive Grant no. XXX-XXXXX-XXXXX from the USDA National Institute of Food and Agriculture."

We also expect that you will use our agency's official identifier in all of your slide and poster presentations resulting from your AFRI award.

Please alert us of significant findings, publications, news releases, and other media coverage of your work. With your permission, we may highlight your project in a National Impact story or News Release. If your research is featured on the cover of a scientific journal, we can showcase the cover as well. Examples of these publications can be found in our News room http://www.nifa.usda.gov/newsroom/newsroom.html

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List of Active Projects

Name	Institution	Email	Phone
Aleksandra Drizo	U. of Vermont & State Agricultural College	adrizo@uvm.edu	802-656-2717
Alexandria B. Boehm	Stanford University	aboehm@stanford.edu	650-724-9128
Alice Jones	Eastern Kentucky University	alice.jones@eku.edu	859-622-1424
Burton C English	U. of Tennessee	benglish@utk.edu	865-974-3716
Chenggang Wang	Texas Tech University	chenggang.wang@ttu.edu	806-742-0261 ext. 238
Ching-Hua Huang	Georgia Institute of Technology	ching-hua.huang@ce.gatech.edu	404-894-7694
Chittaranjan Ray *	University of Hawaii	cray@hawaii.edu	808-956-7847
Christophe Darnault	University of Illinois at Chicago	darnault@uic.edu	312-996-2429
Christopher C Obropta	Rutgers University	obropta@envsci.rutgers.edu	732-932-9800, ext. 6209
Christopher P. Higgins*	Colorado School of Mines	chiggins@mines.edu	303-384-2002
Clyde Munster *	Texas A&M University	c-munster@tamu.edu	979-847-8793
David Allen Newburn	Texas Agricultural Experiment Station	danewburn@ag.tamu.edu	979-862-2894
Dawn Reinhold *	Michigan State University	reinhold@egr.msu.edu	517-775-7272
Donald W. Meals	Stone Environmental, Inc.	dmeals@burlingtontelecom.net	802-862-6632
Dwight D Bowman	Cornell University	ddb3@cornell.edu	607-253-3406
Edward P. Kolodziej	Board of Regents, NSHE	koloj@unr.edu	775-682-5553
Erik R. Coats	University of Idaho	ecoats@uidaho.edu	208-885-7559
Francis X. Casey	North Dakota State University	francis.casey@ndsu.edu	701-231-8577
Gang Chen	Florida A&M University	gchen@eng.fsu.edu	850-4106303
Garey A Fox	Oklahoma State University	garey.fox@okstate.edu	405-744-8423
Helen Nguyen	University of Illinois	thn@uiuc.edu	217 244 5965
Hui Li	Michigan State University	lihui@msu.edu	517-355-0271 ext. 1146
Hussni O. Mohammed	Cornell University	hom1@cornell.edu	607-253-3566
Indrajeet Chaubey *	Purdue University	ichaubey@purdue.edu	765-494-5013
James R. Russell	Iowa State University	jrussell@iastate.edu	515-294-4631
Jane Hill	U. of Vermont and State Agricultural College	jane.hill@uvm.edu	802-656-9854
Jason Rohr	U. of South Florida	jasonrohr@gmail.com	813-974-0156
Jianying (Jay) Gan *	U. of California, Riverside	jgan@ucr.edu	951-827-2712
Jim J. Wang	Louisiana State University Agricultural Center	jjwang@agcenter.lsu.edu	225-578-1360
John McEvoy	North Dakota State University	john.mcevoy@ndsu.edu	701-231-8530
John Nielsen-Gammon *	Texas A&M University	n-g@tamu.edu	979-862-2248

Kang Xia	Mississippi State University	kx6@msstate.edu	662-325-5896
Kenneth W Tate	U. of California Davis	kwtate@ucdavis.edu	530-754-8988
Laura Bowling	Purdue University	bowling@purdue.edu	765-494-8051
Linda S. Lee	Purdue University	lslee@purdue.edu	765-494-8612
Patrick C. Wilson *	U. of Florida	pcwilson@ufl.edu	772-468-3922 ext.119
Philip A. Moore	USDA ARS	philipm@uark.edu	479-575-5724
Rachel Todd Noble	U. North Carolina at Chapel Hill	rtnoble@email.unc.edu	252-726-6841
Roderick I. Mackie	University of Illinois	r-mackie@illinois.edu	(217)244-2526
Sangamesh V. Angadi	New Mexico State University	angadis@nmsu.edu	505-985-2292
Sasha Kravchenko	Michigan State University	kravche1@msu.edu	517-355-0271 ext.241
Shane W. Rogers	Clarkson University		
Sharon Walker	Regents of the University of California	sharon.walker@ucr.edu	951-827-6094
Shreeram P. Inamdar	SUNY- Buffalo State College	inamdasp@buffalostate.edu	716-878-6229
Steven D Shultz	Univ of Nebraska at Omaha	sshultz@mail.unomaha.edu	402-5542810
Steven L. Bryant	U. of Texas at Austin	steven_bryant@mail.utexas.edu	512-471-3250
Tammo S. Steenhuis	Cornell University	tss1@cornell.edu	607-255-2489
Tao Yan	University of Hawaii	taoyan@hawaii.edu	808-956-6024
Thomas Harter	University of California	thharter@ucdavis.edu	530-752-2709
Timothy E. Link	University of Idaho	tlink@uidaho.edu	208-885-9465
Warren Albert Dick	The Ohio State University	dick.5@osu.edu	330-263-3877
Wei Zheng	University of Illinois	wzheng@istc.illinois.edu	217-333-7276
Xinhua Jia	North Dakota State University	xinhua.jia@ndsu.edu	701-231-6453
Xu Li *	Univ of Nebraska-Lincoln	xli4@unl.edu	402-472-6042
Zhengxia Dou	University of Pennsylvania	dou@cahp.vet.upenn.edu	610-444-5800 ext. 2242

* Newly funded projects