COMPLETED PROJECTS FROM FY2012 – final reports available on wrc.osu.edu

Dr. Dominic Boccelli, Assistant Professor in the School of Energy, Environmental, Biological and Medical Engineering at the University of Cincinnati recently completed a project titled "**An Integrated Framework for Response Actions for a Drinking Water Distribution Security Network**" funded by the Ohio Water Resources Center via an OWDA sub-award. The specific objectives of this project will help to realize the long term goals of developing the computational and algorithmic framework necessary to achieve an integrated, real-time set of applications associated with distribution system contaminant warning systems.

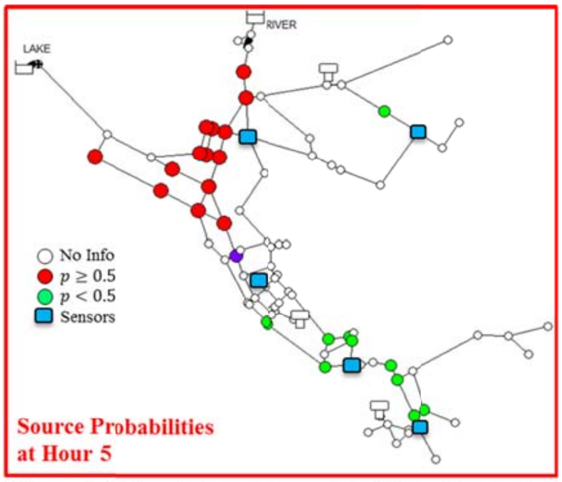


Figure 1 Estimated source probabilities at hour 5 of the simulation; red symbols represent locations with probabilities of being a source greater than 50%, green symbols represent locations with probabilities of being a source lower than 50%.

This research developed a forecasting and confirmatory sampling algorithm, and was evaluated with the test network shown in Figure 1. Using a virtual distribution network with five contaminant sensor locations, the algorithm estimated the probabilities of contaminated (red) and safe (green) locations within the network based upon a simulated intrusion event. This information was used to forecast the potential spread of the intrusion event, and estimate the amount of additional information to be gained by performing confirmatory sampling at un-monitored locations to assist in confirming the injection event. For this particular network and intrusion scenario, the top two sampling locations were the tanks (IDs 1 and 2), which are shown in Figure 2. The locations of the remaining top 10 sampling locations are also shown and demonstrate that the better sampling locations tend to be grouped together. The resulting algorithms will provide the foundation for developing more robust response activities when attempting to mitigate the impact of a potential intrusion event.

<u>Researcher:</u> Dr. Boccelli's primary research interests are in the areas of Water Resources, Water Quality, and Environmental Systems Analysis. His research activities are focused on developing decision support tools based on fundamental principles of environmental engineering and science to assist engineers, managers, and policy makers in making technology, design, and regulatory decisions. More explicitly, these tools will incorporate various mathematical modeling and optimization techniques to attain the desired objectives. Additionally, given his academic and research experience, his research includes laboratory and field experiments, where appropriate, to develop an improved understanding of the processes used in the decision making process. This two-pronged research philosophy has arisen from his research and experience in both Environmental Engineering and Chemistry.

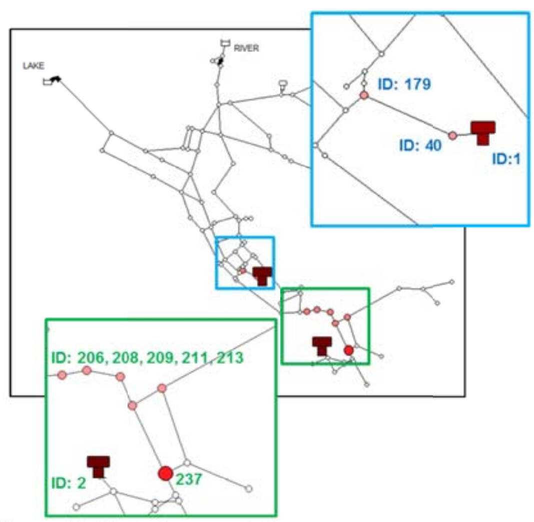


Figure 2 Plots demonstrating the spatial location of the confirmatory sampling nodes that resulted in the greatest increase in information associated with the simulated intrusion event.

Dr. Gil Bohrer, Assistant Professor in Civil, Environmental and Geodetic Engineering at The Ohio State University recently completed an Ohio WRC 104(b) funded project. This project titled "**Green-house-gas budgets of constructed wetlands: understanding the sources to maximize benefits"** aims to evaluate the factors affecting methane emission from wetlands. Since wetlands restoration is gaining momentum nationwide due to its function of cleaning water, removing nutrients and sequestering carbon, evaluating the optimal conditions that enhance these ecosystem services while keeping methane emissions, a potent greenhouse gas, at minimum is imperative.

This research involves continuous high-frequency measurements of weather conditions, such as air and soil temperature and humidity, incoming solar radiation, wind, and the fluxes of heat, water vapor, CO_2 and methane from a central flux tower above the wetland (Figure 1). Using data from this high-tech flux tower, and periodic manual measurements of methane and CO_2 from chambers we have discovered that in addition to the predictable relationships between the thermal state of the wetland (soil water and air temperatures) and methane flux, there is also a tight relationship between vegetation activity and methane emission, which was not anticipated (Figure 2). Different management strategies may be developed to control the physical conditions - water temperature and heat flux for example could be reduced by trees that shade the water, and the ecological state. It seems that macrophyte plants, such as cattails, play a critical role in transport and production of methane and provide one of the imported controls to methane emission rates.

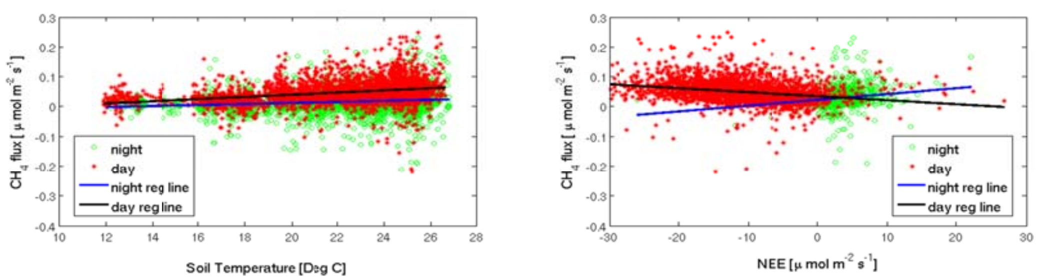


Figure 2 Environmental drivers: Soil temperature (left) and vegetation photosynthesis rates (NEE, right) Vs. methane flux.

<u>Researcher:</u> Dr. Gil Bohrer develops and uses physical and empirical models of the interactions between individual biological organisms and atmospheric and hydrological processes. His research bridges the physical scale gap between regional atmospheric processes and individual plant-scale function and structure. He develops new approaches to parameterization of the effects of small-scale heterogeneity on surface fluxes, on water movement from the soil through plants to the air, and on advection and dispersion of green-house gasses, VOCs and particulate matter. He uses a range of models, from high-power parallel large eddy simulations to simple empirical models, and remote sensing to study the structure of vegetation and land-cover at individual-plant resolution. He conducts meteorological and eddy-flux observations in forests and wetlands to provide the needed information to force, parameterize and evaluate models of green-house gas budgets of ecosystems and the effects of small-scale heterogeneity and intermediate disturbance on these fluxes.

Dr. Isabel Escobar, Professor in Chemical and Environmental Engineering at the University of Toledo recently completed a project titled "**High-performance porous polybenzimidizole membranes for water treatment using forward osmosis**" funded by the Ohio Water Resources Center via OWDA subaward. Polybenzimidazole (PBI) is a material with excellent chemical resistance, and thermal and mechanical stability that might transform the current forward osmosis technology that has the potential to achieve up to a 75 percent decrease in costs and energy consumption compared to current reverse osmosis processes. When applied for desalination and wastewater reuse, this would enable a new resource for fresh water availability, satisfying both economic and environmental concerns.

The focus of Dr. Escobar's study was to investigate the performance of the functionalized flat sheet PBI membranes (Figure 1) in a forward osmosis application. The results of PBI surface functionalization with the intent to increase hydrophobicity, increase surface charge, and decrease the membrane pore size show enhanced membrane performance both with respect to water flux and salt rejection (Figure 2). The reduced pore size coupled with the use of a feed stream carrying divalent or larger ions mixed with colloidal particles may have the ability to yield excellent results and high purity water.

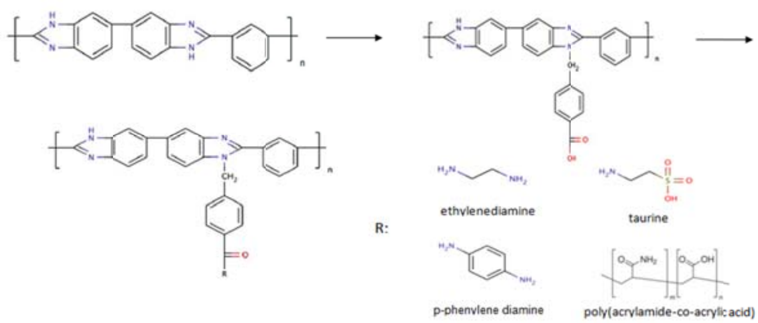


Figure 1 Chemistry for two-step modification procedure.

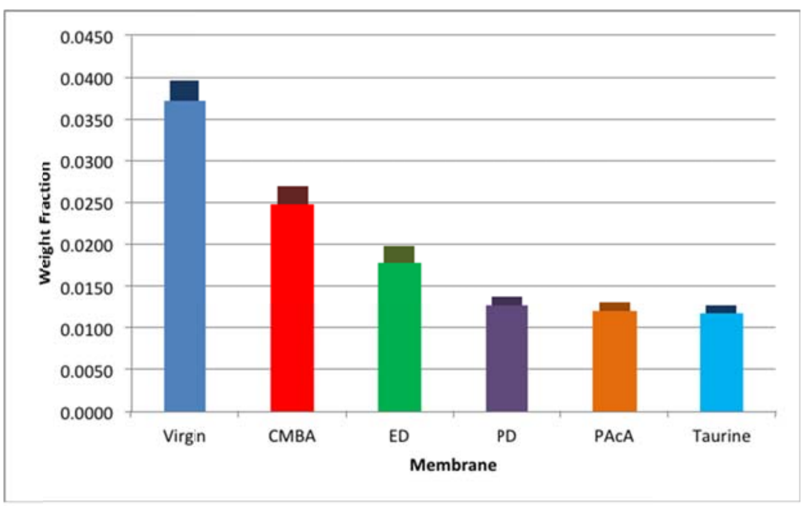


Figure 2 Total salt (back, thin bar) and sodium chloride (front, thick bar) weight fractions for each membrane.

<u>Researcher:</u> Dr. Escobar's research focuses on developing and/or improving polymeric membrane materials for water/wastewater treatment and water reuse operations through membrane post-synthesis modifications, the use of dynamic membranes, and process modifications.

Dr. Ethan Kubatko, Assistant Professor in Civil, Environmental and Geodetic Engineering at The Ohio State University recently completed a project funded by the Ohio Water Resources Center. This project titled “Generating Renewable Energy on Lake Erie with Wave Energy Converters: A Feasibility Study” has aimed to make progress towards meeting the State of Ohio’s energy goal of providing 25 percent of all electricity sold in 2025 from alternative energy sources. He investigated the feasibility of generating clean, renewable energy on Lake Erie by harnessing the Lake’s wave energy through the use of a novel kinetic energy harvesting technology called nPower ® developed by Tremont Electric, LLC, a Cleveland-based alternative energy company; see Figure 1.

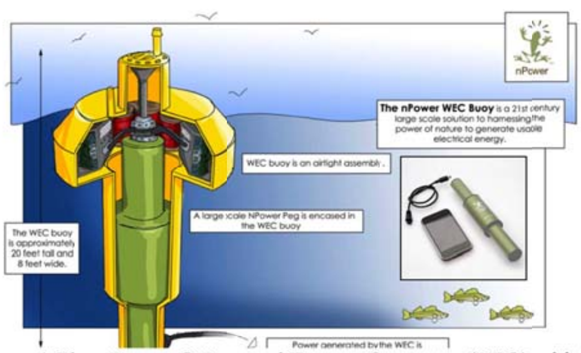
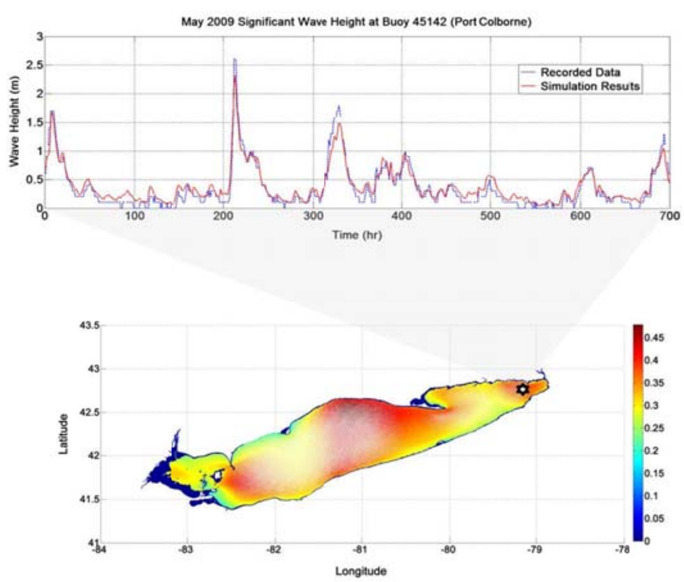


Figure 1 The nPower ® Personal Energy Generator (PEG) which can be used to recharge mobile devices by harvesting the kinetic energy generated from walking (inset), and a schematic of a proposed nPower ® Wave Energy Converter (WEC) encased in an airtight buoy.

The main technical aspect of his work has been the characterization of the so-called wave energy spectrum of Lake Erie to assess the feasibility of this idea. This was accomplished through the development and application of a high-fidelity computational wave simulator. Simulation results showed excellent agreement with historical data of wave conditions and provided graphical outputs of the wave energy density associated with Lake Erie over a range of wind conditions; see Figure 2. Given these results, the next phase of this study is to work in conjunction with Tremont Electric to quantify the conversion of this wave energy into electricity through the use of the wave energy converter devices.

Figure 2 A comparison of wave simulation results to recorded data (top); and simulation results indicating a profile of the monthly average wave conditions (bottom). “Hot spots” of wave energy are shown in red and orange and indicate potentially beneficial spots



Researcher: Dr Kubatko's primary research interests are in the development, implementation, analysis, and application of computational models for fluid flow and transport processes. More specifically, his main research goal is the development and application of "next generation" high-performance computing tools, which utilize state-of-the-art methods and algorithms that can be used, for example, to guide improvements in coastal management practices and hazard mitigation strategies. The research is highly interdisciplinary in nature, involving aspects of not only engineering but also applied mathematics, physical oceanography and computer science.

Dr. John Lenhart, Associate Professor in Civil, Environmental and Geodetic Engineering at The Ohio State University recently completed a project funded by the Ohio Water Resources Center. The main goal of this project, titled "**Discriminating Biotic and Abiotic Arsenic Release Processes under Highly Reduced Ground Water Conditions**", was to increase knowledge about conditions governing arsenic release to ground water, therefore aiming to help identify sites in Ohio with the potential for high ground water arsenic levels. This knowledge will help to protect the health of residents in Ohio since roughly 40% of the population depends upon ground water as their source for drinking water and 17% of public supply wells contain arsenic levels exceeding the safe limit.

The project combines bench-scale laboratory experimental work with atomic-level spectroscopy and molecular techniques to evaluate arsenic release and sequestration under transient redox conditions. A series of batch microcosm experiments were conducted with solids and ground water collected with the assistance of researchers from the USGS Ohio Water Science Center from three redox zones in a single aquifer system identified as iron-reducing, sulfate-reducing, and methanogenic. At the same time a parallel set of experiments was conducted using dissolved organic matter amended microcosms and acetate amended microcosms (Figure 1).

Figure 1 Preparation of laboratory microcosm samples.

Over the course of the 70-day study, concentrations of total arsenic were observed to roughly double from an initial concentration of approximately 5 ppb to 10 ppb (Figure 2). Most of this increase occurred over the first forty days and coincided with the rapid increase and subsequent decline in iron as well as a decrease in total sulfur. Overall these trends are consistent with release of arsenic concurrent with the reductive dissolution of iron. Experiments conducted with the organic matter and acetate amended microcosms demonstrated arsenic release over longer periods of time depended upon the formation of iron and arsenic sulfides, which is consistent with sulfate reducing conditions.

<u>Researcher:</u> Dr. Lenhart pursues research directed at elucidating the fundamental physical and chemical mechanisms that determine the fate of chemical compounds in natural and engineered systems. This information is necessary for accurate risk estimation, cost-effective selection of remedial options for contaminated sites, and efficient treatment of water and wastewater. The systems he examines are inherently heterogeneous, typically composed of a mixture of several mineral, organic, biological, water and gaseous phases. Accordingly, much of his work emphasizes reactions occurring at phase boundaries, or interfaces. His work is interdisciplinary in nature and combines careful experimentation, mathematical analysis and fundamental theory.

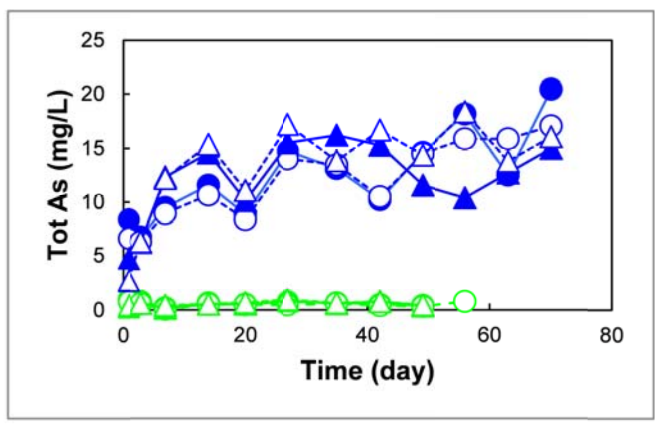


Figure 2 Concentration of total arsenic released during the incubation of groundwater and sediments from iron reducing aquifer. The green symbols are for abiotic control and the blue symbols are for different carbon amendments.

Dr. Xiaozhen Mou, Assistant Professor in Biological Sciences at the Kent State University recently completed an Ohio WRC funded project titled "**Identification of Microcystin Degrading Bacteria in Lake Erie Western Basin and the Grand Lake St. Marys**". Despite much Federal and State research and restoration efforts that have been made to regulate and monitor the nutrient loading, periodic nuisance cyanobacterial (blue green algae, such as *Microcystis*) harmful blooms (cyanoHABs) occur every summer in recent years in these two lakes and with increased affected area, frequency and intensity. Research on in situ microcystin-degrading bacteria is limited and virtually absent in Ohio lakes, although they might aid in management of the toxin.

Figure 1. Sampling sites and photos taken during GLSM sampling in June 2012. The dark green color of the water indicates an intense Microcystis bloom.

The focus of Dr. Mou's study is to investigate the ability of lake bacteria to degrade microcystin. Based on incubation experiment, her team found that both GLSM and LEWB bacteria have high potentials in degrading microcystins. Of the 50 isolates screened based on the BIOLOG assay, one isolate from Lake Erie was found to degrade Microcystin-LR (Figure 2). Work on this project is ongoing to sequence and characterize the microbial community and microcystin degrading isolates.

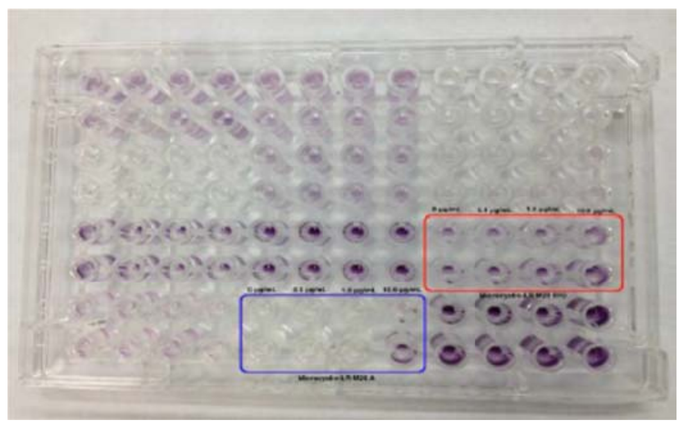


Figure 2 MT2 MicroPlateTM results. The red box denotes the microcystin-LR M21 B10 isolate that showed negative results for microcystin degradation. The blue box denotes the microcystin-LR M26 A isolate that showed positive results for microcystin-LR degradation. Each well is carbon limited and is pre-treated with nutrients and tetrazolium violet. Four concentrations (0 µg/mL, 0.1 µg/mL, 1.0 µg/mL, 10.0µg/mL) of microcystin-LR or microcystin-RR were added to each well, which acted as the sole carbon source for the bacterial isolates. Color change from transparent to purple indicates the usage of microcystin.

<u>Researcher:</u> Research in Dr. Mou's lab focuses on linking bacterial phylogeny with their metabolic functions in natural aquatic environments. This direct linkage is important to understand fundamental questions in an ecological/environmental context, such as the role of bacteria in biogeochemical cycling of essential nutrients, e.g., carbon, nitrogen and sulfur. Experimental metagenomics and metatranscriptomics coupled with bioinformatics are employed as the core approach to simultaneously identify the taxonomic diversity, genetic capability, and metabolic activity of selected taxonomic and functional groups of aquatic bacteria. Other advanced molecular biology techniques, such as T-RFLP, DGGE, qPCR, RT-PCR, CARD-FISH, and flow cytometry (FACS), and cultivation-based studies, such as whole genome micorarray, are also regularly employed.

Dr. Paula Mouser, Assistant Professor in Civil, Environmental and Geodetic Engineering at The Ohio State University recently completed a project funded by the Ohio Water Resources Center. This project entitled "**The Constructed Wetland Dilemma: Nitrogen Removal at the Expense of Methane Generation?**" evaluated environmental conditions leading to nitrogen removal wetlands without generating excessive greenhouse gas emissions.

This research product involved laboratory microcosm experiments for three biomes and two depths incubated at two different temperatures relevant to global warming. Sediments for incubation studies were collected from OSU's Olentangy River Wetland Research Center (Figure 1). Dr. Mouser's findings suggest that wetland biome and soil depth greatly influence the methane flux potential at higher temperatures due to the availability of labile carbon substances and the presence of methanogenic archaea. While all biomes efficiently removed nitrogen, the shallow, open water sediments produced the greatest amount of methane while deeper vegetated sites produced the least. The prevalence of methanogens at the open water site and its ability to thrive under cooler and warmer temperatures suggest that designing wetlands with open water areas may contribute a larger greenhouse gas footprint than wetlands designed with more vegetated areas. Deeper sediments lacked either the microbial community producing labile carbon (e.g. acetate) or the appropriate carbon substrate for methanogenesis to occur (Figure 2).

Figure 1 Student Mike Brooker on the site collecting wetland sediments for the laboratory incubation experiments

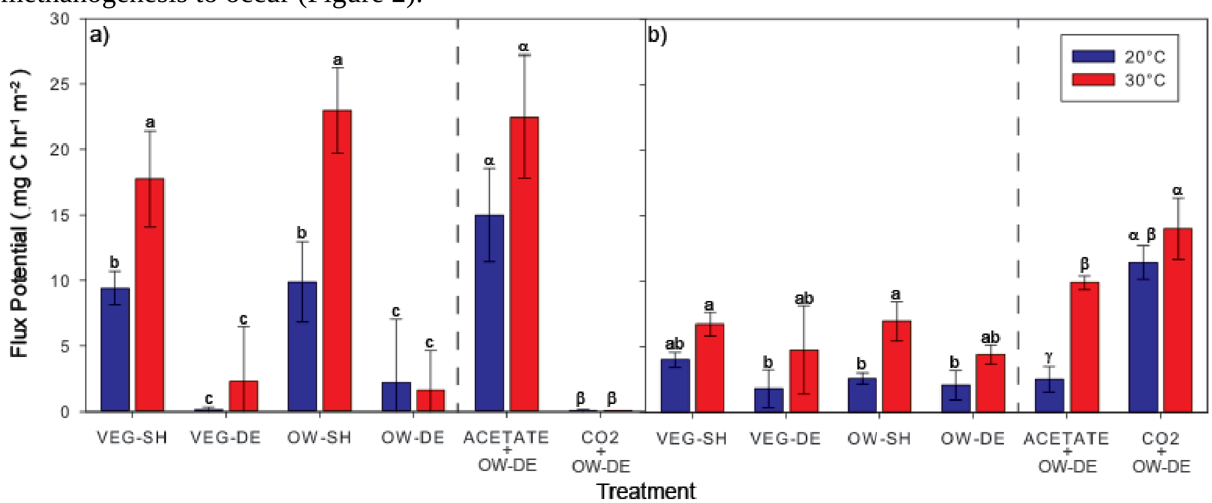


Figure 2 Methane (a) and carbon dioxide (b) flux potentials calculated from the biomes and amendments at two temperatures. VEG represents sediment collected from vegetated site, OW sediment from open water site, SH is shallow sediment and DE is deep sediment. Letters represent levels of statistical differences between each set.

<u>Researcher:</u> Dr Mouser is investigating the role that microorganisms play in mediating biochemical reactions in environmental systems using biotechnology methods. Her focus has been on deciphering the complex relationship between bio-physio-chemical processes in subsurface environments impacted by waste disposal activities and industrial processes. Applications of such research include improving detection and remediation strategies for the protection of water resources, and optimizing restoration activities for contaminated sites.

Dr. John Senko, Assistant Professor in the Department of Geoscience at the University of Akron recently completed a project titled "**Microbial modulation of acidic coal mine drainage chemistry: implications for passive treatment of minewater"** funded by the Ohio Water Resources Center via 104(b) USGS program. Acid mine drainage (AMD) that is produced from abandoned coal mines is one of the most serious water quality problems in the Appalachian coal mining regions of the United States, particularly in eastern and southeastern Ohio. AMD has the potential to cause long stretches of "dead" streams by its high acidity and high iron content. Therefore Dr. Senko investigated the potential of biologically removing dissolved iron from AMD using soil and iron mound bacteria to develop inexpensive, efficient, and sustainable approaches to treating AMD.

Figure 1 Dr. Senko collecting samples from iron mound in the Mushroom farm, Lima, OH

The main goal of this research was to determine how microorganisms associated with formerly pristine soil and AMD develop "iron mounds" that could be exploited for removal of Fe from AMD (Figure 1). The results from laboratory microcosms experiments are quite striking in that they illustrate the rapid rate at which microbial communities associated with pristine soil adapt to intrusion of acid mine drainage, resulting in rapid rates of Fe(II) oxidation (Figure 2). The robust Fe(II) oxidizing activities appear to be attributable to some type of synergistic activities of microorganisms associated with the formerly pristine soil and microorganisms suspended in the AMD that may colonize the soil. We observed that this adaptation is quite rapid, with combined soil- and AMD-associated microorganisms catalyzing Fe(II) oxidation at rates comparable to iron mound sediment after one exchange with fresh AMD. This response appears to be enhanced by the addition of iron mound material (with associated microorganisms).

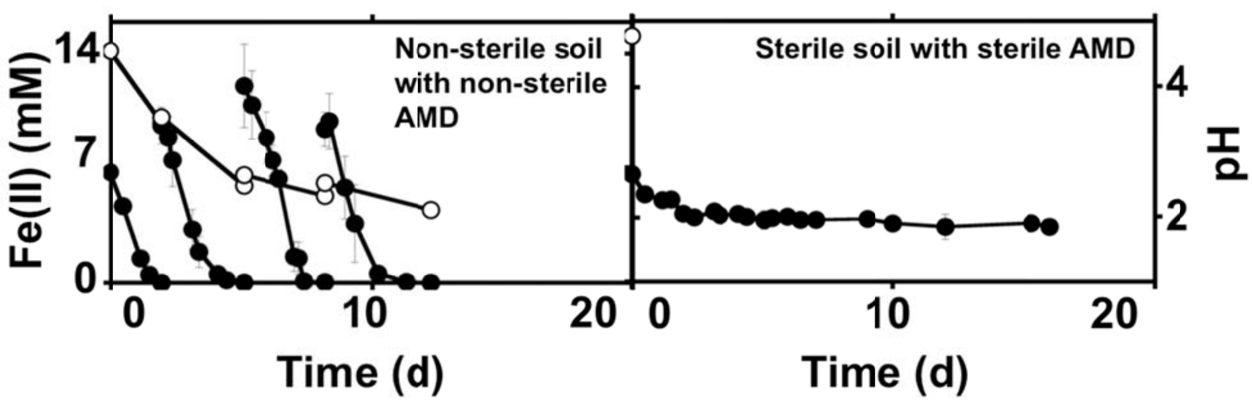


Figure 2 Dissolved Fe(II) (closed circles) and pH (open circles) in two different microcosm incubations including pristine soil and AMD from an AMD-impacted system. These results illustrate 1) that Fe(II) removal from AMD is mostly a biological process, and 2) the development of microbial communities that are capable of rapid and efficient removal of dissolved Fe(II) from AMD.

<u>Researcher:</u> Dr. Senko studies the microbially mediated formation and dissolution of mineral phases and controls on the activities of microorganisms mediating such processes. He is particularly interested in how the ecology, physiology, and in-situ activity of these microorganisms influence migration of environmental contaminants. The major focus of work in his lab is on microbially mediated redox transformations of iron in AMD-impacted systems, and how these activities can be exploited to mitigate the widespread and legacy problem associated with nearly 200 years of coal mining activities in the Appalachian coal-producing regions of the United States.