Dr. Ishi Buffam, Assistant Professor in the Department of Biological Sciences and Dr. Dominic Boccelli, Assistant Professor in the College of Engineering and Applied Science at the University of Cincinnati are nearing completion of an Ohio Water Resources Center funded project via a joint USGS 104(b) and OWDA subaward. This project entitled "**Assessment of a Novel Application of Biochar to Improve Runoff Water Quality from Vegetated Roofs"** aims to improve nutrient retention of vegetated roofs using biochar (Figure 1). Vegetated roofs are becoming increasingly more important as a part of green-engineered solutions for stormwater management in urban areas.

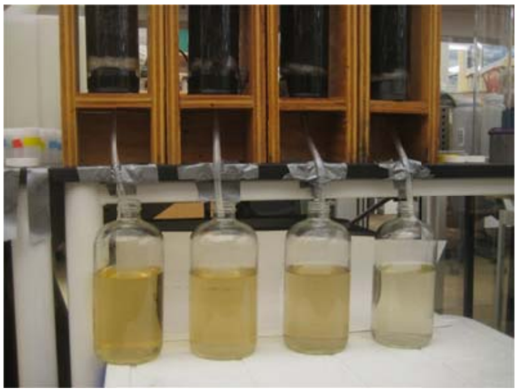

**Figure 1** Leachate from laboratory columns of green roof growing media with varying amounts of biochar ranging from no biochar (left) to high biochar (right). Note the reduction in color in the water is due to biochar binding organic matter which minimizes its elution.

The integration of biochar is a potential breakthrough in reducing water quality degradation by green roof runoff, but very little is known about the sensitivity to variation in the proportion of the biochar amendment, or the dynamics of sorption kinetics or equilibria. Our project has demonstrated that a biochar amendment substantially decreases ammonium leaching from green roof substrate, by up to 75% for the high biochar (14% w/w) treatment (Figure 2). The high biochar treatment also doubled water holding capacity of the substrate, a finding with great significance for green roof design for stormwater runoff reduction. This is of particular note because on a per mass basis, biochar is no more expensive than typical commercially available green roof substrate mixes. The patterns of breakthrough curves also give insight into likely physicochemical mechanisms of nutrient binding. Follow-up work using different sorption breakthrough models and isotherms are underway to further explore the sorption/desorption dynamics. The research demonstrates the water quality improvements associated with a biochar-amended green roof, but will also result in a modeling component that can be used within an integrated assessment framework both within and beyond the Ohio River Valley.

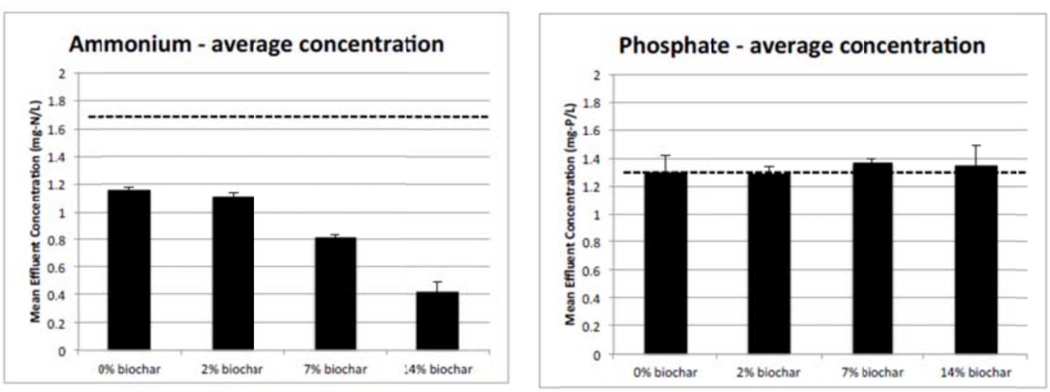


**Figure 2** Volume-averaged mean effluent nutrient concentrations for the entire 5-day experiment for columns varying in biochar % integrated into green roof substrate. Error bars represent standard error of the mean for duplicate trials. The horizontal dotted lines represent the volume-averaged influent "precipitation" concentration in the experiment. Substrate alone resulted in a 34% reduction in $NH_4^+$, with higher biochar resulting in a reduction of up to 76% of $NH_4^+$. In contrast, $PO_4^{3-}$ fluxes were not affected significantly by either substrate alone, or biochar amendments.

<u>Principal Investigator:</u> Dr. Ishi Buffam is an ecosystem ecologist and aquatic biochemist. He uses a combination of field vegetation and soil surveys, lab-based water and soil chemistry/biogeochemistry analysis, empirical modeling and GIS-based modeling to evaluate the relationship between landscape/watershed characteristics and surface water chemistry and biotic communities. Many of his current projects are centered on quantifying ecosystem services and potential disservices associated with green (vegetated) roofs, since little is known about the direct biogeochemical functions of green roofs.

Dr. George Bullerjahn, Professor in the Department of Biological Sciences at the Bowling Green State University is nearing completion of an Ohio Water Resources Center funded project via a joint USGS 104(b) and OWDA subaward. His project entitled "**Source Tracking of *Microcystis* Blooms in Lake Erie and its Tributaries"** is focused on identification of the geographic sources of toxic, bloom-forming cyanobacteria in Lake Erie. The results can affect the lake management, as bloom events that occur in Lake Erie may rely on intervention strategies implemented upstream.

The funded work is targeting cyanobacteria sampling at Sandusky Bay, the Maumee River and Lake St. Clair, comparing the bloom-forming genera at each site using high-throughput DNA sequencing of diagnostic target genes. The results from the first year of sampling indicated that all toxic *Microcystis* strains found in Lake St. Clair clustered with toxic strains found in samples previously collected from Lakes Erie and Ontario, demonstrating extensive genetic connectivity between the three systems and establishing Lake St. Clair as an important immediate and historical source of toxic *Microcystis* to lakes Erie and Ontario (Figure 1). Furthermore while Lake Erie *Microcystis* genotypes are found in abundance upstream in Lake St. Clair, nearshore sites in Lake Erie (Sandusky Bay and Maumee River) are dominated by microcystin-producing *Planktothrix*.

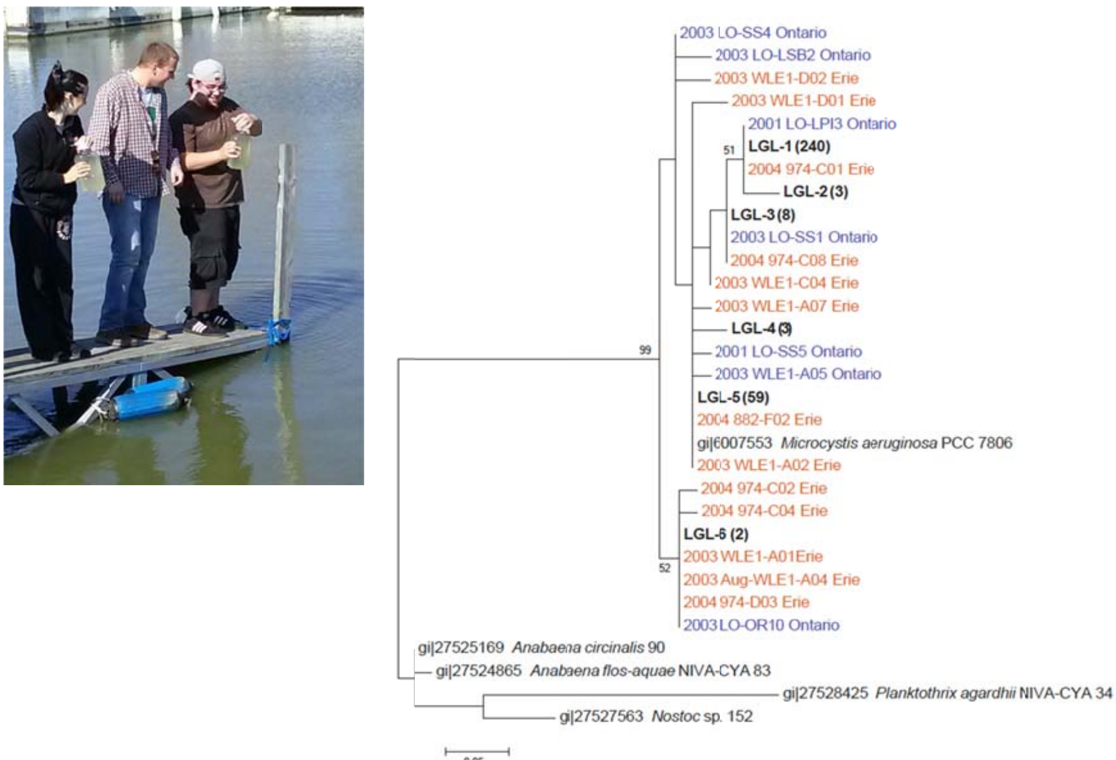


**Figure 1** Sandusky Bay Marina sampling October 2014 and Phylogenetic tree of microcystin synthetase toxin *(mcyA)* gene sequences from Lake St. Clair, compared with environmental sequences from Lakes Erie and Ontario. The Lake St. Clair sequences (LGL) exist as six genotypes that are detected as abundant bloom formers downstream in Lakes Erie (orange) and Ontario (blue).

<u>Researcher:</u> Dr. George Bullerjahn's work is currently focused on enumeration and the physiological performance of phototrophs and ecologically important chemolithotrophs in aquatic systems. His group has identified genes and gene products inducible under nutrient (N, P) limitation and stationary phase conditions, and this work has aided in the development of whole-cell biosensors detecting the bioavailability of nutrients in environmental samples. Additionally, he examines the composition and dynamics of cyanobacterial and nitrifying communities in freshwater environments, focusing primarily on the N and P cycles in the Laurentian Great Lakes.

Dr. Chin-Min Cheng, Senior Research Associate, and Dr. Linda Weavers, Professor, in the Department of Civil, Environmental and Geodetic Engineering at the Ohio State University are working on an Ohio Water Resources Center funded project via an OWDA subaward. Their project titled **"Separation of Phosphorus- and Nitrogen-nutrients from Agricultural Degraded Waters Using Pervious Filter Material Developed from Industrial By-products"** aims to evaluate usage of industrial waste materials for nutrient filtration. These developed filter materials would be a low cost alternative for separation of nutrients from agricultural drainage waters. Furthermore these filters might be potentially recycled and reused as soil amendments or fertilizers (Figure 1).

**Figure 1** Previous Filter Material

In this project, two types of pervious filter materials to remove nutrients, i.e., nitrate and phosphate, from agriculture drainage waters (ADW) are being developed and characterized (Figure 2). The P-type filter material contains fly ash, sulfite-rich flue gas desulfurization (FGD) material and quick lime to selectively bind phosphorus. The nitrogen capture materials (N-type filter) are prepared from red mud, fly ash, and stabilized FGD material. The cured filter materials were tested for their chemical (i.e., elemental and mineral compositions), physical (density and surface morphology), and engineering (i.e., permeability (k) and/or hydraulic conductivity (K)) properties and the testing of their nutrient sorption capabilities is starting.

We observed 95% removal of phosphate from synthesized agriculture drainage waters using one of the developed P-type filters. Furthermore, adsorption of nitrogen nutrients appears to occur using the N-type filter. The effectiveness and applicability of using the industrial waste-derived filter material to separate and recover nitrogen- and phosphorus-nutrients from ADW will be evaluated in more detail over the remainder of the project period.

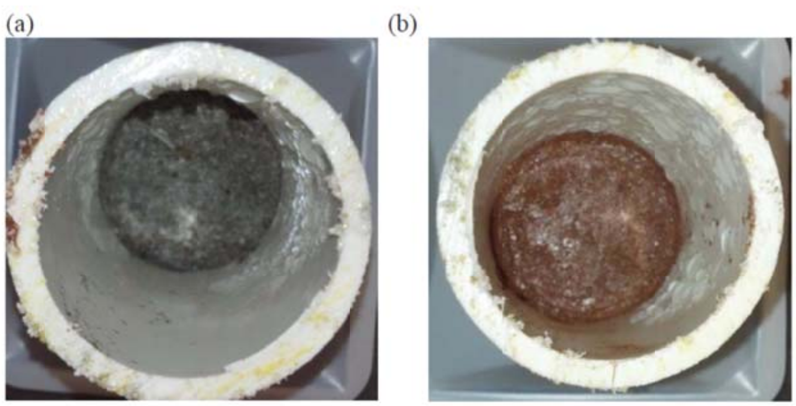


**Figure 2** Prepared pervious filter materials; (a) P-type and (b) N-type

<u>Researcher:</u> Dr. Chin-Min Cheng's work is to seek approaches to better manage by-products produced from industrial processes and agricultural operations, which consequently improves the sustainability of our society by reducing the consumption of natural resources and associated environmental impacts.

Dr. Isabel Escobar, Professor in Chemical and Environmental Engineering at the University of Toledo progressed toward completion of an Ohio Water Resources Center funded project via an OWDA subaward. Her project entitled **“High-performance Biologically Inspired Membranes for Water Treatment”** relies on the idea of combining the ultra-efficient functioning of biological molecules with the productivity of synthetic membranes. These biomimetic membranes with structure and function similar to the membranes of living organisms may offer the ultimate breakthrough for low-energy desalination.

**Figure 1** Membrane preparation

The objective of the project is to make a new class of biomimetic nanofiltration membranes by modifying their surface and making them chemically and mechanically stable. In short, aquaporins were treated with polysaccharides to protect them, and then were embedded in amphiphilic PVA-alkyl matrix (Figure 1). This PVA alkyl with embedded aquaporins will be used as the nanofiltration membrane active layer. Two main membranes were developed - Polybenzimidazole (PBI) hydrophobic membranes and modified surface activated 4-chloromethyl benzoic acid (CMBA) that imparted the negative charge on membrane surface and serves as platform for functionalization of the membrane. Virgin PBI and PVA-alkyl modified membranes are currently tested to determine the flux decline during operation and flux decline of virgin and PVA-alkyl modified PBI membrane are shown in Figure 2. Further surface modification and testing of the newly developed biomimetic membranes is underway.

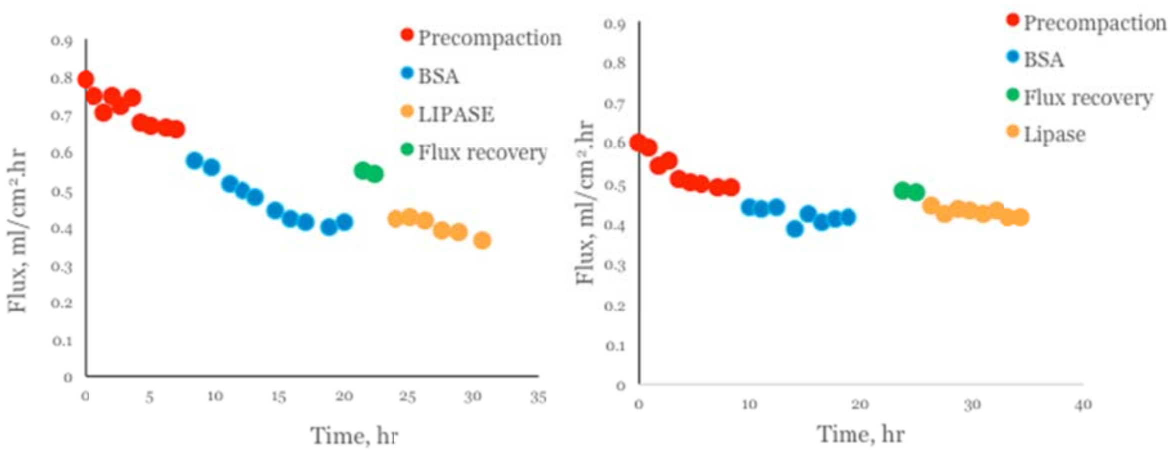


**Figure 2** Flux analysis of virgin (left) and PVA-alkyl modified (right) PBI membrane

<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. Paula Mouser, Assistant Professor in the Department of Civil, Environmental and Geodetic Engineering at the Ohio State University together with Professors Linda Weavers and Henk Verweij progressed toward completion of an Ohio Water Resources Center funded project via a joint Office of Energy and Environment at OSU and OWDA subaward. The overall objective of their project titled **“Characterizing the influence of surface chemistry and morphology on biofilm formation of ceramic membranes in wastewater treatment”** is to better characterize biological fouling of membranes used for water and wastewater treatment, and identify innovative cleaning technologies or improvements in membrane sciences to help prevent or reduce the rate of biological fouling.

Initial measurements indicate that only 10% of the total proteins pass through the membrane, with 90% retention on the membrane surface and within the pores. Polysaccharides, on the other hand, more readily pass through the membrane, with only about 50% of these being retained by the membrane. Results of preliminary ultrasonic cleaning experiments indicate biologically-fouled layers are effectively cleaned from ceramic membranes, although some remnant matter remains on the membrane following cleaning (Figure 1). Although initial cleaning of ceramic membrane surfaces by means of ultrasonic cavitation looks promising, there are considerations for long-term cleaning effectiveness to be made. Certain components of biological fouling layers may persist and be difficult to remove with ultrasonic cleaning. This hypothesis has become evident based on experiments assessing repeated fouling and cleaning procedures. Initial cleaning recoveries are typically 90% or higher, with subsequent cleanings declining in their initial membrane flux when compared to a clean membrane surface. Our goal will be to better quantify the biological components resistant to ultrasonic cleaning in order to develop cleaning or preventative maintenance strategies to specifically target these constituents.

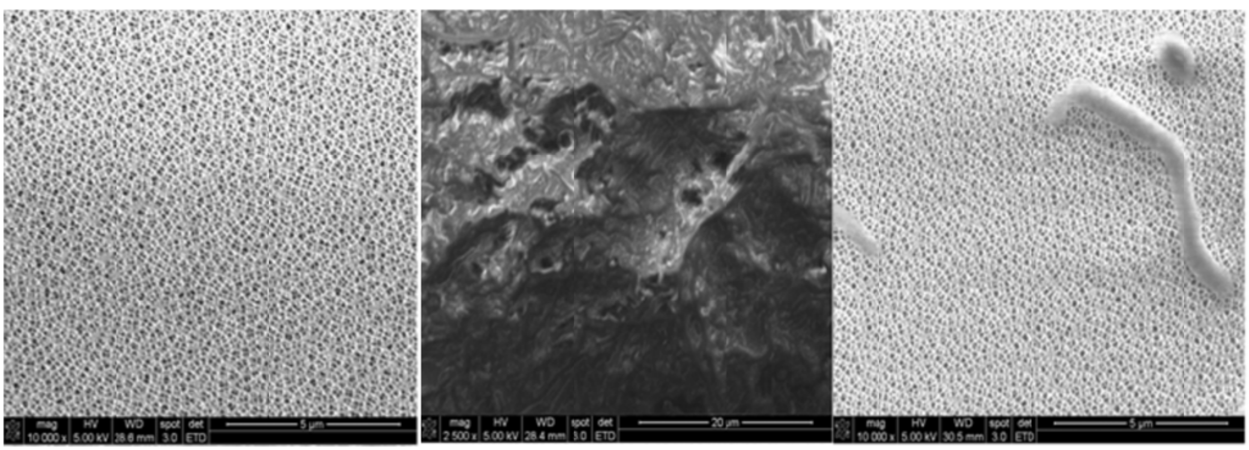

**Figure 1** Scanning electron microscope (SEM) images of a clean ceramic membrane surface (left), a fouled membrane after wastewater filtration (middle), and the surface of a ceramic membrane following cleaning with ultrasound at 620 kHz for 30 seconds (right).

<u>Principle Investigator:</u> Dr. Paula 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. Christopher Spiese, Assistant Professor in the Department of Chemistry and Biochemistry and Dr. Bryan Boulanger from Civil Engineering at the Ohio Northern University completed an Ohio Water Resources Center funded project funded through a joint USGS 104(b) and OWDA subaward. Their project titled "**Rural On-site Waste Treatment as a Source of Nutrients to a Eutrophic Watershed"** evaluated the extent to which residential on-site wastewater treatment in rural watersheds are a source of nitrogen, phosphorus, and pathogenic bacteria. Identification of sources of nutrients into Lake Erie tributaries is critical for understanding how to control these loadings and ultimately maintain a long-term oligotrophic status in the Lake.

**Figure 1** Student Joanne Berry sampling tile drainage (Photo: Ken Colwell, ONU)

At six sites across Putnam County, OH, tile drainage water was sampled over the course of four months (Figure 1). Caffeine was found with mean ± standard deviation concentrations ranging from non-detect at the control site to 0.74±1.14 µg/L in some tile drainage effluents. Because nitrogen is a large component of human waste, there was a significant positive relationship between nitrate and caffeine (Figure 2). Caffeine and total phosphorus on the other hand had a significant negative correlation (Figure 2). The study results are interesting because the observed caffeine-total phosphorous correlation indicates that septic effluents are not significant contributors to phosphorus loadings within the rural watershed, but may contribute to nitrogen loadings. Additionally, commonalities in nutrient fingerprints (total and speciated phosphorous and nitrogen) in groundwater and tile drainage highlight the complex relationships for nutrient and water quality management in irrigation drainage waters. Groundwater from a nearby well indicated a mean total phosphorous 0.39 mg P/L. A mean phosphorous tile drain concentration for the entire study was determined to be 0.4±0.07 mg P/L. Taken together our results indicate that efforts to improve or replace septic systems with an aim toward mitigating phosphorus pollution may be misguided or at least less effective than anticipated.

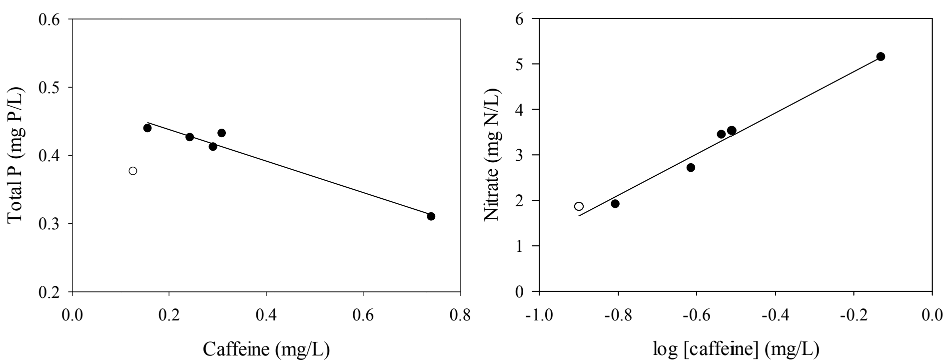


**Figure 2** Correlations between caffeine and total phosphorus (left) or nitrate (right). Points denote mean of all samples. Correlation coefficients were significant for total phosphorus ($p = 0.001$) and nitrate ($p = 0.0002$).

<u>Principal Investigator:</u> Dr. Christopher Spiese is an environmental chemist and biogeochemist. His research area is an interdisciplinary program that incorporates chemistry, biology, geology, and limnology, but his main focus is on sulfur and phosphorus. He currently has projects examining the role of marine phytoplankton in the production of methylated sulfur compounds, the permeability of these compounds across cell membranes as well as project aimed at developing new methods for dissolved phosphorus analysis and water quality in the Blanchard River.