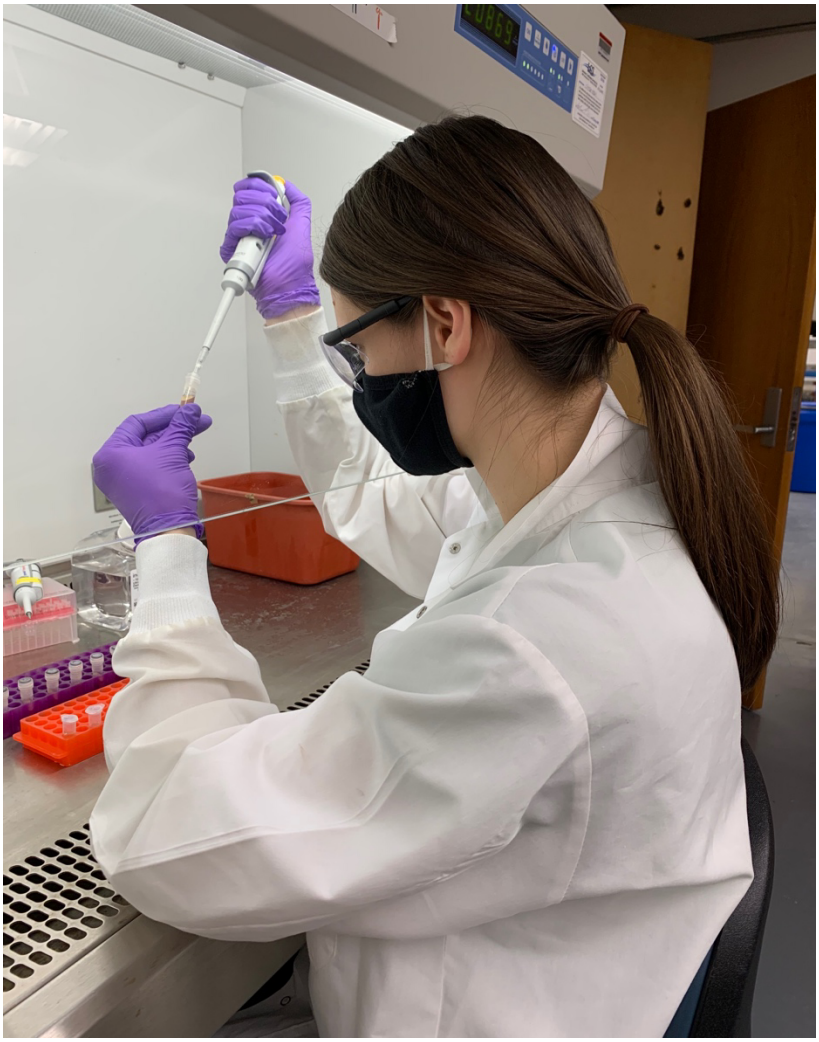
# COMPLETED PROJECTS SUMMARIES FY2020



2021OH200O Berardo

2020OH204O Bohrerova

2020OH203O Chae

2020OH143B Hood

2020OH201B Saxton

2020OH202B Senko

OHIO WATER RESOURCES CENTER

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Dr. Ramiro Berardo, Associate Professor, and Dr. Joseph Campbell, Lecturer, in the School of Environment and Natural Resources at Ohio State University completed an Ohio Water Resources Center funded project via the Ohio Water Resources Center's "Time Critical" Research Request for Proposals. The film titled **"And Water for All. A documentary on water access and affordability in Ohio"** aimed to educate a broad audience about the challenges to building and maintaining the costly infrastructure needed to deliver clean water to all Ohioans, analyze the causes of the affordability crisis in rural and urban settings and facilitate a nuanced, non-partisan discussion about viable ways to address the Ohio water affordability crisis in future decades.

*Figure 1. Interview at the Northeast Ohio Regional Sewer District.*

Across the nation, rates charged for drinking water, sewer management and stormwater services continue to increase, placing a heavy burden on families and communities who lack the financial capacity to face these costs. In Ohio, affording water and sewer bills continues to be a pressing issue. Drs. Berardo and Campbell created a 55-minute educational documentary to discuss these challenges by highlighting the views of a wide range of stakeholders, including urban and rural residents of the state, policymakers from the two major political parties, members of environmental NGOs, public utilities representatives and academics.

Dr. Berardo co-directed the film with Kirk Mason, owner of the Columbus-based filming company Mason Productions, and it was executive produced by Dr. Campbell. It was filmed with top-of-the-line video equipment including Canon and Panasonic cameras, Zoom H5N audio recorders, Sennheiser boom and lavalier microphones and Neewer and Aputure light systems. "And Water For All" includes a variety of interviews, b-roll shots and infographic and animations produced during the editing portion of the project with Adobe Premiere Pro and Adobe After Effects. The documentary debuted on March 22, 2022 (World Water Day) at Ohio State's Environmental Professionals Network breakfast program and was followed by a community screening and discussion at Studio 35 in Columbus. The film is currently available for free on YouTube and will be used in multiple undergraduate and graduate classes at Ohio State University.


*Figure 2. Premiere of "And Water For All' at the Environmental Professionals Network breakfast program.*

<u>Researcher Profiles:</u> Dr. Berardo has been conducting water-related research since the mid-2000s both in the U.S. and Latin America. He received his doctorate in Political Science from Florida State University and focuses his research on understanding how complex governance systems operate. Dr. Campbell is the director of the Environmental Professionals Network, and his research focus is on the balance between community development and natural resource management. He received his doctorate in Rural Sociology from The Ohio State University.

Dr. Zuzana Bohrerova, former Associate Director of the Ohio Water Resources Center, led a project funded by the Federal CARES grant to the State of Ohio during the COVID-19 pandemic and CDC grant via the Ohio Department of Health (ODH) titled **"Coordination and management of statewide and campus SARS-CoV-2 wastewater monitoring."** The project aimed to coordinate — in partnership with the Ohio Environmental Protection Agency (EPA), U.S. EPA and ODH — an effort to develop a network of analytical laboratories at Ohio's universities and commercial labs to measure SARS-CoV-2 in raw wastewater.

*Figure 1. Wastewater monitoring at an Ohio State University dorm.*

Prior to 2020, wastewater monitoring had not been applied on a scale as large as detecting worldwide infectious disease spread, and it was primarily utilized for research purposes rather than public health and response. Wastewater monitoring for SARS-CoV-2 ribonucleic acid is a novel surveillance tool that monitors trends and changes in the occurrence of COVID-19 in communities. The network collaborated with water reclamation facilities that were willing to collect samples for analysis on a regular basis. Samples were collected twice a week and sent to the labs for testing to determine the presence of coronavirus ribonucleic acid (RNA) fragments. Through the project, wastewater samples were collected and analyzed from 70 communities and 12 universities across Ohio, covering 49% of the population.

The SARS-CoV-2 wastewater surveillance has provided communities with valuable information such as early indications of whether COVID-19 cases in the community are increasing or decreasing, helping local hospitals prepare for potential outbreaks. Over 1000 notifications have been sent to local health districts. At the end of June 2022, management of the wastewater monitoring network transitioned to ODH along with Dr. Bohrerova. As people increasingly take at-home COVID-19 tests which are not publicly reported, wastewater surveillance will continue to play a vital role in evaluating the spread of COVID-19 in communities.

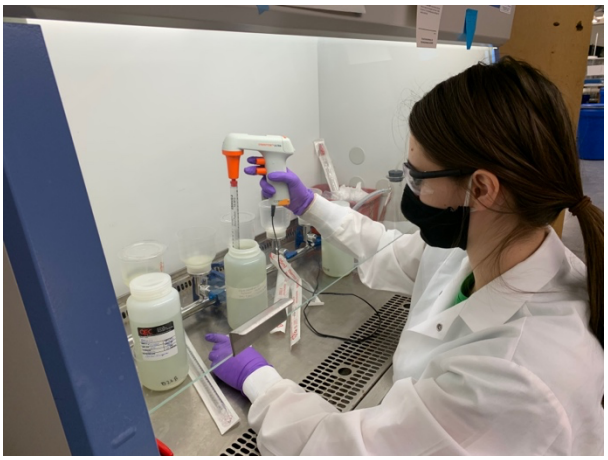

*Figure 2. Filtration and extraction of wastewater sample in a lab.*

<u>Researcher Profile:</u> Dr. Bohrerova is the former Associate Director of the Ohio Water Resources Center and former Research Specialist in the Department of Civil, Environmental and Geodetic Engineering at Ohio State University, focusing on water treatment and other water issues in Ohio. She now serves as the Ohio Department of Health Program Manager of the Ohio Wastewater Monitoring Network.

Dr. Soryong Chae, Associate Professor in the Department of Chemical and Environmental Engineering at the University of Cincinnati, completed an Ohio Water Resources Center funded project via the Ohio Water Development Authority subaward. The project titled **"Efficient removal of emerging per- and poly-fluoroalkyl contaminants using electrically heatable carbon nanotube hollow fiber membrane distillation"** aimed to pioneer an innovative engineering system to achieve energy-efficient removal of per- and poly-fluoroalkyl substances (PFAS) from water and wastewater.

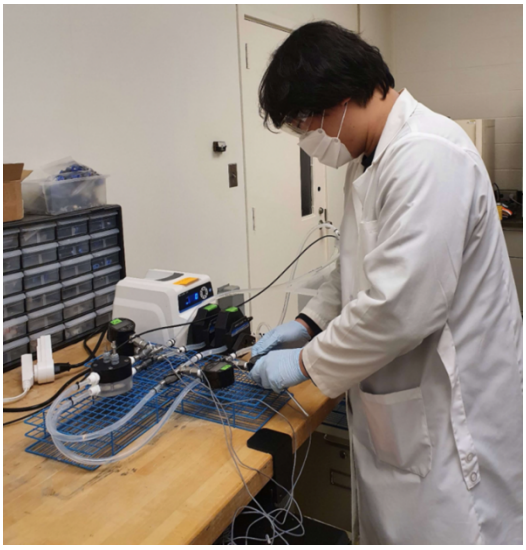

*Figure 2. A graduate student (Mr. Hyunsik Kim, Ph.D. candidate) is optimizing a bench-scale membrane distillation system with the carbon nanotude/PVDF hollow fiber membranes to remove PFAS from water efficiently.*

PFAS have a significant impact on drinking water quality, fish and animal habitat, human health and ecosystem services in Ohio. The extreme environmental persistence of PFAS with the increasingly higher aqueous solubility as the chain length shortens creates increasing difficulty for impacted water to be treated by many conventional remediation and treatment technologies. Dr. Chae and his team focused on the incorporation of carbon nanotube (CNT) sheets onto hollow fiber membranes and the effects of Joule heating on the removal of emerging PFAS via membrane distillation (MD) from water to address the current performance and productivity of MD technology.

The removal of PFAS by the electively heatable CNT (30 layers)/PVDF hollow fiber membrane was studied using a bench-scale vacuum membrane distillation (VMD) process (treatment capacity = ~7.6 L/d). The CNT hollow fiber membranes with 30 CNT layers showed excellent removal (> 99.9%) of a model PFAS compounds (i.e., PFOA) at lower concentrations in feed (i.e., 1 and 10 mg/L PFOA) during 12 hr operation. However, when the VMD system was fed with 1,000 mg/L PFOA solution, PFOA concentration in the membrane permeate gradually increased, and the removal efficiency dropped below 99% after 6 hr operation. The results provide insight into processes for the effective removal of PFAS from water and wastewater subjected to advanced treatment technologies for safe and beneficial re-use of the reclaimed water as well as fundamental and mechanistic understanding of fate and transport of PFAS through CNT layers and polymer membranes.

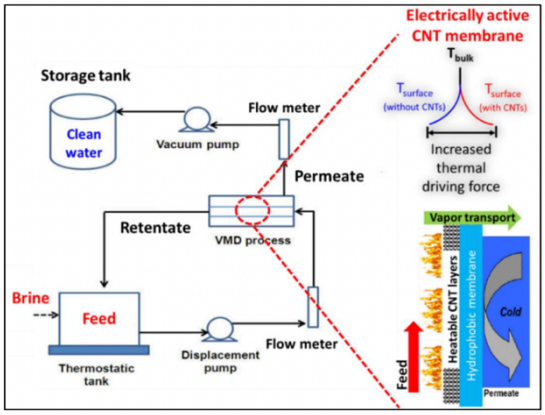


*Figure 1. Schematic diagram of a bench-scale VMD system with electrically active CNT hollow fiber membranes.*

Researcher Profile: Dr. Chae received his Ph.D. from Korea Advanced Institute of Science and Technology (KAIST) in 2004 and pioneered research in the application of nanotechnology for membrane, water and energy. His research interests include environmental implications and applications of engineered nanomaterial, membrane technology for drinking water production and MBR for municipal and industrial wastewater recycling.

Dr. Jim Hood, Assistant Professor in the Department of Evolution, Ecology and Organismal Biology at Ohio State University, completed an Ohio Water Resources Center 104(b) funded project titled **"What role does nutrient cycling by zooplankton play in supporting HAB production in western Lake Erie?"** The project aimed to determine the relative importance of zooplankton-mediated nitrogen (N) and phosphorus (P) recycling on harmful algal bloom (HAB) development, timing, and magnitude in the western basin of Lake Erie, identify the physicochemical and biological controls of zooplankton nutrient recycling rates and ratios, and understand zooplankton feeding on HABs and other phytoplankton groups.

*Figure 1. Lyndsie Collis, graduate student, taking samples of zooplankton in western Lake Erie*

HABs have increased in severity in western Lake Erie, resulting in serious public health and economic consequences. Although spring P-loading from the Maumee River strongly predicts the summer algal bloom extent, it is not clear how the P is stored and cycled prior to and during bloom formation. Dr. Hood's team completed measurements of zooplankton nutrient recycling (ZNR) and grazing on nine sampling events by quantifying N and P excretion rates by micro- and mesozooplankton regularly at one site in western Lake Erie near the Maumee River mouth. Since planned sampling during the 2020 field season was postponed due to COVID-19, measurements were conducted during the 2021 field season.

Preliminary results indicated the team obtained measurable individual zooplankton P excretion estimates on four of nine dates for total zooplankton excretion and on two of five dates for microzooplankton excretion. Not all microzooplankton excretion soluble reactive phosphorus (SRP) samples have been analyzed. Estimates of community microzooplankton and total zooplankton excretion rates require density estimates of both zooplankton groups and thus will not be available until those samples are enumerated; therefore, the team cannot presently evaluate the relative importance of ZNR. The team will not be able to address ZNR rates and ratios until they finish analyzing the microzooplankton community samples, but they anticipate completing this analysis by the end of 2023. As for zooplankton grazing rates and patterns, preliminary results indicated that during cyanobacteria blooms, mesozooplankton grazed primarily on cyanobacteria, but also diatoms or cryptophytes. In contrast, microzooplankton did not have measurable grazing rates for any phytoplankton group during August and grazed only on green algae during September.

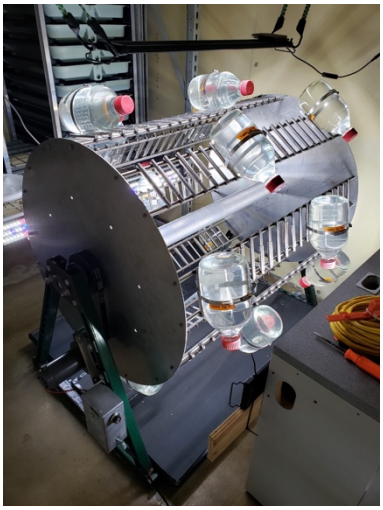

*Figure 2. Plankton wheel incubating total zooplankton bottles (2.3 L) in an environmental chamber set at ambient western basin Lake Erie water temperature*

<u>Researcher Profile:</u> Dr. Hood is an aquatic ecosystem ecologist and Assistant Professor in the Department of Evolution, Ecology, and Organismal Biology at Ohio State University. As an ecologist, he seeks to both improve general understanding of aquatic ecosystems and to determine how material and energy pathways are influenced by human induced changes.

Dr. Matthew Saxton, Assistant Professor in the Department of Biological Sciences at Miami University, completed an Ohio Water Resources Center funded project via USGS 104(b) subaward. The project titled **"Microorganisms and enzymes driving glyphosate degradation in Lake Erie"** aimed to understand how microorganisms in water react to pesticides running off from agricultural fields into downstream bodies of water.

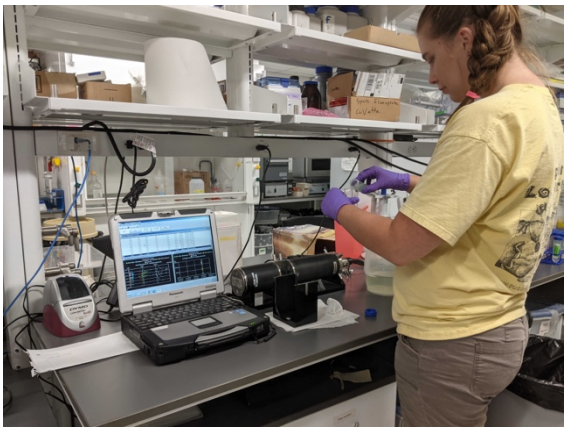

*Figure 1. Undergraduate student Emma Jones using a fluoroprobe to investigate algal community structure.*

The chemical structure of glyphosate, the most widely applied herbicide in the world, includes phosphorus and nitrogen, making the contribution of this chemical to eutrophication of increasing interest. Bacterial biodegradation of glyphosate has been observed in bacterial cell culture and is presumed to occur in nature, but the gene pathways that drive this metabolism in the environment are unclear. Understanding these processes will help obtain a full picture of Lake Erie's nutrient cycles and to specifically understand its recent algal bloom formation.

Dr. Saxton and his team added six different herbicides and five different insecticides to water collected from Acton Lake, a reservoir in a highly agricultural area of southwest Ohio, to study how algae and bacteria in the water reacted to the chemical application. They observed that while Acton Lake bacteria and algae did respond to individual chemicals, the bacteria nor the algae responded in a similar way to either the herbicides or insecticides. The team also exposed water collected from Sandusky Bay in Lake Erie to glyphosate and several of its breakdown products to study how the bacteria and algae in the ecosystem respond to this chemical by learning which genes they turn on when exposed.

Logistical and supply chain problems due to SARS-CoV-2 delayed data acquisition, but with their final data, the research team will be able to determine the gene pathway or multiple pathways used to degrade glyphosate in Lake Erie. The results will provide evidence as to the forms through which glyphosate-derived nutrients enter Lake Erie and the likelihood of downstream impacts on harmful algal blooms and hypoxia.

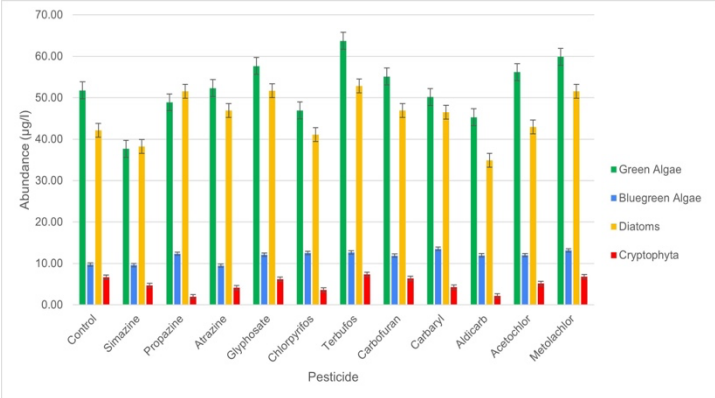


*Figure 2. Algal concentration with pesticide treatment.*

<u>Researcher Profile:</u> Dr. Saxton is an Assistant Professor at Miami University. His research focuses on how the strain on the world's freshwater, estuarine and coastal resources from a rapidly increasing global population influences microbial community dynamics and activity and how affected microbial communities impact important environmental issues, such as eutrophication, harmful algal bloom formation, hypoxia and climate change. He received his doctorate in Microbiology from the University of Tennessee, Knoxville.

Dr. John Senko, Associate Professor in the Department of Geosciences and Biology at the University of Akron, and Dr. Chelsea Monty-Bromer, Associate Professor in the Department of Chemical and Biomedical Engineering at Cleveland State University, completed an Ohio Water Resources Center funded project via 104(b) USGS. The project, titled "**Electrochemical sensors for microbial activities in benthic sediments: A sentry for lacustrine P biogeochemistry,"** aimed to investigate how electrical current measurements using sensors positioned in lake sediments could serve as an early warning system for harmful algal blooms (HABs) resulting from internal phosphate loading.

HABs form when there are high levels of nutrients, such as phosphorus and nitrogen, in a body of water. A relatively unstudied source of phosphorous in water is internal phosphorus loading—the release of phosphorus (generally as phosphate) from sediments on a water body's floor—because the potential for and extent of it is difficult to monitor. The research team set up experiments where they mimicked different processes in lake sediments by placing sediments from Old Woman Creek estuary on Lake Erie in separate chambers with a synthetic Lake Erie water and Fe(III) minerals. The team utilized a split-chamber zero resistance ammetry (SC-ZRA) technique, a relatively inexpensive and low-power approach, to detect varying microbiological activities in benthic sediments.

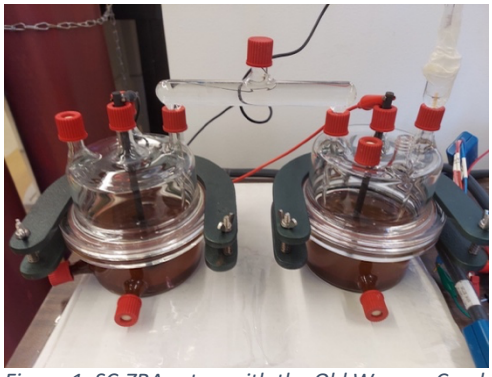

*Figure 1. SC-ZRA setup with the Old Woman Creek sediments.*

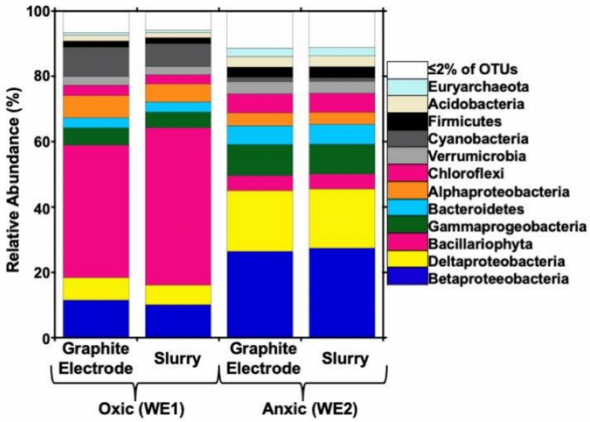


*Figure 2. Relative abundances of taxonomic groups (based on 16S rRNA gene sequencing) ZRA electrodes and OWC sediment-SLEW slurries in the oxic and anoxic sides of SC-ZRA incubations amended with 50 mmol/L $Fe(OH)_3$.*

The team was able to electrochemically detect the Fe(III) reducing microbiological activities using the SC-ZRA approach, where electrodes were deployed in sediments with contrasting terminal electron accepting regimes (oxic/aerobic and anoxic/Fe(III) reducing). These contrasting conditions gave rise to contrasting microbial communities. Comparison of current and voltage patterns between Fe(III) (hydr)oxide and Al (hydr)oxide amended SC-ZRA incubations indicates that Fe(III) reduction may give rise to a unique current and voltage pattern. Results indicate that ZRA-based approaches might be used to detect microbiological activities in sediments. The use of ZRA sensors could predict phosphate solubilization in the sediments. Importantly, the microbial communities associated with the electrodes were similar to those of the bulk sediments, indicating that the electrochemical phenomena were not an artifact of the electrodes, but reflective of overall processes in the sediments. Additionally, ZRA could be used to detect fine-scale contrasts in terminal electron accepting processes that might not be detected by bulk sediment analyses.

Researcher Profiles: Dr. Senko is an Associate Professor in the Department of Geosciences and Biology at the University of Akron. He studies how microorganisms influence the prevailing chemical conditions of a variety of "natural" and man-made systems. Dr. Monty-Bromer is an Associate Professor in Chemical and Biomedical Engineering at Cleveland State University. Her research focuses on using electrochemical techniques and novel nanocomposite biomaterials to better understand biological processes at a variety of spatial scales.