HARMFUL ALGAL BLOOM RESEARCH INITIATIVE

2015 Report to the Ohio Department of Higher Education

Track Blooms From the Source

Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders

Chancellor John Carey
Ohio Department of Higher Education

March 23, 2016

On behalf of the current consortium of Ohio universities engaged in the Ohio Department of Higher Education Harmful Algal Bloom Research Initiative (HABRI), we are pleased to submit the initial progress report for the research activities funded in Round 1, covering year one of these two-year projects.

As shown in the report, the 18 Round 1 projects are already providing needed answers that help water treatment operators, regulators, farmers and legislators deal with harmful algal blooms in the present, better predict the situation for the coming years, and lay the foundation for longer-term mitigation and prevention activities.

Whereas Round 1 requirements were primarily driven by OEPA inputs, we are pleased to note the current HABRI advisory board has active representation from OEPA, ODNR, ODH, ODA and the Lake Erie Commission and that they played a key role in setting research priorities and selecting the 13 new projects just funded in Round 2 in February 2016.

We anticipate sharing even more actionable research solutions from the combined efforts of both research cohorts in our next annual report as well as in periodic updates to ODHE. At present, ten Ohio research universities are engaged in HABRI.

We would like to recognize the Ohio Sea Grant team for their management of HABRI projects from start to finish and for preparing this report on behalf of the HABRI university consortium.

And finally, it is fitting that we submit this report to the Ohio Department of Higher Education during the week of World Water Day in light of ODHE's visionary support for creating a sustainable water future for the state through university research, education and outreach/engagement. Thank you.

Thomas Bridgeman
University of Toledo

Bruce McPheron
The Ohio State University

Consortium Co-Chairs

Introduction

After the Toledo water crisis in August 2014, the Ohio Department of Higher Education (then the Ohio Board of Regents) allocated $2 million to Ohio universities for research to solve the harmful algal bloom problem in Lake Erie. The funding was matched by participating universities for a total of more than $4 million.

Led by representatives from The Ohio State University and the University of Toledo, and managed by Ohio Sea Grant, the first round of the Harmful Algal Bloom Research Initiative (HABRI) includes 18 projects involving researchers from seven Ohio universities and partners as far-flung as South Dakota and Japan.

The initiative also provides invaluable training for Ohio students, from undergraduate to doctoral candidates, which distinguishes university research from other scientific institutions and gives taxpayers a double return on their investment.

Input from partners such as the Ohio Environmental Protection Agency, Ohio Department of Natural Resources and the Lake Erie Commission (Appendix I) ensures that projects complement state agency efforts to protect Ohio's fresh water and that results address known management needs to ensure sustainable water for future generations.

HABRI used Ohio Sea Grant's proposal development system to streamline project proposals, project management and public engagement, capitalizing on Sea Grant's strong reputation among various stakeholder groups including the research community.

This report describes the process of HABRI's first cohort of 18 funded two-year projects and offers an overview of the goals of the initiative in the year to come as researchers seek innovative solutions for harmful algal blooms.

Background Information

A harmful algal bloom (HAB) is any large increased density of algae that is capable of producing toxins. In freshwater, such as Lake Erie, those algae tend to be cyanobacteria — more commonly known as blue-green algae — which grow excessively in warm water with a high phosphorus concentration.

Phosphorus enters the water from agriculture, suburban and urban sources, and likelihood of runoff is strongly affected by climatic factors including drought, severe weather and average temperatures.

Many HABRI projects seek to understand both how phosphorus and other elements like nitrogen affect algal blooms, and how runoff can be reduced without negative impacts on farmers and other industries. Other projects focus on the public health impacts of toxic algal blooms, ranging from drinking water issues to food contamination.

Category Definitions

Track Blooms From the Source

Projects aim to improve existing technologies and develop new methods to track algal blooms as they develop and move, giving lakeshore residents and state agencies quicker and more effective tools to understand whether algal blooms might cause a hazard.

Produce Safe Drinking Water

In addition to monitoring bloom locations, researchers are developing new treatment methods for drinking water to remove algal particles and toxins.

Protect Public Health

Projects in this focus area examine the effects of the algal toxin microcystin on people and animals and study whether microcystin is found in produce irrigated with algal-contaminated water.

Engage Stakeholders

Research in this focus area analyzes the decisions that stakeholders have to make—from nutrient management to dealing with algal blooms—and develops tools to make these decisions more clear, systematic, and supported by the latest science.

Track Blooms From the Source

Projects in this focus area aim to improve use of existing technologies as well as develop new methods to detect, prevent and mitigate harmful algal blooms and their impacts. This will help to ensure drinking water safety and a healthy environment for lakeshore residents by scientifically connecting many of the potential causes and effects of harmful algal blooms, from the runoff that fuels them to the toxins that contaminate water supplies.

Early-Warning Systems for Lake Erie Algal Blooms

Two complementary projects in this focus area are developing warning networks for Lake Erie's western basin, where harmful algal blooms are most common. Tailored specifically for Maumee Bay and Sandusky Bay, the networks provide basin-wide data coverage of bloom-affected areas by streaming data from water quality buoys and sensors positioned near water treatment plant intakes to an online database.

The early warning system in Sandusky Bay already demonstrated its potential during the 2015 season. A rapid increase in chlorophyll, a green plant pigment, was detected on July 17, 2015, indicating that algae were present at the primary water intake for Sandusky's Big Island Water Works. While the rise in algae happened too quickly to keep the water from entering the treatment plant, operators had enough warning to adjust treatment to prevent a temporary water shutdown for more than 100,000 residents.

A related project focuses upstream of Lake Erie, monitoring both nutrient amounts and their sources (fertilizer, manure, human or wild animal waste) in the rivers and streams flowing to Lake Erie. This project integrates and augments an existing array of river monitoring stations maintained by a combination of federal, state and university partners.

Combining data from river sensors, lake buoys and existing climate models will refine predictive tools that will give water managers more time to react to developing bloom events in the near future, and ultimately will lead to a better understanding of how to prevent harmful algal blooms altogether.

Projects in this Focus Area

HAB Detection, Mapping and Warning Network: Maumee Bay Area
Lead: University of Toledo

HAB Detection, Mapping and Warning Network: Sandusky Bay
Lead: Bowling Green State University

Identifying the Best Strategy to Reduce Phosphorus Loads to Lake Erie From Agricultural Watersheds
Lead: Heidelberg University

A new early warning system for
ALGAL BLOOMS
in Sandusky Bay protected
the water supply for
100,000
residents from algal toxins
in July 2015.

Produce Safe Drinking Water

One of the most direct public impacts of algal blooms was seen in August 2014, when a harmful algal bloom in Toledo caused a “Do Not Drink” order to be issued for more than two days, an impact felt by residents and businesses alike. With direct guidance from state agencies at the front lines of Toledo and related algal drinking water crises, HABRI researchers are developing new treatment methods that will give public health and water treatment professionals the tools they need to make informed decisions when water supplies are threatened by algal blooms.

Treating Drinking Water to Remove Toxins

Researchers are developing new methods to remove the algal toxin microcystin from drinking water, using various filtration methods as well as ozone gas. The laboratory models can eventually be scaled up for use at water treatment plants that deal with harmful algal blooms in their water supply so they can better ensure their customers’ drinking water is safe to use.

Lab results so far have shown that bubbling ozone into a microcystin solution can lead to 100% destruction of the toxin. Further experiments are in process to achieve similar results at ozone concentrations and treatment times that work with treatment plant procedures. A range of filter membranes are also showing promising results, removing up to 96.9% of microcystin from tested solutions in the lab experiments.

Once these separate experiments are completed, combinations of ozone and filter membranes will be examined to determine the best pairing for toxin removal and cost effectiveness. The ultimate goal is to provide water treatment plant managers with a series of strategies to remove toxins.

Projects in this Focus Area

Treatment of Cyanotoxins by Advanced Oxidation Techniques
Lead: University of Cincinnati

Development of Microcystin Detoxifying Water Biofilters
Lead: University of Toledo

Investigation of ELISA and Interferences for the Detection of Cyanotoxins
Lead: University of Toledo

Guidance for Powdered Activated Carbon Use to Remove Cyanotoxins
Lead: The Ohio State University

Prevention of Cyanobacterial Bloom Formation Using Cyanophages
Lead: The Ohio State University

Identifying Bacterial Isolates for Bioremediation of Microcystin-Contaminated Waters
Lead: Kent State University

Investigation of Water Treatment Alternatives in the Removal of Microcystin-LR
Lead: University of Toledo

Transport and Fate of Cyanotoxins in Drinking Water Distribution Systems
Lead: University of Toledo

Preliminary results
have shown

100%

destruction of microcystin when contaminated water is treated with high ozone gas concentrations.

Protect Public Health

While safe drinking water is a major focus for public health officials and researchers, scientists are also working on other health impacts of harmful algal blooms and the associated toxins. The algal toxin microcystin affects the liver, nervous system and skin, and potentially causes cancer in humans. Projects in this focus area examine those effects, develop techniques to detect the toxin in biological samples, and study whether microcystin is found in fish or produce grown in algae-contaminated water.

What's On Your Lettuce?

Water affected by harmful algal blooms doesn't just end up in residential sinks, it also travels through agricultural irrigation systems that water fields of lettuce, carrots and other vegetables. The recent increase in harmful algal blooms in the region means there is a need to determine whether this produce is a possible source of human exposure to microcystin, how that contamination occurs, and how it could best be prevented.

So far, researchers at The Ohio State University have examined microcystin concentrations in lettuce, tomatoes and carrots watered both above- and below-ground. Preliminary results show that all three vegetables had low levels of microcystin in their tissues, but that concentrations varied depending on irrigation method and type of vegetable: some crops watered from above contained more microcystin than the same crops watered near the roots, while others showed the opposite pattern. Adjusting watering methods based on this data may help reduce the occurrence of microcystin in crops destined for human consumption.

Microcystin in the water used for irrigation also slowed crop growth of all vegetables when compared to water not containing the toxin. This was especially significant in the tomato plants, and adds yet another checkmark to the long list of economic impacts stemming from harmful algal blooms.

Projects in this Focus Area

Method Development for Detecting Toxins in Biological Samples
Lead: University of Toledo

Fish Flesh and Fresh Produce as Sources of Microcystin Exposure to Humans
Lead: The Ohio State University

Evaluation of Cyanobacteria and Their Toxins in a Two-Staged Model of Hepatocarcinogenesis
Lead: The Ohio State University

Water containing microcystin

SLOWS CROP GROWTH

compared to toxin-free water.

Engage Stakeholders

All the research in the world won't be able to solve the harmful algal bloom problem if results and recommendations aren't passed on to the people who need them. Researchers in this focus area are developing ways to disseminate information more effectively, by establishing how information moves through existing networks of people and using those networks – such as Extension and farmer partnerships – to distribute new information about harmful algal blooms.

Sampling Networks Involve Farmers Right From the Start

Fifty-six farmers in the western Lake Erie basin are working with HABRI researchers to collect data about their own fields and the effects that their cropping, irrigation, and soil management practices have on downstream factors like nutrient runoff. Led by Ohio State Extension, these farmers collected information about conditions in 80 fields throughout the 2015 field season with more expected to join in 2016.

While the farmers' data will be used to better understand the effects of variables such as farm practices, climate, and soil type on the development of downstream harmful algal blooms, the farmers' participation allows for tight feedback loops that can inform their choices directly as they make business and land stewardship decisions.

Ultimately, the information can be used to test model predictions, ensuring that watershed managers, state agencies and legislators to have the most current information when making decisions about how best to deal with freshwater harmful algal blooms without negatively impacting other economic sectors such as agriculture.

Projects in this Focus Area

Maumee Basin Lake Erie HABs Nutrient Management Options Comparative Analysis
Lead: The Ohio State University

Farmer/Farm Advisor Water Quality Sampling Network
Lead: The Ohio State University

Maumee Basin Lake Erie HABs Stakeholder Informed Decision-Making Support System
Lead: University of Toledo

Social Network Analysis of Lake Erie HABs Stakeholder Groups
Lead: Kent State University

56 farmers

in western Lake Erie are providing **nutrient and weather data from 80 fields** to researchers studying Lake Erie algal blooms.

Appendix I

CORE HABRI PARTNERS

Universities

Heidelberg University
University of Toledo
Bowling Green State University
The Ohio State University
Kent State University
University of Cincinnati
University of Kentucky
USDA-ARS

Agency Advisory Board

Lake Erie Commission
Ohio Department of Agriculture
Ohio Department of Health
Ohio Department of Natural Resources (ODNR)
ODNR Division of Wildlife
Ohio Environmental Protection Agency
Ohio Sea Grant College Program

External Partners Affiliated With Individual Projects

ABS Materials
Al Szuch Live Bait
Bay's Edge Bait and Tackle
Big Island Water Works
Biosortia Pharmaceuticals
Blanchard River Watershed Partnership
City of Toledo
City of Oregon
Erie Hopper Sportfishing Charters
Great Lakes Water Quality Agreement
Kyoto University
NASA Glenn Research Center
NASA Marshall Space Flight Center
ODNR Division of Wildlife
River Marine Supply
Seneca Conservation District
South Dakota State University
Toledo Water Treatment Plant
US Geological Survey (USGS)
USGS Lake Erie Biological Station

Appendix II

TRACK BLOOMS FROM THE SOURCE

HAB Detection, Mapping and Warning Network: Maumee Bay Area

Principal Investigator
Thomas Bridgeman, University of Toledo
Partners: The Ohio State University

PROJECT SUMMARY

Harmful algal blooms often produce toxins that need to be filtered out of the water before it is safe to drink. Currently, water treatment plants such as in Toledo, Ohio only detect these toxins in Lake Erie water when they're already pulling the water into the plant. Since that's not enough time to switch treatment techniques, they have to use expensive, non-specific techniques to ensure clean water for customers.

A team led by Thomas Bridgeman, an associate professor of environmental sciences at the University of Toledo, is developing a warning system for water treatment plants that gives them 12-24 hours of lead time before water reaches the intake in Lake Erie, allowing them to adjust treatment protocols accordingly.

By combining water quality sensors with environmental monitoring, this early warning system can be thought of as working toward a "weather radar" for harmful algal blooms, which could reduce water treatment costs during the bloom season.

THE BOTTOM LINE

Clean drinking water for communities and money savings for water plants that will be able to apply powdered activated carbon in a more targeted fashion.

SYNOPSIS OF YEAR 1

Relevance: This project was undertaken in response to the Toledo water crisis of 2014. Part of the reason for the water crisis was inadequate advance warning of high concentrations of algal toxins approaching the Toledo water intake on Lake Erie.

Response: A major goal of the project is to increase advance warning times for public water utilities in order to give them more time to adjust water treatment levels to neutralize HAB toxins. This was accomplished by deploying a water quality buoy in an area near the Toledo and Oregon intakes that is prone to the development of high toxin concentrations and by frequent sampling using the University of Toledo research boat. We are also improving the capability of tracking HABs near water intakes using sensors mounted on aircraft. Data from the buoys was made available in real-time to plant operators and the public. Toxin concentration data was forwarded to our partnering plant operators and researchers.

Results: The results of our project helped to ensure timely and efficient toxin removal and treatment of drinking water for the cities of Toledo and Oregon during the HAB season of 2015. Economic return may have resulted from the advance warning allowing water utilities to match treatment to need, thus avoiding costly overtreatment – although this is difficult to measure. The success of our project along with the cities' efforts ensured safe drinking water in 2015 and returned a measure of public confidence in the water supply. The model of a network of water quality buoys and frequent vessel and aircraft-based monitoring trips is now expanding to other intakes and locations in Lake Erie.

Recap: In the summer of 2015, we successfully employed a HAB early-warning system consisting of a water quality buoy and weekly vessel and aircraft-based HAB monitoring trips to provide important HAB information to water plant managers, other researchers and the public. A repeat of the Toledo water crisis of 2014 was avoided and a measure of public confidence in the water supply was restored.

Appendix II

TRACK BLOOMS FROM THE SOURCE

HAB Detection, Mapping, and Warning Network: Sandusky Bay

Principal Investigator
George Bullerjahn, Bowling Green State University
Partners: Kent State University, The Ohio State University

PROJECT SUMMARY

Harmful algal blooms often produce toxins that need to be filtered out of the water before it can be safe to drink. Currently, these toxins are detected at the water intake for the water plant in Sandusky, Ohio, requiring potential overtreatment of incoming water to ensure toxins are eliminated before water is delivered to customers.

A research team led by George Bullerjahn of Bowling Green State University is developing a warning system for the water plants that extends early warning capacity to 12-24 hours before water reaches the water intake in Lake Erie, allowing water plants to adjust treatment protocols before water reaches the intake.

By combining water quality sensors with environmental conditions monitoring (e.g., wind speed and direction), this early warning system could allow researchers to develop models that can predict the scenarios under which harmful algal bloom toxicity could present an imminent health concern.

THE BOTTOM LINE

Clean drinking water for Ohio residents and reduced costs for municipalities, using a system that can be expanded to other communities.

SYNOPSIS OF YEAR 1

Relevance: Sandusky Bay is plagued by a toxic *Planktothrix* (cyanobacterial) bloom that threatens drinkable and recreational waters used by residents and more than 3 million tourists each year. The need exists to provide information to users on the extent, movement, intensity and toxic potential of the bloom.

Response: An early warning system of water quality sensors (sondes) was installed at the City of Sandusky's water treatment plant to alert personnel to bloom events at the water intakes. Bloom biomass and toxin production was assessed during 2015 in concert with chemical and physical measures in Sandusky Bay and surrounding Lake Erie coastal waters.

Results: The warning system was successfully linked to an online network of water quality sondes. Increases in algae were detected at Sandusky and allowed for modifications in water treatment protocols in real time that prevented a potential shutdown in early August. Analysis of nutrient dynamics in Sandusky Bay indicates a nitrogen-limited environment suitable for *Planktothrix* success, and that management of nitrogen as well as phosphorus is appropriate to mitigate bloom events in the bay. However, total chlorophyll does not predict toxigenicity. Field samples collected during the course of the summer when coupled with MODIS remote sensing data enabled the development of maps of potentially toxic and nontoxic algae for Sandusky Bay and the Western Basin of Lake Erie at 1km resolution. We are in the process of applying this same algal identification method to NASA's hyperspectral sensor system, which will enable us to further differentiate the algal composition from the air at 1m rather than 1km resolution.

Recap: A system to alert Sandusky of cyanobacterial blooms was successfully deployed and used. Toxic *Planktothrix* dominates in Sandusky Bay likely due to active nitrogen cycling, warranting management of nitrogen and phosphorus. A new method to identify algae from airborne and spaceborne sensors was refined and implemented.

Appendix II

TRACK BLOOMS FROM THE SOURCE

Identifying the Best Strategy to Reduce Phosphorus Loads to Lake Erie from Agricultural Watersheds

Principal Investigator
Laura Johnson, Heidelberg University
Partners: Bowling Green State University, The Ohio State University

PROJECT SUMMARY

Ohio researchers are working to identify the best strategies to reduce the amount of phosphorus that runs off farm fields that reside in the Lake Erie watershed to help improve the overall health of the Great Lake.

Experts say soluble phosphorus runoff from farms is an important source of harmful algal blooms plaguing Lake Erie and other lakes in recent years. In August, a toxic bloom in western Lake Erie led to a two-day drinking water ban in Toledo. As a result, this spring, Ohio, Michigan and Ontario, signed an agreement to work to reduce phosphorus by 40 percent by the year 2025.

A research team led by Laura Johnson, a research scientist at Heidelberg University's National Center for Water Quality Research, is using automated sampling equipment and sensors to test water samples throughout four watersheds – Rock and Honey Creeks (subwatersheds of the Sandusky), the upper Portage River watershed, and the Blanchard River (subwatershed of the Maumee) – to identify possible high phosphorus-contributing locations and different sources of phosphorus runoff that may contribute to loading into Lake Erie.

The team will provide this information to regional modeling experts to help update current watershed models and thus identify the most effective and innovative methods to lessen phosphorus entering into the Lake Erie watershed.

THE BOTTOM LINE

Less phosphorus and fewer harmful algal blooms in Lake Erie.

SYNOPSIS OF YEAR 1

Relevance: The biggest question facing the health of Lake Erie today is "How can phosphorus be reduced to levels that will lead to minimal HABs?" This project identifies the appropriate strategy needed to meet these target reductions in phosphorus. Specific project questions include: will addressing only the highest contributors of phosphorus be enough to reduce the phosphorus that feeds algal blooms? How much should we focus on other sources of phosphorus, such as point sources and animal waste?

Response: We are investigating variation in watershed nutrient export by intensively monitoring subwatersheds in the Western Lake Erie Basin (WLEB) to see how nutrient export varies in time and space. Innovative methods to help fingerprint phosphorus are being used to parse out the many sources that can run off into waterways.

Results: So far, the project has found locations draining various soil types, and types of agricultural management as well as located various sources of phosphorus to be fingerprinted. Sampling has begun or will begin soon to characterize the 2016 water year. The complex methods used for fingerprinting phosphorus have been developed and sampling to differentiate sources will begin shortly.

Recap: Sampling to identify the variation in nutrient runoff as well as sources of phosphorus across 3 major Western Lake Erie Basin (WLEB) watersheds is currently underway. Results will identify the best management strategy in the WLEB required to reach reductions in nutrients that will reduce the occurrence of harmful algal blooms plaguing the lake.

Appendix II

PRODUCE SAFE DRINKING WATER

Treatment of Cyanotoxins by Advanced Oxidation Techniques

Principal Investigator
Dionysios Dionysiou, University of Cincinnati

PROJECT SUMMARY

New research from the University of Cincinnati is looking into finding new and cost-effective ways to remove and destroy cyanotoxins from drinking water.

Using various technologies to treat different stages of water from the Greater Cincinnati Water Works, the research team led by Dionysios Dionysiou from the University of Cincinnati will explore different doses and types of degradation processes to see which will destroy the algal toxin microcystin-LR the fastest. The processes being tested in the lab include combinations of chlorination and light degradation via ultraviolet (UV) rays. A related project at the University of Toledo is expanding the range of methods tested with ozonation and filtration.

The hope is that the project will find not only the most cost-effective technologies for the treatment of water contaminated with cyanotoxins, but also understand the mechanisms behind different processes. Another concern is what products the cyanotoxins may leave behind after they are degraded, so water treatment plants don't replace one harmful compound with another by accident.

THE BOTTOM LINE

Using new removal processes, cities' treatment plants will be able to eliminate cyanotoxins in drinking water at a lower cost and with higher water quality.

SYNOPSIS OF YEAR 1

Relevance: The need to develop efficient methods in removing/destroying cyanotoxins from several water sources is high priority in the U.S. and around the world. Feasible technologies with lower chemical and energy consumption are in urgent need.

Response: Different Advanced Oxidation Techniques (i.e., ultraviolet light and chlorine, citrate acid, iron, and persulfate, and solar radiation, iron and hydrogen peroxide) have been tested to determine the degradation of cyanotoxins. The effects of chemical dosage, light irradiation time, presence of natural organic matters, and pH were examined. Water samples at different treatment stages in Greater Cincinnati Water Works were tested. The researchers efficiently degraded microcystin (MC-LR) in pure and natural water samples, where increasing ionic strength and presence of other organic compounds affected the rates of destruction.

Results: Findings indicate that there is potential to provide drinking water at lower costs and with a smaller footprint. Our researcher won the 2015 Sigma Xi Grants-in-Aid-of-Research Award for her efforts and outstanding findings. The results will be presented in a national meeting of the American Chemistry Society, and the International Conference on Advanced Oxidation Technologies for Treatment of Water, Air and Soil.

Recap: Our group effectively destructed cyanotoxins using several Advanced Oxidation Techniques to lower the costs and increase the water quality of areas that frequently suffer from algae blooms and their toxins.

Appendix II

PRODUCE SAFE DRINKING WATER

Development of Microcystin-Detoxifying Water Biofilters

Principal Investigator
Jason Huntley, University of Toledo

PROJECT SUMMARY

Researchers at the University of Toledo are putting toxin-eating bacteria to work purifying water.

When lakes or reservoirs develop harmful algal blooms, communities have to think twice about what's coming out of the tap. Normally, water treatment plants ensure safe drinking water by putting the incoming water through a series of standard cleansing steps. But with the increasing frequency of harmful algal blooms, water treatment experts are seeking effective and affordable techniques to remove algal toxins from water.

A team of researchers from the University of Toledo has developed a new low-cost treatment method that harnesses bacteria that naturally feed on the toxin microcystin. Led by Jason Huntley, an assistant professor of medical microbiology and immunology, the team is growing helpful bacteria on the filters that water must pass through during purification. They are currently testing the combination of filter material, bacteria type and water conditions that remove microcystin fastest from water. The next step will be to build a pilot processing system and test the technique on larger scales.

THE BOTTOM LINE

A new technique in the toolbox of water treatment plants that face harmful algal blooms in their source waters.

SYNOPSIS OF YEAR 1

Relevance: Naturally-occurring bacteria can form films (biofilms) on various substrates and perform important functions. It is possible that microcystin-degrading bacteria exist in Lake Erie that these bacteria could form biofilms on filters commonly used in municipal water treatment facilities, and that biofilters could degrade microcystin (MC-LR) from Lake Erie water. Biofilters would offer municipal water treatment facilities a safe, efficient, and cost-effective alternative for microcystin removal from Lake Erie water.

Response: Following the Toledo water crisis in the summer of 2014, our research group proposed to develop biofilters, using naturally-occurring bacteria that degrade microcystin, to remove microcystin from drinking water.

Results: Throughout the summer of 2015, we collected Lake Erie water samples to select for and identify microcystin-degrading bacteria. We currently are analyzing these bacteria using advanced DNA sequencing techniques to identify what type of bacteria they are and to help understand how they degrade the microcystin toxin. Upcoming studies will test biofilm development and biofilter utility.

Recap: Our research group is isolating naturally-occurring microcystin-degrading bacteria to aid in biofilter development, so that the microcystin toxin can be safely and efficiently removed from municipal water supplies.

Appendix II

PRODUCE SAFE DRINKING WATER

Investigation of ELISA and Interferences for the Detection of Cyanotoxins

Principal Investigator
Dragan Isailovic, University of Toledo
Partners: The Ohio State University, University of Cincinnati

PROJECT SUMMARY

A research project at three Ohio universities aims to double-check the accuracy of the most widely used test for harmful algal toxins.

During the 2014 water quality crisis in western Lake Erie caused by harmful algal blooms, there was one test that all public health agencies turned to: ELISA. Standing for Enzyme-Linked ImmunoSorbent Assay, ELISA is the most widely used way to test water for harmful algal toxins. However, there may be some conditions — for instance, when certain other chemicals like calcium are present in water — under which ELISA may give inaccurate answers.

In order to know for sure, a research partnership among the University of Toledo, The Ohio State University and the University of Cincinnati are checking ELISA's answers against results from a much more time-consuming but reliable method, liquid chromatography-mass spectrometry (LC-MS). The team will test ELISA's performance detecting algal toxins in many possible mixtures that simulate lake and reservoir water as well as the stages that water goes through in a water treatment plant.

THE BOTTOM LINE

More certain results when public officials need to monitor and communicate water quality information about harmful algal blooms.

SYNOPSIS OF YEAR 1

Relevance: Due to harmful algal blooms that affect Lake Erie and other reservoirs of drinking water, it is necessary to develop capabilities in Northwest Ohio for accurate quantification of algal toxins (also known as microcystins) in water and biological samples.

Response: The researchers at the University of Toledo have used a state-of-the art LC-MS system to perform separation and quantification of microcystin standards by LC-tandem mass spectrometry (MS/MS). The LC-MS/MS methodology developed can be used for quantification of toxins in water, to test purification of water containing microcystin, and to analyze toxins in biological samples.

Results: A high-resolution LC-MS system has provided capabilities for detection and quantification of microcystins that have not been available at the University of Toledo before. Microcystin standards have been detected and quantified at low concentration levels confirming that LC-MS/MS is an excellent tool for quantification of algal toxins. Multiple collaborators and industrial partners can benefit from the results of this work. Additionally, graduate students were trained to perform the analyses and interpret experimental data needed to complete this important project.

Recap: The scientists at the University of Toledo are developing accurate LC-MS/MS methodologies to detect and quantify algal toxins in water samples.

Appendix II

PRODUCE SAFE DRINKING WATER

Guidance for Powdered Activated Carbon Use to Remove Cyanotoxins

Principal Investigator
John Lenhart, The Ohio State University
Partners: University of Toledo

PROJECT SUMMARY

Harmful algal blooms can produce a family of toxins called microcystins that have to be scrubbed from water before it is safe to drink. Most water treatment plants use powdered activated carbon (also called activated charcoal) to absorb and remove the toxins, but knowing the specific dosage of carbon to use can be a complicated matter, as it depends on varying levels of toxin and environmental conditions.

A research team, led by John Lenhart, an environmental engineer at The Ohio State University, will develop guidelines for water treatment plant operators to help them know exactly which dosage of powdered activated carbon to use under which conditions. These guidelines will take into account the types and concentrations of toxins present and the composition of the water — for instance, the presence of decaying organic matter from plants and animals, which is known to affect how the carbon absorbs toxins.

THE BOTTOM LINE

Clean drinking water for communities and money savings for water plants that will be able to apply powdered activated carbon in a more targeted fashion.

SYNOPSIS OF YEAR 1

Relevance: Seasonal harmful algae blooms (HABs) that produce cyanotoxins have recently increased in frequency and intensity. In many locations, utilities treating water impacted by these blooms for human consumption utilize powdered activated carbon (PAC) to remove cyanotoxin. Unfortunately, details on the proper amount of PAC and form of PAC needed to remove cyanotoxins are limited. In recognition of the uncertainty Ohio utilities face in determining proper PAC dose to ensure cyanotoxin removal, we are investigating factors that influence cyanotoxin removal by PAC in order to develop a framework to optimize PAC dosage.

Response: Work is being conducted to evaluate the uptake of common cyanotoxins by PAC. These experiments are evaluating a suite of PAC types and will investigate a range of physical and chemical variables that may affect cyanotoxin uptake by PAC.

Results: The work only recently began, however, it appears utilities in Ohio that employ PAC for cyanotoxin removal do so for reasons not necessarily directly related to the ability of the PAC utilized to remove cyanotoxins. This confirms the need to develop specific guidance to aid utilities in the selection of PAC type and dose for treatment of cyanotoxins.

Recap: This project will benefit utilities and residents by providing guidance to select treatment conditions in order to provide safe drinking water during periods where algae blooms are experienced and by easing treatment costs from the use of improper or excess PAC.

Appendix II

PRODUCE SAFE DRINKING WATER

Prevention of Cyanobacterial Bloom Formation Using Cyanophage

Principal Investigator
Jiyoung Lee, The Ohio State University

PROJECT SUMMARY

Jiyoung Lee, an environmental health scientist for Ohio State, is searching for a more environmentally friendly way to reduce microcystins in both lake water and water treatment plants.

Ingesting water contaminated with microsystins can cause everything from stomach cramps to liver failure. In August 2014, microcystins shut down Toledo's water supply for more than two days. Microcystins are a toxin produced by the cyanobacteria, also known as blue-green algae, that cause harmful algal blooms.

Lee believes there may be a solution in cyanophages, which are viruses prevalent in water that infect only their host, cyanobacteria. Cyanophages can add or delete genes from their host.

"Cyanophages have been studied in marine water, but not much in lake water," Lee said. "We need to better understand what kind of cyanophages we have in Ohio lakes, and quantify them."

THE BOTTOM LINE

The hope is that researchers will discover a way to use cyanophages to both limit cyanobacteria in lake water located near a water intake, and to use them in water treatment plants in place of chemicals such as chlorine, activated carbon and ozone.

SYNOPSIS OF YEAR 1

Relevance: Harmful cyanobacterial blooms impact human health, natural ecosystem balance, and economies around the globe. In Ohio, these blooms have greatly impacted both Lake Erie and smaller inland lakes and their intensity has reached record-setting levels in recent years. Unfortunately, there is currently no environmentally friendly and easy solution for controlling these blooms. Our research project seeks to study a class of naturally occurring phages (viruses that infect these cyanobacteria). While such cyanobacteria-infecting viruses (known as "cyanophage") have been isolated previously (such as in Japan), very little work has been done toward their isolation and characterization in the US.

Response: Our project seeks to detect cyanophages for understanding their relationship with cyanobacteria. We also want to identify and isolate a set of cyanophages that have the capability to infect the two most common types of cyanobacteria in Ohio. Once we have these isolated cyanophages, we will investigate their potential efficacy in the prevention and control of cyanobacterial blooms at a laboratory scale.

Results: We established a detection method for *Microcystis*-specific cyanophage. Experiments for quantifying and isolating the cyanophages are currently underway.

Recap: Better understanding the natural role of cyanophages in Lake Erie bloom dynamics and their potential use in the remediation of cyanobacterial blooms could contribute to mitigating current and future trends of the blooms in Lake Erie and inland lakes in a cost-effective and sustainable way.

Appendix II

PRODUCE SAFE DRINKING WATER

Identifying Bacterial Isolates for Bioremediation of Microcystin-Contaminated Waters

Principal Investigator
Xiaozhen Mou, Kent State University

PROJECT SUMMARY

Because of its unusual shape, the chemical microcystin does not break down easily in the conditions found in most water treatment plants. However, bacteria naturally present in lake water and sediments have evolved to use microcystin and related chemicals as a food source — a fact that water treatment plants would like to take advantage of.

Kent State University microbiologist Xiaozhen Mou and her team have been collecting water and sediment samples since 2013 to find bacteria that thrive when exposed to microcystin. Now, they are purifying cultures of the bacteria to see if they can be used as part of bioremediation systems in water treatment plants.

THE BOTTOM LINE

A better understanding of lake ecology and a hope for a new clean drinking water technology.

SYNOPSIS OF YEAR 1

Relevance: Each summer, water in Lake Erie turns green due to excessive growth of cyanobacteria (blue-green algae). In addition to this "cosmetic defect," the growth of cyanobacteria deteriorates the water quality by promoting the growth of pathogens, depleting the dissolved oxygen and, more importantly, releasing microcystins. Microcystins are liver toxins that harm the health of human and wild animals if ingested. Bacterially mediated processes are believed to be the major means to remove microcystins in natural waters. However, the organisms and mechanisms involved in microcystin degradations have not been well studied in Lake Erie.

Response: This project aimed to isolate pure bacteria cultures from Lake Erie and use them as models to study the microcystin degradation pathway and its regulating factors. The obtained isolates may potentially be used for bioremediation and/or bioaugmentation for water treatment. We partnered with the U.S. Environmental Protection Agency and U.S. Geological Survey to collect samples. We also partnered with a local business (ABS Materials) and will search for potential application of obtained isolates to commercial filter materials to achieve efficient microcystin removal.

Results: We will have better knowledge on the bio-degradation activities offered by natural bacterial communities. The obtained isolates can serve as potential candidates for development and/or improvement of environmentally-friendly and cost-effective water treatment. We will work with our engineer collaborators to test the performance of bacteria-amended sand filters and run experiments to examine the potential for "scaling-up" the model system to pilot plant-scale.

Recap: This project will obtain bacterial isolates that are useful to develop environmentally-friendly and cost-effective water treatment means.

Appendix II

PRODUCE SAFE DRINKING WATER

Investigation of Water Treatment Alternatives in the Removal of Microcystin-LR

Principal Investigators
Youngwoo (Young) Seo, University of Toledo
Isabel Escobar, University of Kentucky
Partners: The Ohio State University, University of Cincinnati

PROJECT SUMMARY

Research under development at the University of Toledo and The Ohio State University is designed to create alternative treatments for algal toxins often found in drinking water drawn from Lake Erie.

While activated carbon is an effective way to remove algal toxins such as microcystin from drinking water, high toxin levels can lead to extensive and potentially unsustainable use of activated carbon, which can add as much as $10,000 to water treatment costs per day. An effective alternative is needed to expand treatment plants' options for water treatment during harmful algal blooms.

A research team led by Youngwoo Seo at the University of Toledo will screen three water treatment processes for their abilities to remove or destroy microcystin toxin in drinking water, and to determine the ideal environmental conditions in which each treatment method functions best. Information will be shared with the City of Toledo, who is a partner in the project, and at statewide meetings of community water managers.

THE BOTTOM LINE

Cities will be able to provide clean drinking water while maintaining cost-effectiveness of activated carbon treatments that reduce algal toxins.

SYNOPSIS OF YEAR 1

Relevance: On August 2, 2014, the greater Toledo area woke up to a Do Not Drink or Boil Water Advisory. The advisory was due to the presence of microcystin-LR (MC-LR) in the drinking water supply that exceeded the World Health Organization (WHO) provisional guideline of 1 ug/L. The current water treatment processes were not enough to prevent MC-LR from entering the drinking water supply.

Response: Three water treatment processes — ozonation, biofiltration and membrane filtration — along with their combinations were selected to be investigated for their ability to remove/destroy MC-LR. The target is a removal/destruction at elevated pH values to match both pH values of Lake Erie during algal blooms and during water treatment.

Results: Knowledge on the ability of ozonation, potassium permanganate oxidation, biofiltration, ultrafiltration and nanofiltration as effective methods to remove algal toxins have been obtained from experiments carried out in our labs. It has been demonstrated that ozonation is able to destroy MC-LR in water at elevated pH levels. Potassium permanganate oxidation did not cause significant organic matter releases from tested water samples. The other techniques are still being improved upon and examined to demonstrate their effectiveness.

Recap: The presence of microcystin-LR in Lake Erie and the lack of availability of sustainable treatment processes to remove algal toxins from water led to this research. Ozonation, biofiltration, ultrafiltration and nanofiltration as alternative methods in water treatment are being examined. Results so far demonstrate that ozonation is capable of destroying MC-LR in water even at elevated pH levels. Research is still ongoing on the effectiveness of the other techniques.

Appendix II

PRODUCE SAFE DRINKING WATER

Transport and Fate of Cyanotoxins in Drinking Water Distribution Systems

Principal Investigator
Youngwoo (Young) Seo, University of Toledo
Partners: The Ohio State University, University of Cincinnati

PROJECT SUMMARY

Research under development at the University of Toledo will examine whether toxins from harmful algal blooms "stick" to water infrastructure like pipes and storage tanks, and how that potential stickiness could impact toxin concentrations in drinking water.

While reducing harmful algal bloom toxins at water treatment plants is a well-studied process, how toxin travels through and potentially remains in other parts of the system between plant and consumer is not well understood. "Flushing pipes" after a toxin event can remove any dissolved toxins in the water itself, but particles could adhere to pipes and be released later, potentially raising toxin levels after checks are performed at the water treatment plant.

The research team, led by Youngwoo Seo at the University of Toledo along with scientists from the University of Cincinnati and The Ohio State University will determine how cyanotoxins interact with various pipe and storage tank materials in laboratory experiments. That data will then be used to update commercial software used in water treatment plants, which in turn will be evaluated by engineers familiar with the software packages.

The team is partnering with the City of Toledo, whose water supply was heavily affected by the August 2014 harmful algal bloom in western Lake Erie.

THE BOTTOM LINE

Safe drinking water for community residents and peace of mind for water managers who want to ensure the entire water delivery system is safe again after a toxin event.

SYNOPSIS OF YEAR 1

Relevance: Even after the Do Not Drink water advisory was lifted for the City of Toledo, both city and regional residents who received water from the City had great concern over water quality in the miles-long water distribution system and buildings. While significant emphasis has been placed on removing the cyanotoxin microcystin-LR (MC-LR) at the water treatment plant, the transport and fate of MC-LR within the water distribution system is not understood well.

Response: To adequately assess the potential exposure risk to the populace and/or develop remediation strategies for MC-LR in our potable water supply, MC-LR degradation tests under relevant water distribution system conditions have been conducted. The development of a computational model to simulate the fate and transport of MC-LR commenced.

Results: During this reporting period, knowledge on the effectiveness of chlorine disinfection on degradation of MC-LR under various water distribution system conditions has been obtained from conducted experiments. MC-LR was effectively inactivated by free chlorine. However, at the elevated pH (pH 9), the effectiveness decreased requiring higher chlorine dose to achieve desired MC-LR removal. From experimental results, model parameters for water quality simulations (MC-LR and chlorine) are also obtained.

Recap: In order to develop a model to simulate the transport and fate of MC-LR in the water distribution system, the degradation of MC-LR has been examined. Results so far demonstrated that MC-LR decay rate decreased at elevated pH levels. Experiments are in progress to better understand both abiotic and biotic degradation of MC-LR in water distribution systems and to obtain parameters for developing a computational water quality model.

Appendix II

PROTECT PUBLIC HEALTH

Method Development for Detecting Toxins in Biological Samples

Principal Investigator
Kenneth Hensley, University of Toledo

PROJECT SUMMARY

Researchers at the University of Toledo are developing a method to detect microcystin compounds in human tissue.

Since harmful algal blooms are a relatively recent issue, scientists are still developing the tools needed to tell whether algal toxins or their byproducts remain in the tissue of plants, animals or humans exposed to them. Accurately measuring these toxins in urine, blood and human tissues is a necessary first step in understanding the ways in which these substances might be hazardous to health.

A research team at the University of Toledo is contributing to this effort. Led by Kenneth Hensley, an associate professor of pathology, they are refining a laboratory method to measure how the family of algal toxins of greatest concern — the microcystins — can be found in the human body. The team is using a technique called liquid chromatography-mass spectrometry that is able to separate and quantify several different forms of microcystin as well as the related compounds that result when the body breaks them down.

THE BOTTOM LINE

By measuring how much microcystin remains inside the body after exposure, this technique will help public health officials understand the potential health effects — neutral, negative or positive — of coming into contact with algal toxins.

SYNOPSIS OF YEAR 1

Relevance: When the algae toxin microcystin is ingested, it is rapidly converted by the body into substances that don't show on standard tests. Therefore, in order to monitor human or animal exposure, better assays need to be developed and validated that measure major microcystin metabolites in human and animal blood, tissue or fluids.

Response: Researchers at the University of Toledo Health Science Center Campus and the Department of Chemistry (University of Toledo Main Campus) chemically reacted microcystin with glutathione to form GS-MC, the major human metabolite formed when microcystin is taken into the body. Our team used state-of-the-art mass spectrometry-based instrumentation to develop an assay for microcystin and GS-MC, and we are validating it presently.

Results: Microcystin and GS-MC can be detected at part-per-billion (ppb) levels in fluid extracts. When this work is complete the scientific community and community partners (such as municipalities and hospitals) will have gained access to an assay which can rapidly monitor human microcystin exposure.

Recap: University of Toledo scientists are developing a new instrumental assay to detect products formed in the body when a human or animal ingests microcystin. This assay will allow stakeholders to determine whether a human or animal has been exposed to toxic levels of microcystin.

Appendix II

PROTECT PUBLIC HEALTH

Fish Flesh and Fresh Produce as Sources of Microcystin Exposure to Humans

Principal Investigator
Stuart Ludsin, The Ohio State University

PROJECT SUMMARY

Some (specifically cyanobacteria) bloom-forming algae contain toxins known to be harmful to humans if ingested. These toxins may accumulate in fish residing in a bloom or in produce irrigated with contaminated water. But until now, regulators have no solid scientific data to be able to guide citizens about eating fish or produce affected by algal blooms.

A multi-college research team co-led by Stuart Ludsin and Jiyoung Lee at The Ohio State University is trying to figure out how much of the algal toxin microcystin is detectable in the flesh of fish such as walleye and yellow perch from Lake Erie that were exposed to harmful algal blooms. They are also looking at whether the same toxin can be found in fresh produce that was irrigated with bloom-infected water.

THE BOTTOM LINE

A better understanding of how algal blooms affect fresh food that will help regulatory agencies develop guidelines for eating fish or produce irrigated with lake water during an algal bloom.

SYNOPSIS OF YEAR 1

Relevance: Algal blooms that produce toxins known to be harmful to humans if ingested have increased in Lake Erie during recent years. These toxins may accumulate in fish residing in a bloom or in produce irrigated with contaminated water. However, state regulatory agencies currently do not fully know how much toxin accumulates in fish and produce that are exposed to algal toxins. Such information could help these agencies set appropriate consumption guidelines during the bloom season.

Response: This research seeks to develop and then use new methods to measure the algal toxin microcystin in the flesh of Lake Erie fish, including walleye and yellow perch, during the algal bloom season. It also is exploring whether the same toxin can be found in fresh produce such as carrots, lettuce and tomatoes, if irrigated with water containing the toxin.

Results: Because this project is new, toxin levels have not yet been measured in Lake Erie walleye and yellow perch collected during 2015. However, lab experiments conducted at Ohio State have shown that vegetables such as lettuce and carrots can accumulate microcystin if it is in the water used to irrigate the crops. This research also has shown that irrigating produce with water containing microcystin can slow crop growth.

Recap: With the recent increase in toxic algal blooms in Lake Erie, the need exists to determine if fish flesh and fresh produce are possible sources of human exposure to microcystin. This study offers a means to do this, which will help state regulators develop consumption guidelines for the public during future harmful algal bloom events.

Appendix II

PROTECT PUBLIC HEALTH

Evaluation of Cyanobacteria and Their Toxins in a Two-Staged Model of Hepatocarcinogenesis

Principal Investigator
Christopher Weghorst, The Ohio State University

PROJECT SUMMARY

Illnesses caused by exposure to cyanobacterial toxins – which come from harmful algal blooms – are well known. That's especially true for microcystin, the bacterial toxin that led to a drinking water ban in Toledo in 2014.
For those who drink the water, symptoms range from skin irritation to stomach cramps, vomiting, nausea, diarrhea, fever, sore throat, headache, muscle and joint pain, blisters of the mouth and liver damage. Those who swim in the water may suffer from asthma, eye irritation, rashes and blisters around the mouth and nose.

What researchers don't know for sure is how carcinogenic the toxins might be.

Enter Christopher Weghorst, environmental health scientist and associate dean for research in the College of Public Health at Ohio State. His research will examine whether chronic exposure to drinking water containing microcystins as well as other components in cyanobacteria increases liver cancer development in mice.

THE BOTTOM LINE

Medical scientists are examining whether microcystin in drinking water increases the occurrence of liver cancer in mice exposed to the toxin. Knowing more about the effects of such chronic exposure will help protect the health of Lake Erie residents and guide medical decisions.

SYNOPSIS OF YEAR 1

Relevance: Cyanobacterial blooms are an emerging environmental and public health problem worldwide affecting freshwater lakes, ponds and rivers; all potential source of community drinking water. Limited data suggest that exposure to drinking water contaminated with microcystins and other cyanobacterial toxins may be associated with increased rates of liver cancer development.

Response: A senior scientist is investigating if long-term exposure of mice to either toxin-containing cyanobacteria or toxin alone in the drinking water will cause an increase in the development of liver cancer.

Results: The study is currently still in progress; mice have been obtained and are currently being exposed to various doses through various routes.

Recap: Using this approach, we will assess not only one of the most potent cyanobacterial toxins, but will also explore potential additive or synergistic effects related to the influence of all cyanobacterial intracellular components on liver cancer development.

Appendix II

ENGAGE STAKEHOLDERS

Maumee Basin Lake Erie HABS Nutrient Management Options Comparative Analysis

Principal Investigator
Timothy Haab, The Ohio State University

PROJECT SUMMARY

There is more than one way to reduce the amount of nutrients that get into Lake Erie from agricultural lands. To help decision makers and stakeholders address the issue, an Ohio State researcher is developing a comparative analysis for the Maumee Basin.

Timothy Haab, professor and department chair for Ohio State's Department of Agricultural, Environmental, and Development Economics, will create a grid of management options and metrics. "We need to understand what we know and what we don't know about current nutrient reduction efforts and possible solutions," Haab said.

His analysis will include the relative strengths, weaknesses, pros, cons, costs and benefits of possible solutions. Each proposed solution will be measured against a specified target such as a given reduction in a nutrient overage. The management options will likely include the status quo, incentive-based solutions, voluntary and engineering solutions and direct controls on nutrient use. Haab will look at traditional cost and benefit measures as well as indicators of social acceptability and/or political feasibility. He will use existing data and identify critical gaps in data.

THE BOTTOM LINE

A new tool to help decision makers weigh the water quality impacts of their decisions.

SYNOPSIS OF YEAR 1

Relevance: To achieve a socially acceptable, economically feasible and physically effective reduction in nutrient loads into Lake Erie requires information on what we know and what we don't know about current nutrient reduction efforts and possible solutions. A comparative analysis of the relative strengths, weaknesses, pros, cons, costs and benefits of possible solutions will provide information to decision makers, the agricultural community and the broader public as to the relative desirability of various solutions.

Response: Using a combination of advanced literature review and assessment techniques, we will survey, categorize and inventory existing informational sources and data warehouses to develop a catalogue of current and future nutrient management options for the Maumee Basin. Based on this catalogue, we will develop a matrix of management options and metrics for comparative assessment of management options. These management options are likely to include the status quo, incentive-based solutions, voluntary and engineering solutions and direct controls on nutrient use.

Results: Once completed, the results of the comparative assessment will be incorporated into the proposed Maumee Basin Lake Erie HABs Stakeholder Informed Decision-Making Support System. The result of the analyses conducted will be an enhanced base of information for stakeholder and decision-maker use in addressing HABs in Lake Erie.

Recap: Using a combination of advanced literature review and assessment techniques, we survey, categorize and inventory existing informational sources and data warehouses to develop a catalogue of current and future nutrient management options for the Maumee Basin.

Appendix II

ENGAGE STAKEHOLDERS

Farmer/Farm Advisor Water Quality Sampling Network

Principal Investigator
Greg LaBarge, The Ohio State University
Partners: Heidelberg University, Bowling Green State University

PROJECT SUMMARY

This project gives a farmer the chance to find out how much Dissolved Reactive Phosphorus (DRP) in pounds per acre is leaving their field site, based on their crop production system. Farmers will be provided their individual data from the study plus summary data for all sites in the project. The data will be used to better understand what conditions lead to DRP loss and be able to better recommend Best Management Practices (BMPs) to reduce nutrient loss.

Experts say soluble phosphorus runoff from farms is an important driver of the harmful algal blooms plaguing Lake Erie and other lakes in recent years. In August 2014, a toxic bloom in western Lake Erie led to a two-day drinking water ban in Toledo.

A research team led by Greg LaBarge, an Ohio State University Extension field specialist and a leader of Ohio State's Agronomic Crops Team, is creating a system that would collect the water and soil samples, along with farm level data on management practices that can be used by researchers on projects to lessen the chance of nutrient runoff into Lake Erie.

The data will be used to compare predicted water quality impacts with actual water quality results to better identify high-risk fields to help famers apply the best management practices for their specific field situation that improve the water quality of Lake Erie.

THE BOTTOM LINE

Assistance for farmers identifying the best techniques that optimize agriculture outputs and water quality.

SYNOPSIS OF YEAR 1

Relevance: Increase in Dissolved Reactive Phosphorus has been identified as a key trigger for increased cyanobacteria blooms in the Western Lake Erie Basin. Agriculture, due to its extensive land use in the Maumee River Watershed, has been identified as a large non-point source contributor of Dissolved Reactive Phosphorus.

Response: The project has dual goals. First, giving farmers a better understanding of the Dissolved Reactive Phosphorus delivery from the edge of their field through sampling they participate in. Second, provide data that can be used by the scientific community to gain a better understanding of the problem and identify higher risk scenarios where Best Management Practices should be applied.

Results: The first sampling period began October 2015 with 56 participating farmers sampling 80 field environments. Samples were collected in December 2015 and are being analyzed.

Recap: Farmers have responded to a water quality sampling project to better understand contributions of Dissolved Reactive Phosphorus from their fields.

Appendix II

ENGAGE STAKEHOLDERS

Maumee Basin Lake Erie HABs Stakeholder-Informed Decision-Making Support System

Principal Investigator
Patrick Lawrence, University of Toledo

PROJECT SUMMARY

A research project at the University of Toledo will collect information on Lake Erie harmful algal blooms into an easily accessible web-based portal for access by interested stakeholders.

Applying accurate information when assessing potential solutions for the harmful algal bloom problem is critical, but many stakeholders can be overwhelmed by the wide range of information sources available to them. A web-based support system, featuring timely science-based information, will help decision makers obtain that accurate information in less time and with less effort required.

Resources will include key studies, videos, reports and resources that land managers can use to inform their decision making. Lead researcher Patrick Lawrence will also work with current researchers in the region to ensure information from other projects is integrated into the website.

The team will also work with key people within the Maumee River watershed through a series of workshops and meetings to identify their information needs and how those needs can be addressed through the web portal.

THE BOTTOM LINE

A common resource for decision makers in the Maumee watershed to obtain information on harmful algal blooms and apply that information to their community.

SYNOPSIS OF YEAR 1

Relevance: In order to address Lake Erie harmful algae blooms (HABs) there is an essential need to engage key stakeholders within the Maumee watershed so as to provide them important information on HABs to assist with their informed decision-making regarding potential options to address HABs in the area of nutrient management.

Response: A Lake Erie HABs data management system is in development which will include key sources of information on HABs drawn from published studies and the scientific literature, collected and available from a web based product. This system will be made publicly available with particular focus on an identified stakeholder network with members provided access to such information to assist them in considering nutrient management options.

Results: Work is in progress. There are no major final results yet to report. Web-based product is not available yet.

Recap: Only by informed decision-making by Maumee watershed stakeholders will it be possible to identify and assess the opportunity to address Lake Erie HABs by use of a variety of nutrient management strategies.

Appendix II

ENGAGE STAKEHOLDERS

Social Network Analysis of Lake Erie HABs Stakeholder Groups

Principal Investigator
V. Kelly Turner, Kent State University

PROJECT SUMMARY

Improving water quality requires sharing knowledge and experiences across community and county boundaries. But without knowing who the key stakeholders are and how they are connected with each other, central agencies may be lacking valuable input or missing the mark when trying to send public safety messages.

A research team led by Kelly Turner, assistant professor of geography at Kent State University, aims to develop a map of the social connections between important players in the Lake Erie watershed. Those connections will be examined to determine how strong each link is — for example, between a watershed management group and a crop advising company — and whether the groups share information back and forth or just listen without talking back.

The final network map will inform decision making and education efforts, and will show communities how they can more effectively collaborate to improve water quality.

THE BOTTOM LINE

Better information sharing that helps communities learn from each other and reduces the cost of adapting to and preparing for water quality issues such as harmful algal blooms.

SYNOPSIS OF YEAR 1

Relevance: Implementing management practices that effectively reduce nutrient loads benefits from information sharing and coordination among diverse stakeholder groups; however, without knowing the various organizations and initiatives already in place, it is difficult to know that the right information is getting to the right places.

Response: A Kent State University team is constructing a social network of all organizations and initiatives responsible for land and water management in the Maumee watershed to determine how information and resources travel between stakeholder groups and identify potential gaps in the network.

Results: We have compiled a list of 150(+) stakeholders and have developed a method that mines constitutional documents to construct a social network. We are able to isolate information and resource flows by individual organization, political jurisdiction (e.g., county), and sub-watershed using this method.

Recap: A social network of land and water managing organizations and initiatives in the Maumee watershed identifies information and resource flows between stakeholders to improve management implementation.

Appendix III

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Appendix III

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Appendix III

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Appendix III

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Appendix III

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Appendix IV

SELECTED MEDIA COVERAGE

Title of coverage	Venue	Date released	Relevant details
UT's new boat set for algae, lake research	Toledo Blade	7/17/15	http://www.toledoblade.com/local/2015/07/17/UT-s-new-boat-set-for-algae-lake-research.html
Algae season over — water remains safe to drink	Press Publications Inc.	10/26/15	http://www.presspublications.com/16827-algae-season-over-water-remains-safe-to-drink
Algae levels could rival 2011's	Toledo Blade	7/9/15	http://www.toledoblade.com/local/2015/07/10/Lake-algae-levels-could-rival-2011-record-bloom.html
New boat will fight algae	Toledo Blade	7/16/15	http://www.toledoblade.com/local/2015/07/17/UT-s-new-boat-set-for-algae-lake-research.html
Toledo says it's better prepared to keep toxins out of water	Monroe Evening News	7/27/15	http://www.monroenews.com/news/2015/jul/27/toledo-says-its-better-prepared-keep-toxins-out-wa/
Ohio higher ed spending millions on algae fight	Toledo Blade	1/27/15	http://www.toledoblade.com/local/2015/01/28/Ohio-higher-ed-spending-millions-on-algae-fight.html
Lake Erie Algal Blooms: Former chief chemist seeks better toxin ...	Press Publications Inc.	6/15/15	http://www.presspublications.com/16084-lake-erie-algal-blooms-former-chief-chemist-seeks-better-toxin-detection
Algae forming in western Lake Erie	Toledo Blade	7/7/15	https://www.toledoblade.com/local/2015/07/07/Algae-forming-in-western-Lake-Erie.html
UT receives state fund to help with early warnings of algal blooms	Ch 11 WTOL Toledo	1/29/15	http://www.wtol.com/story/27968846/ut-receives-state-fund-to-help-with-early-warnings-of-algal-blooms
Leading Edge with Jerry Anderson	Ch 11 WTOL Toledo	2/1/15	... Bridgeman and Professor of Engineering Dr. Isabel Escobar about legislation aimed at cleaning up Lake Erie..... Bridgeman and Professor of Engineering Dr. Isabel Escobar about legislation aimed at cleaning up Lake Erie... http://www.wtol.com/story/28016941/leading-edge-with-jerry-anderson-feb-1-2015
Results back from UT research team on Lake Erie	Ch 11 WTOL Toledo	7/30/15	http://raycomgroup.worldnow.com/story/29673984/results-back-from-ut-research-team-on-lake-erie
Leading Edge with Jerry Anderson	Ch 11 WTOL Toledo	4/5/15	Discussed the algal bloom problem and described the objectives of the NSF Workshop on HABs held at BGSU

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Title of coverage	Venue	Date released	Relevant details
Conklin and Company	13 ABC WTVG Toledo	4/12/15	Discussed the algal bloom problem and described the objectives of the NSF Workshop on HABs held at BGSU
Northwest Ohio Journal	WBGU	4/30/15	Discussed the algal bloom problem and outcomes of the NSF Workshop on HABs held at BGSU
Newspaper interview	Sandusky Register	4/24/15	Discussed current issues with *Planktothrix* blooms in Sandusky Bay
Lake Erie's Algae Monitored from Space	Kent State University Research and Sponsored Programs Website	7/15/15	http://www.kent.edu/research/lake-eries-algae-monitored-space
Toxic Threat	June 2015 issue of the Kent State University Magazine	6/25/15	Discussed current issues with Planktothrix blooms in Sandusky Bay and Western basin of Lake Erie and efforts developed to monitor the bloom from space
Scientists: Algae not just Toledo Problem	Toledo Blade	9/27/15	http://www.toledoblade.com/local/2015/09/27/Scientists-Algae-not-just-Toledo-problem.html
Toxic Water	Summer 2015 issue of BGSU magazine	7/1/15	https://www.bgsu.edu/news/2015/04/toxic-water.html
That Bloomin' Algae	Fall 2015 issue of Transformations, the BGSU College of A&S magazine	10/1/15	https://www.bgsu.edu/content/dam/BGSU/college-of-arts-and-sciences/documents/alumni/transformations-september-2015.pdf
The Relevant University	radio	7/27/15	http://www.utoledo.edu/therelevantuniversitytoledo/archive/07272015.html. Interview on the anniversary of water crisis.
Leading Edge with Jerry Anderson	tv	2/1/15	http://www.wtol.com/story/28016941/leading-edge-with-jerry-anderson-feb-1-2015. A discussion on what was being done to address Lake Erie HABs and water treatment.
Science News for Students	web interview	end of 14/early 15	https://student.societyforscience.org/article/will-water-woes-leave-americans-thirsty. An interview on what happened with respect to the water crisis and what can be done in the future.
2015 Farmer Led Water Quality Monitoring in Western Lake Erie Basin	Crop Observation Recommendation Network Newsletter (C.O.R.N.)	7/13/15	http://corn.osu.edu/newsletters/2015/2015-21-1 advertised program to 25,000 farmers and crop advisers.
NW Ohio Farmers: Sign Up for Project Designed to Improve Ohio Water Quality	The Ohio State University-CFAES News release	7/27/15	Program signup news release that was published in part or entirety in numerous publications in state and national. http://cfaes.osu.edu/news/articles/nw-ohio-farmers-sign-for-project-designed-improve-ohio-water-quality

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Title of coverage	Venue	Date released	Relevant details
UT Researchers to lead majority of Ohio water quality research projects	Local campus press release	2/6/15	http://utnews.utoledo.edu/index.php/02_06_2015/ut-researchers-to-lead-majority-of-ohio-water-quality-research-projects
Ohio Board of Regents Funds Study of to Determine Possible Health Impacts of Lake Erie Contaminants	The Ohio State University College of Arts & Sciences Website	6/15/15	https://artsandsciences.osu.edu/news/eeob-researcher-pi-ohio-board-regents-study-determine-possible-health-impacts-lake-erie
HABs FAQs: "Are fish caught in a harmful algal bloom safe to eat?"	Ohio Sea Grant Website	9/3/15	https://www.facebook.com/ohioseagrant/posts/10153067687056560
Kent State Researchers to Launch Three New Studies to Monitor Lake Erie	Website	2/19/15	http://www.kent.edu/cas/news/kent-state-researchers-launch-three-new-studies-monitor-lake-erie Announcement of the launch of the project
Ohio Board of Regents Funding Tackles Harmful Algal Blooms	Magazine	Spring 15	TwineLine, V. 37, I. 1 Funding Tackles Harmful Algal Blooms
What color is your water? On Lake Erie, it's still green	The Times Bulletin	9/4/2015	http://www.usagnet.com/state_headlines/state_story.php?tble=OH2015&ID=847
What color is your water? On Lake Erie, it's still green	The Delphos Herald	9/3/2015	http://www.ohioagconnection.com/story-state.php?Id=847&yr=2015
What color is your water? On Lake Erie, it's still green	Putnam Sentinel	9/2/2015	http://ocj.com/2015/09/osu-making-strides-with-water-quality/
Ohio's new manure laws: There's a right (and wrong) time and place	Putnam Sentinel	9/2/2015	http://www.usagnet.com/state_headlines/state_story.php?tble=OH2015&ID=789
Ohio's new manure laws: There's a right (and wrong) time and place	The Times Bulletin	9/2/2015	http://www.indianaagconnection.com/story-state.php?Id=783&yr=2015

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Title of coverage	Venue	Date released	Relevant details
Ohio's new manure laws: There's a right (and wrong) time and place	The Delphos Herald	9/1/2015	http://www.ohioagconnection.com/story-state.php?Id=789&yr=2015
NW Ohio farmers: Sign up for project designed to improve water quality	Ag Professional	7/31/2015	http://www.agprofessional.com/news/nw-ohio-farmers-sign-project-designed-improve-water-quality
Massive algae bloom on Erie predicted	Outdoor News	7/30/2015	http://www.outdoornews.com/July-2015/Massive-algae-bloom-on-Erie-predicted/
Farmers needed for Field Water Quality Monitoring Project	Ada Herald	7/30/2015	http://adaherald.com/Content/News/Agriculture/Article/Farmers-needed-for-Field-Water-Quality-Monitoring-Project/2/400/111557
OSU Extension looking for water quality cooperators in Maumee River Basin	Ohio's Country Journal	7/10/2015	http://ocj.com/2015/07/osu-extension-looking-for-water-quality-cooperators-in-maumee-river-basin/
Farmers' assistance sought in research project	Putnam Sentinel	7/8/2015	http://www.putnamsentinel.com/Content/News/Agriculture/Article/Farmers-assistance-sought-in-research-project/1/569/23771
Farmers' assistance sought in research project	Putnam Sentinel	7/8/2015	http://www.putnamsentinel.com/Content/News/Agriculture/Article/Farmers-assistane-sought-in-research-project/1/569/23771
What color is your water? On Lake Erie, it's still green	The Times Bulletin	9/4/2015	http://timesbulletin.com/Content/News/News/Article/What-color-is-your-water-On-Lake-Erie-it-s-still-green/2/4/197560
What color is your water? On Lake Erie, it's still green	The Delphos Herald	9/3/2015	http://www.delphosherald.com/Content/News/News/Article/What-color-is-your-water-On-Lake-Erie-it-s-still-green/191/1183/194566
What color is your water? On Lake Erie, it's still green	Putnam Sentinel	9/2/2015	http://www.putnamsentinel.com/Content/News/Local-News/Article/What-color-is-your-water-On-Lake-Erie-it-s-still-green/1/1/24065
Ohio's new manure laws: There's a right (and wrong) time and place	Putnam Sentinel	9/2/2015	http://www.putnamsentinel.com/Content/News/Local-News/Article/Ohio-s-new-manure-laws-There-s-a-right-and-wrong-time-and-place/1/1/24075
Ohio's new manure laws: There's a right (and wrong) time and place	The Times Bulletin	9/2/2015	http://timesbulletin.com/Content/News/News/Article/Ohio-s-new-manure-laws-There-s-a-right-and-wrong-time-and-place/2/4/197494

Appendix V

SELECTED PRESENTATIONS

Event name	Size of audience	Title of talk
Lake Erie Center seminar series	60	The Latest on HABs in Lake Erie
Great Lakes Observing System Annual Conference	40	Measure to Manage: A Case Study in Lake Erie
Western Lake Erie Basin Partnership Conference	60	An update on Harmful Algal Blooms in Lake Erie
Toledo RockHounds meeting	80	An update on Harmful Algal Blooms in Lake Erie
The Nature Conservancy	80	Harmful Algal Bloom Update: Western Lake Erie 2015
University of Toledo Board of Trustees Meeting	30	A Harmful Algal Bloom Early Warning System for Western Lake Erie
Ohio Board of Regents Meeting	10	Board of Regents Lake Erie R&D Initiative Summary of Projects
Global Solutions for Regional Problems: NSF/NOAA Workshop on Cyanobacterial Harmful Algal Blooms	104 attendees from 15 states and 5 foreign countries	PI Bullerjahn, co-PI McKay were conference organizers; co-PI Ortiz was a discussion leader
Community Enrichment Series, BGSU Firelands campus	125	Cyanobacterial blooms in Lake Erie: Causes, mitigation, research and knowledge gaps
IAGLR Annual Meeting, Burlington, VT	40 each	Bullerjahn: Evaluation of increasing N and P concentrations on Planktothrix in Sandusky Bay Ortiz: Airborne Hyperspectral remote sensing of Harmful Algal Blooms in Western Lake Erie (For collaborator John Lekki). Ortiz: An estimate of the composition of the 2014 Lake Erie CyanoHAB by VNIR derivative spectroscopy.
Science writer's symposium, OSU Stone Lab	40	HAB Detection, mapping and warning network: Sandusky Bay
Invited seminar, North Carolina A&T University	50	Harmful algal blooms in Lake Erie

Appendix V

Event name	Size of audience	Title of talk
Third Annual KSU Water Symposium: Water in a Changing Climate: Regional to Global Issues	350	Poster titles: Ortiz et al., Climate change and the potential future of CyanoHABS in Sandusky Bay: Insights from the 2015 CyanoHAB Avouris et al., Algal and Cyanophyte Blooms in Lake Erie: Identifying Color-Producing Agents Using Derivative Spectroscopy Slodysko et al., The Effect of Nutrient Amendments on Microcystin Production and Growth Rates on Sandusky Bay Planktothrix spp. Boehler and Bade, Differential rates of N2-fixation between two Lake Erie transects
2015 NASA HyspIRI Science and Applications Workshop	100	Vicarious calibration and visible derivative spectroscopy to estimate the composition of the 2015 CyanoHAB in Sandusky Bay, Lake Erie, 13-15 October 2015 (Presented by collaborator Jeff Luvall for Ortiz).
University of Akron, Department of Geosciences Seminar Series	50	Toxic Algae in Ohio Waterways
Kent State University Department of Chemistry Seminar Series	75	Identification of toxic algae in Ohio's waterways by visible derivative spectroscopy
NASA Glenn Rocket University Working group	15	Summer 2014 CyanHAB field work: Kent State University ASD FieldSpec Spectroradiometer data 2015
Lake Erie Conference, Lake Erie Waterkeepers	75	Finding Microcystin Bloom
Documentary film (in production) by Running Wild Media, Toledo OH		
Ohio Water Environment Association symposium, Maumee Ohio 10/14/15	130	Harmful algal blooms in Lake Erie
Ohio Lake Erie Commission meeting, Toledo Ohio 10/7/15	35	2015 Lake Erie Cyanobacterial bloom update
Practical Talk: How Cover Crops keep the Water Quality Dashboard on Green, Kansas Ohio 9/16/15	30	Harmful algal blooms in Lake Erie
Wood County Sewer Water Conservation District, Stone Lab 9/3/15	20	Harmful algal blooms in Lake Erie
Local Decision Makers symposium, OSU Stone Lab 9/1/15	50	Lake Erie Harmful Algal Bloom Update
Science writer's symposium, OSU Stone Lab 8/25/15	40	Lake Erie Harmful Algal Bloom Update
Harmful Algal Bloom Forecast webinar, OSU Stone Lab, July 2015	233 attendees	Forecast for the 2015 HAB in western Lake Erie
Local Decision Makers symposium, OSU Stone Lab 8/24/15	50	Lake Erie Harmful Algal Bloom Update
Put-in-Bay Garden Club, Put-in-Bay Yacht Club 7/14/15	20	Harmful algal blooms in Lake Erie
Stone Laboratory Research Lecture 7/9/15	35	The Role of Nitrogen in Regulating Cyanobacterial Bloom Toxicity

Appendix V

Event name	Size of audience	Title of talk
TEDx	120 at venue, and on the web	Worldwide Water: http://tedxtalks.ted.com/video/Worldwide-Water-Isabel-Escobar or https://www.youtube.com/watch?v=-wbHD77kMWE
Engineers Without Borders 2015 Regional Conference	100	Algae and Water: The Toledo Experience of August 2014
American Institute of Chemical Engineers (AIChE) Annual Conference (to happen on 11/11/15, Salt Lake City, Utah)	30-50	Title of talk: Investigation of water treatment alternatives in the removal of microcystin-LR
Sigma Xi Scientific Society Fall Mixer at University of Cincinnati	40	Treatment of Cyanotoxins by Advanced Oxidation Processes
WLEB OSU Extension Ag Educators Conference Call	8	Understand goals and recruitment process for water quality monitoring program
E-mail to ODNR, SWCD and NRCS	25	Provided information on the program and sought their help in identifying participants for the project
Biological Sciences Departmental Seminar at Bowling Green State University by Laura Johnson on 10/28/15	~50	Phosphorus and Lake Erie: Perspectives from between the land and lake
Toledo Rotary Lake Erie Crisis Conference poster by Laura Johnson on 10/24/15	~300	Detecting change and providing solutions from the National Center for Water Quality Research
Kent State 3rd Water Research Symposium, 10/14-10/15/15	400	Dissolved Organic Matter Transformation in Marine and Freshwater Systems Revealed by Microbial Community Omics
Kent State 3rd Water Research Symposium, 10/14-10/15/15	400	(Poster presentation) Identification and Characterization of Microcystin Degrading Bacteria in Lake Erie
Kent State 3rd Water Research Symposium, 10/14-10/15/15	400	(Poster presentation) The Effects of Nutrient Variability on Microbial and Zooplankton Community Compositions along a Transect in Lake Erie
Department of Chemistry and Biochemistry seminar	25	Ecology and Biochemistry of Toxins Produced by Harmful Cyanobacterial Blooms
American Geophysical Union Fall meeting 12/14-12/18/2015	24,000	(Poster presentation) Isolation, Identification and Phenotypic Characterization of Microcystin-Degrading Bacteria from Lake Erie
Kent State Annual Water Symposia	100	The Human Dimensions of Water Resource Management
East Lakes Association of American Geographers	30	A Social Network Analysis of Lake Erie HABs Stakeholders
2015 Toledo Rotary Water Conference	200	Removal of Phosphorus Entering Maumee Bay: How to Attain a 10% Reduction (poster)
Ohio State University Environmental Professionals Network Breakfast Club: Ohio's Water Resources and Citizens at Risk - Ag-related Practices and Policies to Prevent Harmful Algal Blooms, Post-Toledo	150	The Policy: Laws, rules, engagement/ outreach

HARMFUL ALGAL BLOOM RESEARCH INITIATIVE

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