

2018



HARMFUL ALGAL BLOOM

YEAR 3
PROJECT UPDATE

RESEARCH INITIATIVE



Track Blooms
From the Source



Produce Safe
Drinking Water



Protect
Public Health



Engage
Stakeholders



HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

YEAR 3 PROJECT UPDATE | OCTOBER 2018

IN THE SUMMER OF 2014, cyanobacteria, commonly known as blue-green algae, made people near Lake Erie afraid to use their water. After the crisis was over, front-line state agencies in Ohio worked with science teams at Ohio universities to fill in critical gaps in our knowledge—things that were still unknown about tracking and dealing with harmful algal blooms. The newest results are in from this Harmful Algal Bloom Research Initiative (HABRI), and state agencies are now better prepared to prevent and handle water issues from harmful algal blooms.

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Introduction

Ohio's Harmful Algal Bloom Research Initiative (HABRI) is a statewide response to the threat of harmful algal blooms. The initiative arose out of the 2014 Toledo drinking water crisis, where elevated levels of the algal toxin microcystin in Lake Erie threatened drinking water for more than 500,000 people in northwest Ohio. To better position the state to prevent and manage future algal water quality issues, the chancellor of Ohio's Department of Higher Education (ODHE) worked with representatives from Ohio's universities to solicit critical needs and knowledge gaps from state agencies at the front lines of water quality

crises. ODHE then funded applied research at ten Ohio universities to put answers in the hands of those who need them ahead of future harmful algal blooms.

Since 2015, the initiative has launched a new round of agency-directed research each year, with the first round of projects completed in spring 2017. The Ohio Department of Higher Education has funded all research, with matching funds contributed by participating universities. For the 2018 cohort, the Ohio Environmental Protection Agency (OEPA) provided matching funds for some of the research and monitoring activities undertaken as part of the statewide effort.

ROUND	NUMBER OF PROJECTS	TIME SPAN	STATUS	RESULTS	FUNDING AMOUNT (before 1:1 match by universities)	FUNDING SOURCE
Round 1	19	2015-2017	Complete	Final, 2017 report	\$2 Million	ODHE
Round 2	14	2016-2018	Complete	Final, this report	\$2 Million	ODHE
Round 3	11	2018-2020	Awarded	N/A	\$2.5 Million	ODHE and OEPA
Round 4	10	2018-2020	Awarded	N/A	\$1.5 Million	ODHE



We're All Over the Map

Science teams are made up of faculty and students from ten Ohio universities, spanning the state with water monitoring networks, shared sample analysis and collaborative testing of drinking water treatment options. The teams are also all over the map in terms of expertise—from engineering to medicine to economics—and that's by design. Harmful algal blooms (HABs) have many causes, many impacts and many avenues for smart prevention and management.

What We're Working Toward

Toledo's drinking water ban in August 2014 was a wake-up call to the state and the nation. Harmful algal blooms, which result from spring storms, summer temperatures and nutrient-rich water flowing into bodies such as Lake Erie, are a persistent and increasing issue that impact communities all over the world. The challenge is, we still don't know exactly what kind of risks the blooms might present, how to fully prevent them and the best ways to protect people and watersheds. So Ohio's HABRI science teams are on the case: working with front-line health, environmental and agricultural agencies to bring them the answers they need to get the state—and region—out ahead of HABs.

HABRI Universities



The initiative arose out of the 2014

TOLEDO DRINKING WATER CRISIS

when elevated levels of the algal toxin microcystin in Lake Erie threatened drinking water for over

500,000

people in northwest Ohio.

“Having, through HABRI, a consortium of university experts to take our priorities and quickly do critical, practical research, with conclusions that we can immediately use to inform policy and the public, is invaluable.”

— Craig Butler, Director
Ohio Environmental Protection Agency



Photo by Jo McCulty

Breaking It Down

High-quality research—even driven by urgent needs—takes time. So HABRI divided the major research questions into bite-sized chunks for science teams to turn around in two years or less. Keeping in mind the four focus areas, the first group of projects, launched in 2015, tackled the entire range of open questions—from upstream nutrient movement in tributaries and algal bloom dynamics to water treatment and public health risks. Their final results are in, along with findings from the second round of projects, which were even more focused on explicit needs and knowledge gaps identified by front-line agencies. A third cohort of teams set out in 2018 to build on what we've learned and continue driving toward solutions that will better prepare Ohio for the next crisis.

Contributing to the National and Global HABs Dialogue

With HABRI, Ohio has created a research and outreach framework that other states can use to help solve state-wide environmental issues. As part of that effort, Ohio's university research teams are also capturing their work in the form of publications for peer review, patents and policy briefs. These products, which contribute to efforts such as the World Health Organization developing health guidelines for algal toxins, help to position Ohio as an emerging leader in providing actionable data and systems solutions to this globally relevant threat.

Are We Better Prepared Now?

Unfortunately, harmful algal blooms arise every summer in Lake Erie and in many other lakes, rivers and reservoirs. ODHE launched HABRI to get Ohio ahead of the problem and to prevent another drinking water advisory. HABRI is only three years old, but it has already yielded results.

- Early warning systems are giving water treatment plants a high-resolution picture of what could be affecting drinking water.
- Researchers are working directly with water treatment plant operators to provide practical guidance on producing safe drinking water.
- The Ohio Department of Natural Resources has changed the way they collect information on algal toxin concentrations in sportfish fillets, sampling more frequently during HAB season and from a wider range of Lake Erie locations to better understand how harmful algal blooms affect sportfish.
- OEPA modified its permit procedure to better safeguard Ohioans when HABRI projects showed that farm crops might take in microcystins from water treatment residuals. New HABRI research is now helping OEPA better assess exposure risk from these byproducts of water treatment.
- HABRI has driven information sharing and priority setting between universities and agencies, positioning Ohio to better prevent and manage future crises.

HABRI: What We Do

Fifty-four science teams around the state of Ohio are hard at work getting answers about harmful algal blooms that will directly help state agencies prevent and manage future HABs-related issues and will position Ohio as a leader in understanding this emerging global threat. HABRI teams work under four basic mandates:

FOCUS AREA	CHALLENGE	CRITICAL NEEDS OR KNOWLEDGE GAPS IDENTIFIED BY AGENCIES*
 <p>Track Blooms From the Source</p>	<p>Algal blooms are not necessarily “harmful” unless they contain certain algae species and have the right mix of conditions to make toxins such as microcystin. With standard detection methods, public health officials may have to wait for hours or even days to confirm whether blooms are toxic and how they are growing and moving in the water body.</p>	<ul style="list-style-type: none"> • Rapid determination of whether blooms are toxic and where toxins are moving (even apart from the main algae mass) • Prediction capability for the location and severity of blooms, even months ahead of time • The ability to track nutrients and stormwater upstream and correlate them with particular sources, storm events and algal bloom characteristics • Assessment of bloom and toxin locations within the vertical water column
 <p>Produce Safe Drinking Water</p>	<p>When pollutants end up in the water source for a city, water treatment officials need to know what they’re dealing with and how best to clear them out of the water. But toxins from harmful algal blooms present a relatively new challenge globally, and the detection and treatment protocols are not mature.</p>	<ul style="list-style-type: none"> • Laboratory testing of water treatment methods that give treatment facilities effective and cost-efficient options for clearing out algal toxins using their current infrastructure • Development of new, innovative techniques for producing safe drinking water
 <p>Protect Public Health</p>	<p>Algal toxins such as microcystin are known to have risks for humans and animals under certain circumstances. But the laboratory studies needed to make public health guidelines have not yet been updated and tailored for the more severe, persistent algal blooms we’re seeing in Lake Erie and other freshwater sources around the world.</p>	<ul style="list-style-type: none"> • New laboratory methods to detect the presence of algal toxins and their byproducts in living tissue such as blood • Laboratory studies on the effects of algal toxins at the cellular level and beyond • Testing of fish from affected water bodies to aid officials in advising anglers
 <p>Engage Stakeholders</p>	<p>Effective crisis prevention and management involves many different types of people who need to be connected—ahead of time. The Toledo water quality crisis provided a galvanizing event that revealed the need for closer ties among scientists, agencies, municipalities and landowners.</p>	<ul style="list-style-type: none"> • Development of more integrated response networks to sample water and quickly communicate results • Establishment of connections between various land management practices upstream and nutrient flows downstream

**For a complete list of priorities identified by the agency advisory board, see pages 32-36*

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HARMFUL ALGAL BLOOM FOCUS AREAS

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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 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, to what makes them produce toxins in the first place.



Monitoring tributaries for nutrients that cause algal blooms

Early warning systems for bloom activity

Understanding blooms better for smarter management

Projects in this Focus Area

Determining Sources of Phosphorus to Western Lake Erie from Field to Lake

Lead: Heidelberg University, The Ohio State University

HAB Avoidance: Vertical Movement of Harmful Algal Blooms in Lake Erie

Lead: The University of Toledo

Seasonal Quantification of Toxic and Nontoxic *Planktothrix* in Sandusky Bay by qPCR

Lead: Bowling Green State University

An Investigation of Central Basin Harmful Algal Blooms

Lead: The Ohio State University

How Quickly Can Target Phosphorus Reductions Be Met? Robust Predictions from Multiple Watershed Models

Lead: The Ohio State University

Early Season (March) Phosphorus Inventory of Offshore Waters of Lake Erie

Lead: Bowling Green State University



Algal Blooms Don't Just Happen in the Western Basin

While much of the current research on harmful algal blooms focuses on Lake Erie's western basin, researchers at Ohio State's Stone Lab, along with partners from Defiance College and Kent State University, are also exploring what's happening in the central basin, from Pelee and Kelleys Islands to Erie, Pennsylvania.

Goals include identification of cyanobacteria – the blue-green algae that form harmful algal blooms – that bloom in the central basin, and whether they are capable of producing toxins such as microcystins, which can negatively affect the liver. This information helps guide decision-making processes for state and federal agencies with timely information about water conditions and potential steps they need to take to keep residents safe.

Samples were collected from the central basin between 2013 and 2017 to identify the cyanobacteria in the water, and to measure water quality parameters such as temperature, dissolved oxygen and phosphorus and nitrogen content. A partnership with Lake Metroparks, located in Lake County just east of Cleveland, also allowed the researchers to collect samples near a beach in the park district.

Scientists from NOAA's National Centers for Coastal Ocean Science (NCCOS) used imagery from MODIS and MERIS satellite sensors to quantify bloom biomass in the central basin between 2003 and 2017. Because satellite imagery requires fewer dedicated resources than targeted water sampling, an ongoing goal for the research team is helping the agency make interpretation of those images more relevant to local needs. Linking size and density of the algal blooms to data provided by the water samples is a part of that effort.

The researchers found that central basin blooms occurred earlier in the year than western basin blooms, and that June and early July central basin blooms are mostly made up of Dolichospermum. Sampling indicated that this cyanobacterium can produce saxitoxins, which are of emerging concern in Ohio waters.

In 2016 and 2017, more frequent sampling in June-August targeted identification of any algal toxins in the water. This included quantifying the cyanobacterial genes responsible for producing microcystins, saxitoxins and cylindrospermopsins, three toxins of concern in Lake Erie, to hopefully use the presence of those genes to predict algal toxicity in the future. Partners from the Northeast Ohio Regional Sewer District completed that work.

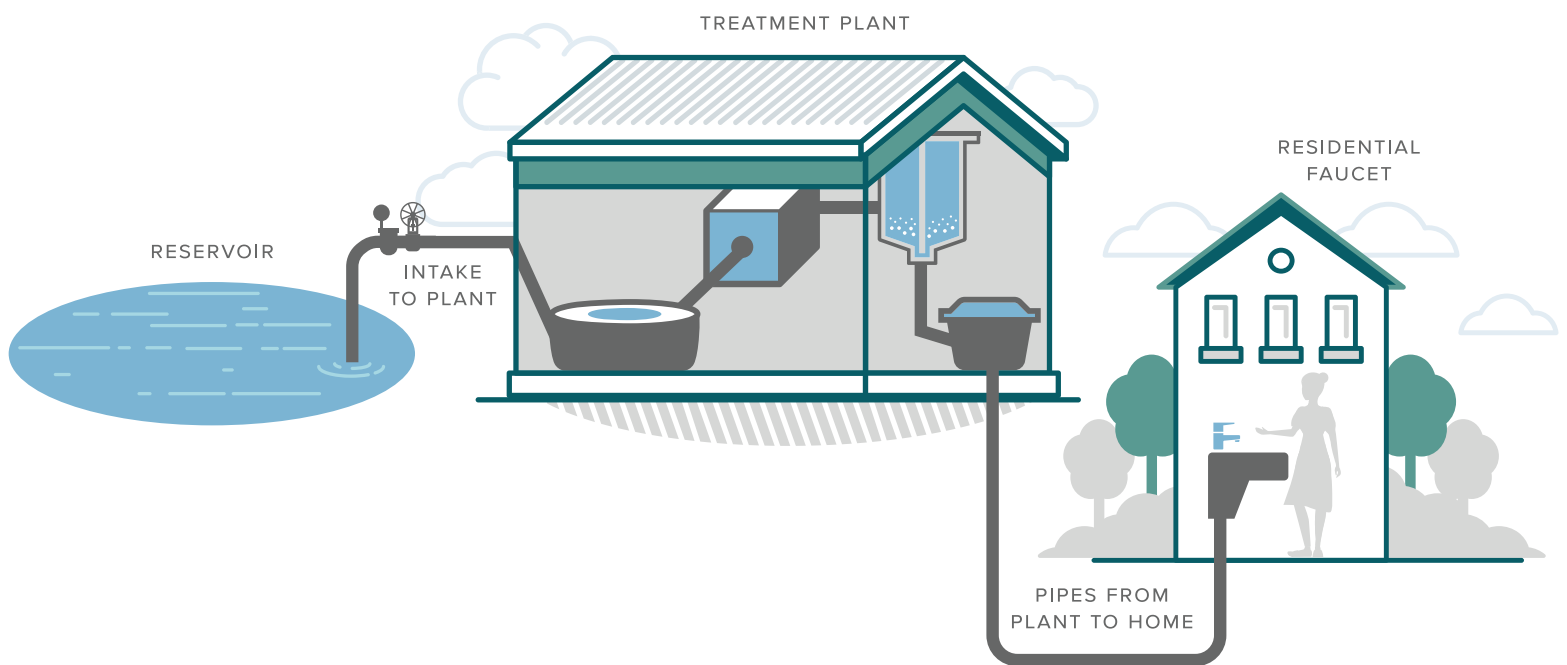
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Produce Safe Drinking Water

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 algal drinking water crises like this one, 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.



Projects in this Focus Area

Discovery of Enzymes and Pathways Responsible for Microcystin Degradation
Lead: The University of Toledo

Optimization of Carbon Barriers for Effective Removal of Dissolved Cyanotoxins from Ohio's Fresh Water
Lead: University of Cincinnati, The Ohio State University

Evaluation of Optimal Algaecide Sources and Dosages for Ohio Drinking Water Sources
Lead: University of Akron

Evaluating Home Point-of-Use Reverse Osmosis Membrane Systems for Cyanotoxin Removal
Lead: The University of Toledo

Kinetic Models for Oxidative Destruction of Cyanotoxins in Raw Drinking Water
Lead: The Ohio State University



How Much is Too Much?

Like any standing body of water, reservoirs that collect water to be used as drinking water tend to grow algae. In the case of reservoirs in the Lake Erie watershed, these algae could well be cyanobacteria capable of producing toxins – *Microcystis* or *Aphanizomenon*, for example – and generally tend to clog up pipes and filters or interfere with other treatment steps, so water treatment plants use algaecides to control their growth.

The problem with killing off cyanobacteria in this way is that quite often, the algaecide may kill non-target organisms like diatoms and green algae, and the dead cyanobacteria release toxin from their cells into the water. The optimal dosage for a given algaecide addressing a certain type of algae is a delicate balance between what kills a reasonable amount of target organisms, such as cyanobacteria, and what keeps toxin release to a minimum.

Researchers at the University of Akron have developed optimal treatment protocols for four water treatment plant reservoirs – City of Akron, City of Barberton, City of Norwalk and City of Willard – that balance algal bloom removal with avoiding toxin release. All plants are now able to use a lower concentration of algaecide than they did before, resulting in a treatment cost savings while keeping drinking water safe for their residents. In-field trials in the City of Akron reservoir with the lower algaecide doses were effective at suppressing cyanobacterial growth for two weeks.

The experimental protocols used to establish those customized treatment protocols are available for other water treatment plants, so their staff can determine which algaecide source and concentration would be optimal for their own reservoir.

The experimental protocols used to establish those customized treatment protocols are available for other water treatment plants, so their staff can determine which algaecide source and concentration would be optimal for their own reservoir. The researchers are also providing education and outreach materials to participating water utilities to help inform users about the basics of harmful algal blooms and the best ways to manage them safely.

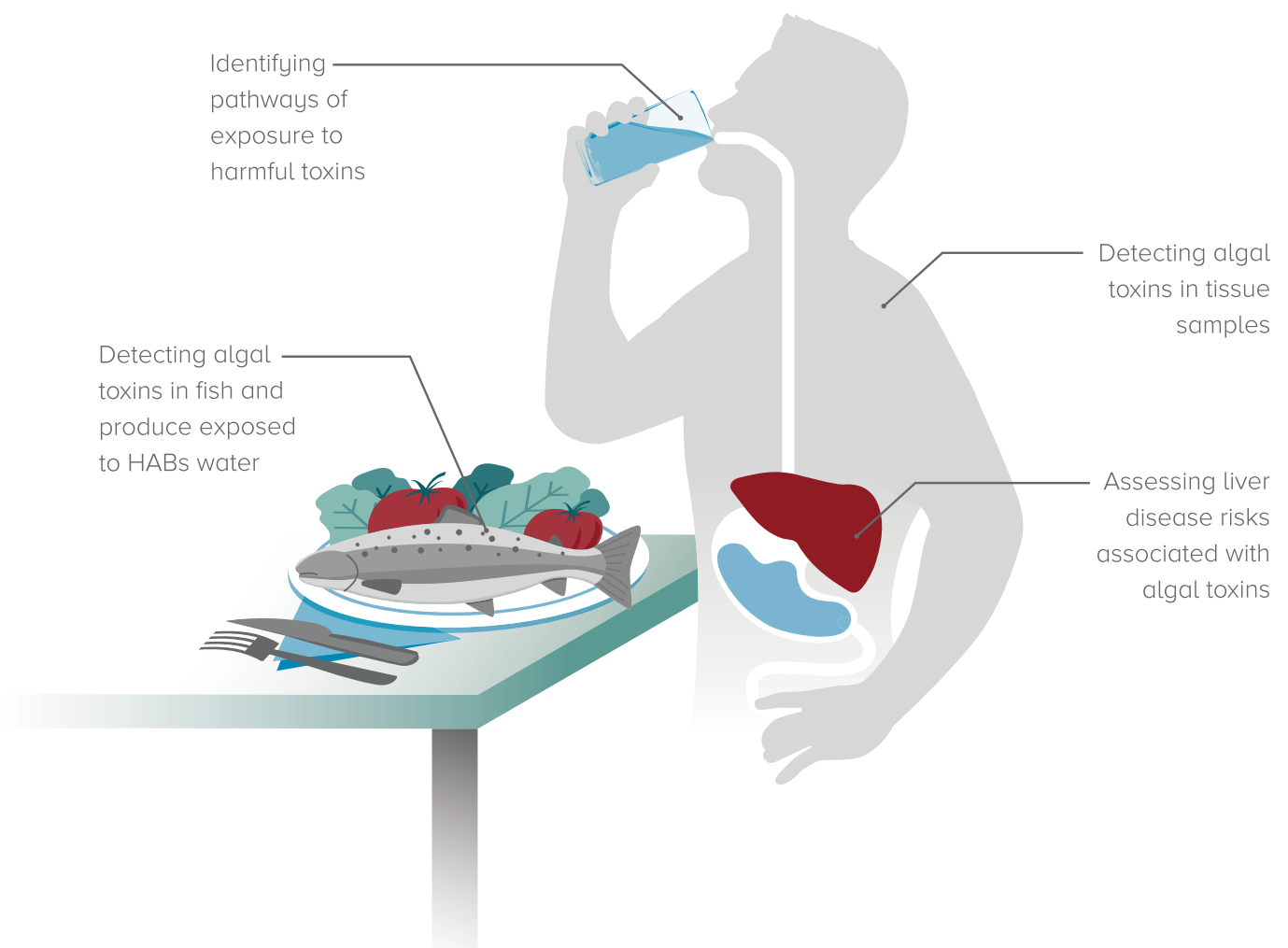
Algaecide dosage experiments were also used as a weeklong experiment for a Women in Engineering summer camp for middle schoolers, held at the University of Akron, that introduces girls to biomedical, civil, chemical, electrical and mechanical engineering topics.

In addition to collaborations with the participating water treatment plants, the project also allowed the researchers to interact more productively with personnel at OEPA and other HABRI researchers. At least one new research proposal involving multiple universities is being prepared for submission.



Protect Public Health

While safe drinking water is a major focus for public health officials and researchers, scientists are also working to determine other ways that harmful algal blooms and the associated toxins—in particular microcystin—may impact human health. In this focus area, science teams develop techniques to better detect toxins in biological samples, study the effects of algal toxins on various types of cells and determine the significance of the different ways that people might be exposed to algal toxins—physical contact, eating fish, etc. These studies aim to assist agencies as they develop guidelines for handling harmful algal blooms in coming years.



Projects in this Focus Area

Characterization of Recreational Exposures to Cyanotoxins in the Western Lake Erie Basin
Lead: The University of Toledo

A Comprehensive Approach for Evaluation of Acute Toxic Responses After Microcystin Ingestion
Lead: The Ohio State University

Development of the MMPB Method for Quantifying Total Microcystins in Edible Lake Erie Fish Tissues
Lead: The Ohio State University



Potential Sources of Exposure to Harmful Algal Blooms in Northwest Ohio Residents

Exposure to microcystins and other harmful algal bloom toxins can come in a number of forms. Most research and prevention measures focus on drinking water, while some studies have examined the effects of swimming in or otherwise coming in direct skin contact with impacted water.

Researchers collected information from individuals who use Lake Erie for recreation or during work to determine when, where and how different kinds of water exposure may be happening. The end goal in the next phase of the research (funded by HABRI round 3) is to connect those potential exposures to any self-reported health impacts, such as skin rashes or respiratory issues, which are common examples of health effects caused by cyanotoxins.

The researchers received 327 survey responses from recreational users – registered boaters, licensed anglers and residents within half a mile of the Lake Erie shoreline – who may be exposed to cyanotoxins through water-related activities like swimming or boating. Respondents were primarily male, college-educated recreational users who mostly spent time around Maumee Bay and the Lake Erie Islands. A majority of respondents use Lake Erie year-round, often for periods of three hours or more.

The water-related activities with the highest number of participants included walking on the shore, motorized boating, swimming, fishing and visiting nature areas. All reported activities in the survey involved some contact with lake water, and water skiing, tubing, jet skiing, wakeboarding and swimming had the greatest number of respondents who actually swallowed lake water during the activities.

Nearly half of recreational respondents did not report a change in their use of Lake Erie over the past five years. Of those who did change, many cited algae or water quality, along with changes in life or health, as the main reasons. About half of the respondents felt that more information on Lake Erie water quality, provided online or via email, would be beneficial to them.

This information can be used to target educational outreach efforts to specific audiences most likely to be exposed to cyanotoxins during recreational activities, and will be used to evaluate potential exposure and health effects during the next stage of the project.

About half of the respondents were willing to continue participating in the project, and the researchers will be able to target additional recruitment efforts based on knowledge gained from this round of surveys.

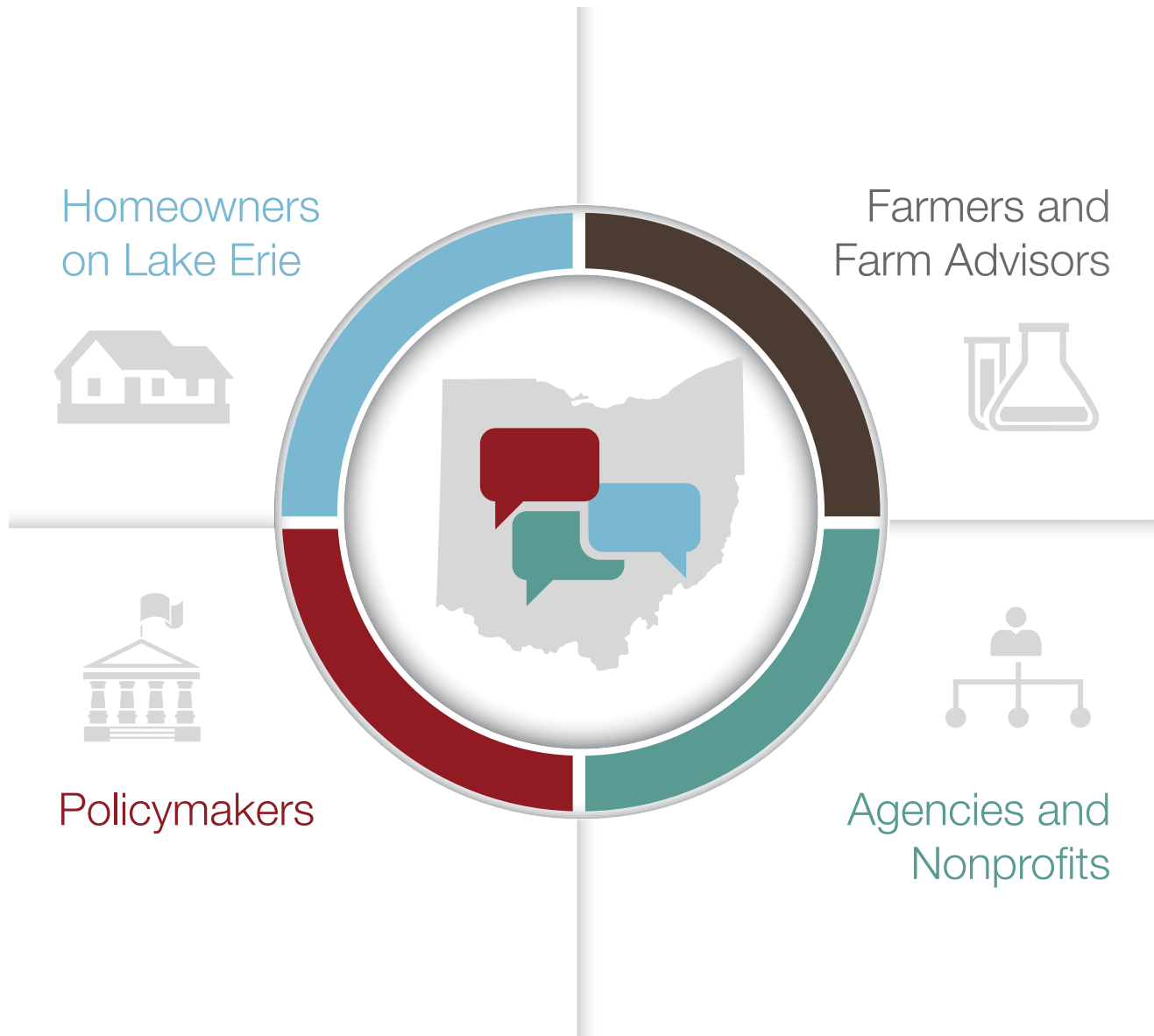
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Engage Stakeholders

Complex issues like harmful algal blooms have many causes and many impacts—which means many different people have perspectives and roles to play in finding solutions. Researchers in this focus area are figuring out how information moves through existing networks of people and how to best use those networks—such as OSU Extension and farmer partnerships—to create effective collaborations to tackle harmful algal blooms.



Projects in this Focus Area

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



Sampling Networks Involve Farmers Right From the Start

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

209 farmers in the western Lake Erie basin worked with HABRI researchers to collect data about their own fields and the effects that their cropping, irrigation and soil management practices can have on downstream factors like nutrient runoff. Led by OSU Extension, these farmers collected information about conditions in 329 fields throughout the 2015-2017 field seasons, covering 15 counties and more than 11,000 acres of farmland. They used diffuse gradients in thin films (DGT) devices, small plastic plates that collect soluble phosphorus over time and can be analyzed after sampling is completed. Samples were collected in the spring and fall during the highest rainfall periods from outlets on field tiles or from drainage water management structures.

During calibration periods both in the lab and on fields, the researchers noted that samplers from the fall of 2015 underestimated phosphorus concentrations when compared to continuous monitoring, while spring 2017 samplers overestimated phosphorus concentrations. This was likely due to weather patterns, as the fall was very dry and the spring very wet. This knowledge should be taken into consideration when using the final data in management decisions.

Overall results indicate a general relationship between higher soil phosphorus and higher phosphorus concentrations in water flowing from fields, but there was a lot of variation seen.

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 also allowed for tight feedback loops that could inform their choices directly as they make business and land stewardship decisions. For example, one farmer noted the impact of cover crops on water and nutrient runoff from his field sites, encouraging an extended use of cover crops for water conservation in the future.

Overall results indicate a general relationship between higher soil phosphorus and higher phosphorus concentrations in water flowing from fields, but there was a lot of variation seen. This means that soil phosphorus testing can provide some measure of risk for phosphorus loss from the field, but other factors such as soil type, distance from the water and tillage choices play a significant role in that phosphorus loss as well.

Ultimately, this information can be used to test model predictions, ensuring that watershed managers, state agencies and legislators 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.



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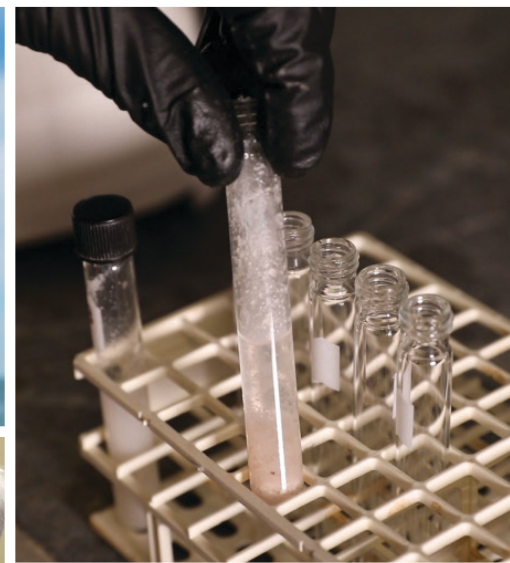
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Where Did This Phosphorus Come From?

RESEARCH PROJECT TITLE:

Determining sources of phosphorus to western Lake Erie from field to lake

Principal Investigator: Laura Johnson, Heidelberg University

Partner: The Ohio State University, Bowling Green State University

PROJECT SUMMARY

Ohio researchers are working to identify the best strategies to reduce the amount of phosphorus that runs off farm fields in the Lake Erie watershed to help improve the overall health of the Great Lake. Experts say soluble phosphorus runoff from farms is the primary driver of harmful algal blooms plaguing Lake Erie and other lakes in recent years.

A research team led by Heidelberg University’s National Center for Water Quality Research used 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.

They found that small losses of phosphorus due to agricultural practices are a major contributor to phosphorus runoff into the lake, and these losses were consistent across all of the subwatersheds, implying that targeting watersheds with high exports will be very difficult. However, they identified an approach to sampling that would help target watersheds with higher exports without sampling as intensively as needed to calculate loads. Ongoing development of a method to determine whether those phosphorus losses are from recently applied fertilizers or legacy phosphorus leaching from the soil will help target efforts to address the problem further.

Scientists at The Ohio State University are also using molecular analysis techniques to develop chemical signatures of organic phosphorus entering Lake Erie from various sources, such as farm fields, cattle operations and sewage treatment plants. The research team has received additional HABRI funding and will continue to use the data already obtained to better track manure-derived phosphorus runoff.

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.

AGENCY PRIORITIES ADDRESSED

- Collect data necessary to determine nutrient loading and flow weighted mean concentrations at priority tributaries in Ohio
- Edge-of-field studies to better understanding of how different agronomic practices affect nutrient loading

THE BOTTOM LINE

Tracking phosphorus from agricultural sources through sampling and chemical fingerprinting can help determine how best to avoid nutrient runoff that fuels Lake Erie’s harmful algal bloom problem.



Up and Down and Up Again: Tracking Algae's Travels Through the Water Column

RESEARCH PROJECT TITLE:

HAB avoidance: vertical movement of harmful algal blooms in Lake Erie

Principal Investigator: Tom Bridgeman, The University of Toledo

PROJECT SUMMARY

Researchers from The University of Toledo, along with researchers from NOAA, Bowling Green State University and Sinclair Community College, are working to understand the vertical movement of different types of algae – such as green algae, cyanobacteria and diatoms – throughout the water column. Their goal is to help water treatment plants better prepare for and reduce the amounts of algae they're taking into their system over the course of a day.

During the 2016 and 2017 harmful algal bloom seasons, water samples from boats, automated sensor buoys and autonomous underwater vehicles (small robot submarines, essentially) combined to provide a profile of how algae were moving throughout the water column during several separate 24-hour periods. In a related project, a drone equipped with a specialized camera developed by NASA scanned the lake surface for floating cyanobacteria.

The researchers are still analyzing the data, along with information collected from other sources, but initial trends indicate that predicting the location of cyanobacteria in the water column isn't a reliable way to prevent water treatment plant intakes from drawing algae into the system. Even when there is a dense surface scum of cyanobacteria, there is still a great deal of cyanobacteria throughout the water column and can be drawn into the intake. In addition, water currents and mixing can overwhelm any advantage gained by tracking the cyanobacteria's regular vertical movement in the water column.

The data collected will contribute to NOAA HAB Tracker models that will be able to incorporate both vertical and horizontal bloom movements into more powerful future predictions.

AGENCY PRIORITIES ADDRESSED

- Movement of HABs within water column: improve understanding of movement of cyanobacteria that contain buoyancy regulating aerotopes

THE BOTTOM LINE

Scientists are developing methods to help water treatment plants decide on the best spot for collecting drinking water.

Pictured above: Autonomous underwater vehicles (small robot submarines, essentially) provide part of the data used in tracking how algae move through the water column during typical days and nights.



Algal Bloom Toxins Like to Go With the Flow

RESEARCH PROJECT TITLE:

Seasonal quantification of toxic and nontoxic *Planktothrix* in Sandusky Bay by qPCR

Principal Investigator: George Bullerjahn, Bowling Green State University

Partner: NOAA Great Lakes Environmental Research Laboratory

PROJECT SUMMARY

Unlike the algal bloom that forms in Lake Erie's western basin each year, which is mostly made up of *Microcystis* cyanobacteria, the harmful algal bloom in adjacent Sandusky Bay consists mainly of *Planktothrix*, another species of blue-green algae. While both species produce microcystin toxins, the blooms otherwise vary in size, duration, temperature preferences and nutrient requirements.

This project's goal was to determine whether high density of algae is connected with high toxin levels, and whether environmental conditions like temperature or waves drive the shift from non-toxic to toxic blooms, using genetic analysis of the algae types found in the water. Based on a request from OEPA, the researchers also included a bloom in the Maumee River that occurred during their sampling period.

Sampling the 2016 Maumee River bloom revealed a solid connection between toxin levels and toxic algae, particularly in an area of the river that became almost stagnant during a dry period with little water flow. Those conditions led to a stable bloom with both high algae counts and high toxicity in the samples.

In Sandusky Bay, the heavy rains of 2015 and the drought in 2016 had little impact on bloom biomass and toxin levels, which were quite similar despite differences in runoff. This is in stark contrast to the *Microcystis* bloom in western Lake Erie, where the 2015 rains yielded a record-breaking bloom, while the 2016 drought resulted in very low algal biomass.



However, there was little correlation between toxin levels and the amount of toxic *Planktothrix* types in Sandusky Bay, which the researchers attribute to rapid changes in water movement that continually mix toxic and non-toxic algae.

AGENCY PRIORITIES ADDRESSED

- Cyanobacteria qPCR: use of qPCR to identify which genera in a mixed bloom are producing toxins

THE BOTTOM LINE

Researchers examined the *Planktothrix* algal bloom in Sandusky Bay to better understand how bloom size and other environmental factors, such as temperature and water movement, are connected to bloom toxicity. They found that *Planktothrix* blooms behave quite differently from *Microcystis* blooms.

Pictured above: Sampling in the Maumee River bloom revealed a solid connection between bloom size and algal toxin levels.



Algal Blooms Don't Just Happen in the Western Basin

RESEARCH PROJECT TITLE:

An investigation of Lake Erie central basin cyanobacterial blooms

Principal Investigator: Justin Chaffin, The Ohio State University

Partners: Kent State University, Defiance College

PROJECT SUMMARY

While much of the current research on harmful algal blooms focuses on Lake Erie's western basin, researchers at Ohio State's Stone Lab are also exploring what's happening in the central basin, between Lorain, Ohio and Erie, Pennsylvania.

Goals include identification of cyanobacteria – the blue-green algae that form harmful algal blooms – that bloom in the central basin and whether they are capable of producing toxins such as microcystins, which can negatively affect the liver.

Samples were collected from the central basin between 2013 and 2017 to identify the cyanobacteria in the water, and to measure water quality parameters such as temperature, dissolved oxygen and phosphorus and nitrogen content. In 2016 and 2017, more frequent sampling in June-August targeted identification of any algal toxins in the water.

The researchers found that central basin blooms occurred earlier in the year than western basin blooms, and that June and early July central basin blooms are mostly made up of *Dolichospermum*. Sampling indicated that this cyanobacterium can produce saxitoxins, which are of emerging concern in Ohio waters. *Microcystis*, the main cyanobacterium present in western basin blooms, was found in the central basin in August and September when the western basin bloom spread eastward.

Collaborators on the project included the Northeast Ohio Regional Sewer District, which analyzed algal samples for cyanotoxin-producing genes, and NOAA's National Centers for Coastal Ocean Science (NCCOS), which used imagery from MODIS and MERIS satellite sensors to quantify bloom biomass. The research team also worked with Lake County Metroparks to collect samples near a beach in the park district.

AGENCY PRIORITIES ADDRESSED

- Triggers for toxin production and release: continue ongoing research in this field

THE BOTTOM LINE

Routine sampling has expanded harmful algal bloom monitoring into the central basin of Lake Erie, providing additional timely information to state and federal agencies.



Offering Realistic Phosphorus Reduction Goals to Management Agencies and Farmers

RESEARCH PROJECT TITLE:

How quickly can target phosphorus reductions be met?
Robust predictions from multiple watersheds and lake models

Principal Investigator: Margaret Kalcic, The Ohio State University

Partners: The University of Toledo, Heidelberg University, Central State University, LimnoTech, U.S. Geological Survey, University of Michigan

PROJECT SUMMARY

Phosphorus runoff from predominantly agricultural watersheds in northwestern Ohio has been linked to water quality problems in Lake Erie.

To reduce the negative impacts in the lake, policy makers have set 2025 as the target year to reduce phosphorus loading by 40% (based on 2008 loads), with an interim goal of a 20% reduction by 2020.

A multi-university team of modeling experts has developed, calibrated and validated six watershed computer models to determine which conservation practices are most likely to lead to target reductions in phosphorus runoff from the Maumee River watershed into Lake Erie. The tools were then used to evaluate how adoption of conservation measures over time would impact overall water quality. These models are also being used to estimate how climate change predictions for the region, which include an increased number of more severe storms, will impact efforts to reduce phosphorus runoff.

This project builds on an existing network of collaboration and modeling efforts. The first step was to improve the existing watershed models to more realistically simulate phosphorus application rates, including manure, as well as combined sewer overflows. Then models were calibrated to predict water quality near the mouth of the Maumee River.

Meaningful engagement of a diverse advisory group provided important guidance for the project. The scenarios tested were not able to reach the dissolved phosphorus target nine out of ten years, as specified in Annex 4 of the Great Lakes Water Quality Agreement. However, many of these scenarios approach the total phosphorus target load. Another finding was that recommended practices to reduce phosphorus runoff can be mixed and matched to work with farmer preferences and opportunities.

Widespread adoption of practices will be necessary, as many scenarios required multiple management practices across at least half the farm fields in the Maumee watershed, so this mix-and-match approach could be essential to achieving the 40% reduction goal.

AGENCY PRIORITIES ADDRESSED

- Develop watershed loading models for nutrients and sediment for Ohio priority tributaries

THE BOTTOM LINE

Results from a multi-partner watershed modeling effort guided development and application of a model that can provide science-based guidance on how best to achieve target phosphorus runoff reduction goals.



Monitoring Lake Erie Even in the Depths of Winter

RESEARCH PROJECT TITLE:

Early season phosphorus inventory of offshore waters of Lake Erie

Principal Investigator: R. Michael McKay, Bowling Green State University

Partners: U.S. Coast Guard, Environment and Climate Change Canada

PROJECT SUMMARY

Winter and early spring tend to be a big gap in understanding of the Lake Erie ecosystem, due to ice cover and extreme weather conditions that prevent regular monitoring and safe sampling in the lake during those months.

By partnering with the U.S. and Canadian Coast Guards, researchers at Bowling Green State University are able to take advantage of those ships' ice breaking capabilities to sample offshore waters in winter and early spring, before state and federal agencies start their monitoring efforts.

In winter of 2016-2018, the researchers collected about 75 offshore surface water samples for analysis, specifically looking into nutrients like phosphorus as well as phytoplankton biomass to determine how algae were growing below the ice. The 2016 and 2017 winters coincided with extreme low-ice years on Lake Erie, possibly providing a look into the lake's ice-free future due to a warming climate. The 2018 winter ice cover, in contrast, was more extensive than in other winters over the past 45 years.

Data from the surveys was submitted to the National Science Foundation's Biological & Chemical Oceanography Data Management Office for inclusion in the archive of a previous project. These data are available to other researchers for use in future projects.

AGENCY PRIORITIES ADDRESSED

- Continue taking open lake measurements of concentrations of total phosphorus and dissolved reactive phosphorus in March each year.

THE BOTTOM LINE

Collaboration with Coast Guard personnel has provided scientists with the opportunity for Lake Erie sampling during months not normally accessible to other state and federal agencies.



Above: Working with the Canadian Coast Guard ice breaker CCGS *Griffon* gave the researchers access to Lake Erie waters before the ice cover melted away, offering a look into a part of the lake's life cycle that tends to be poorly understood.



Using Lake Erie Bacteria to Remove Microcystin from Drinking Water

RESEARCH PROJECT TITLE:

Discovery of enzymes in pathways responsible for microcystin degradation

Principal Investigator: Jason Huntley, The University of Toledo

PROJECT SUMMARY

Some bacteria have the ability to degrade the microcystin toxin MC-LR into non-toxic component parts, including bacteria naturally found in Lake Erie. A previous HABRI project identified and isolated groups of these bacteria, which are now being examined at the genetic level to potentially produce enzymes that can be used in water treatment plants to break down toxins. And of course, those toxin-degrading enzymes can't be ones that cause disease in humans or animals.

The research group has identified Lake Erie bacteria that can degrade microcystin and used next-generation genomic sequencing technology to examine the genetic information from these bacteria in the presence and absence of MC-LR. The toxin triggers increased activity in the genes that guide the production of enzymes that attack it, so a gene that is observed in a higher number of copies when MC-LR is present indicates a potential candidate for further study.

The researchers are now testing whether the selected bacteria can form thin layers called biofilms on lab-scale versions of the sand filters used in water treatment plants, in the hope that the bacteria can be added to these filters to naturally degrade microcystin. They are currently in talks with City of Toledo and Ottawa County water treatment facilities to use offline sand filters to test practical applications of their bacterial isolates at real-world scale.

The research is ongoing with help from the next round of HABRI funding.

THE BOTTOM LINE

Researchers are using naturally occurring Lake Erie bacteria to develop treatments that can break down microcystin in drinking water.



Above: Lake Erie bacteria that can degrade microcystin may soon become the next technology water treatment plants can employ to remove the toxin from drinking water.



Using Activated Charcoal and Carbon Nanofilters Efficiently and Cost-Effectively

RESEARCH PROJECT TITLE:

Optimization of carbon barriers for effective removal of dissolved cyanotoxins from Ohio's fresh water

Principal Investigator: Soryong Chae, University of Cincinnati

Partner: The Ohio State University

PROJECT SUMMARY

Water treatment plants use activated carbon to remove microcystins, the toxins produced by most harmful algal blooms, from the drinking water they provide to their residents. Currently, most Ohio utilities use activated carbon made from bituminous coal, according to local utility managers who are providing information on real-life water treatment processes to the scientists. However, guidelines on how much carbon is needed to remove a certain amount of toxin are scarce, so many operators err on the side of caution, leading to the potential for unnecessarily high treatment costs.

Researchers at the University of Cincinnati and The Ohio State University have developed guidelines for optimal use of activated carbon in drinking water treatment, and designed new carbon nanofilters that have shown high effectiveness in removing various cyanotoxins (>97% for microcystin-LR and cylindrospermopsin).

Results indicate that coconut-based activated carbon is the least effective in removing microcystins from water, probably because the pores in the carbon that would capture the toxin molecules are too small for the molecules to fit into. Better results came from wood-based activated carbon and lignite coal. Currently, most water treatment plants use activated carbon made from bituminous coal as it is cost-effective and convenient to use.

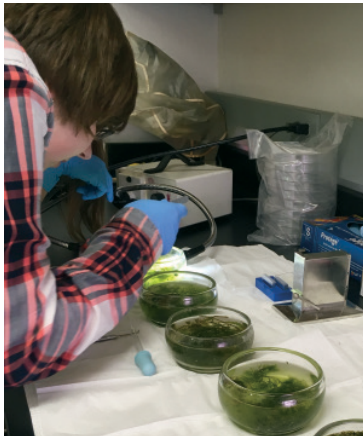
In the presence of dissolved organic matter, wood-based activated carbon was most effective in removing microcystins, followed closely by lignite-coal carbon, while bituminous-coal carbon did not perform well. Additional testing will determine whether lower amounts of organic matter affect performance for microcystin removal, along with balancing removal of this one type of contamination with the need to also consider other contaminants in drinking water sources.

AGENCY PRIORITIES ADDRESSED

- Carbon: conduct rapid small-scale column tests to evaluate effectiveness of different types of GAC on saxitoxin, MC-LR and other common Ohio microcystin variants. The effect of total organic carbon/natural organic matter (TOC/NOM) on toxin adsorption capacity should also be evaluated.

THE BOTTOM LINE

Researchers are developing guidelines for use of activated carbon in drinking water treatment plants, along with new carbon nanofilters that may be more effective than current approaches.



How Much is Too Much?

RESEARCH PROJECT TITLE:

Evaluation of optimal algaecide sources and dosages for Ohio drinking water sources

Principal Investigator: Teresa Cutright, University of Akron

Partner: City of Akron Watershed Division

PROJECT SUMMARY

Like any standing body of water, reservoirs that collect water to be used as drinking water tend to grow algae. In the case of reservoirs in the Lake Erie watershed, these algae could well be cyanobacteria capable of producing toxins – *Microcystis* or *Aphanizomenon*, for example – and generally tend to clog up pipes and filters or interfere with other treatment steps. As a result, water treatment plants use algaecides to control their growth.

The problem with killing off cyanobacteria in this way is that quite often, the algaecide may kill non-target organisms like diatoms and green algae, and the dead cyanobacteria release toxin from their cells into the water. So the optimal dosage for a given algaecide addressing a certain type of algae is a delicate balance between what kills a reasonable amount of algae and what keeps toxin release to a minimum.

Researchers at the University of Akron have developed treatment protocols for four water treatment plant reservoirs: two near Akron, one near Willard, and one near Norwalk. All plants are now able to use a lower concentration of algaecide than they did before, resulting in a treatment cost savings while keeping drinking water safe for their residents.

The experimental protocols used to establish those customized treatment protocols are available for other water treatment plants, so their staff can determine which algaecide source and concentration would be optimal for their own reservoir. The researchers are also providing education and outreach materials to participating water utilities to help inform users about the basics of harmful algal blooms and the best ways to manage them safely.

Algaecide dosage experiments were also used as a weeklong experiment for a Women in Engineering summer camp for middle schoolers, held at the University of Akron, that introduces girls to biomedical, civil, chemical, electrical and mechanical engineering topics.

In addition to collaborations with the participating water treatment plants, the project also allowed the researchers to interact more productively with personnel at OEPA and other HABRI researchers. At least one new research proposal involving multiple universities is being prepared for submission.

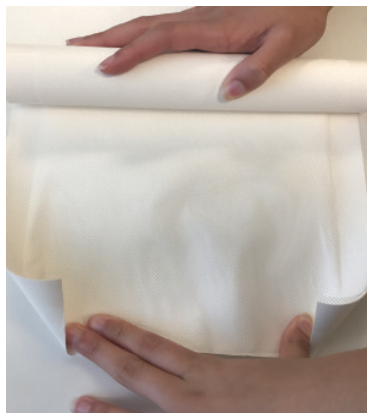
AGENCY PRIORITIES ADDRESSED

- Algaecides: survey of existing research on proper dose/application rate and timing for copper and hydrogen peroxide-based algaecides on cyanobacteria blooms

THE BOTTOM LINE

Researchers have developed optimal dosage protocols, balancing algae removal with avoiding toxin release, for algaecide use in four Ohio reservoirs that provide drinking water to area residents, and released a protocol that other treatment plants can use to establish optimal processes.

Above: Algaecide dosage experiments were used as a weeklong experiment for a Women in Engineering summer camp for middle schoolers, held at the University of Akron.



Stopping Algal Bloom Toxins at the Kitchen Tap

RESEARCH PROJECT TITLE:
Evaluating Home Point-of-Use Reverse Osmosis Membrane Systems for Cyanotoxin Removal

Principal Investigator: Glenn Lipscomb, The University of Toledo

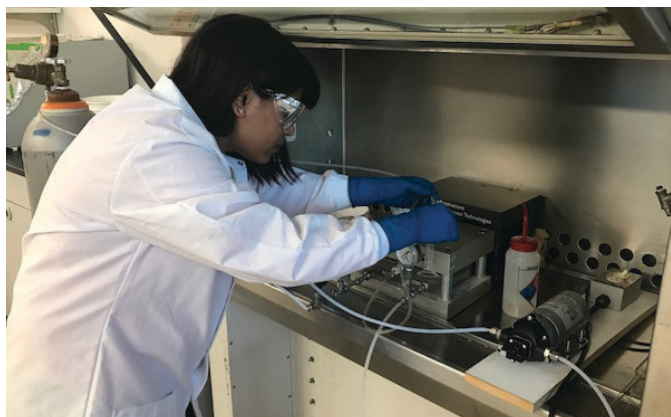
PROJECT SUMMARY

There's already a lot of activity going on in the aftermath of the 2014 harmful algal bloom (HAB) in Lake Erie, which left residents in the City of Toledo without drinking water. Water treatment plants have added additional testing for the algal toxin microcystin that caused Toledo's water shutdown, scientists are monitoring HABs as they develop, and backup intakes let larger plants avoid pulling in potentially contaminated water altogether.

A team at The University of Toledo is taking that activity one step further by showing that reverse osmosis membranes, an essential component of drinking water purification systems installed under kitchen sinks in a number of homes, can remove algal toxins from drinking water.

Reverse osmosis (RO) occurs when water is pushed through a semipermeable membrane with "holes" that are too small for anything but the water molecules themselves. The process removes minerals and particles that can cause undesirable flavors, but to the scientists, the removal of algal toxins was an obvious additional benefit that needed to be explored further.

The research focuses on the reverse osmosis systems commonly sold at home improvement stores, at a relatively low cost of \$250-300. The goal is to develop a certification process for these home membrane systems that shows that they remove microcystin from drinking water.



The three systems tested all removed microcystin to non-detectable levels in the final water. Because the chlorine added to drinking water can damage the membranes that do the filtering, the researchers also used an "accelerated aging" process to evaluate whether the damage affected toxin removal. They found that chlorine degradation equivalent to approximately one to two years of typical home use had negligible effect on the systems' ability to remove microcystin.

THE BOTTOM LINE

Researchers have demonstrated that commercially available home water purification systems can remove microcystin toxin from tap water.

Above: Researchers determined that household water filter systems can remove algal toxins.



Shining a Light on Water Treatment Technologies

RESEARCH PROJECT TITLE:

Kinetic models for oxidative degradation of cyanotoxins in raw drinking water

Principal Investigator: Allison MacKay, The Ohio State University

Partner: University of Cincinnati

PROJECT SUMMARY

Water treatment plants in Ohio use chlorine as part of their arsenal to fight drinking water contamination, including the presence of toxins like microcystin. Researchers wanted to make that treatment technique more effective by adding UV light and a permanganate oxidant into the equation.

The laboratory experiments have shown that rates of toxin degradation and destruction are higher when UV light treatment is added to current water treatment procedures that use chlorine. It also looks like the combination of UV and chlorine is effective in pH ranges that occur during algal blooms, as well as at a wide range of temperatures. These findings bring the researchers another step closer to using this method at water treatment plants.

Applying permanganate to speed the degradation process along also shows promise, without requiring additional or longer treatment to be most effective. The presence of organic matter – plant debris, mud and other things often suspended in lakes and streams – didn't affect the treatment protocols in a negative way.

Overall, chemical oxidants like chlorine and permanganate that are already commonly used in drinking water treatment can be effective in reducing algal toxin concentrations during typical plant operations. Most water conditions will allow chlorine to react with microcystins in less than 20 minutes, and addition of UV light can speed up the process while allowing chlorine doses to be drastically reduced.

Collaborations with local water utilities and Ohio's harmful algal bloom monitoring program have allowed the scientists to confirm whether the water samples used in the laboratory experiments were correlated with an active algal bloom at the time the samples were taken, based on information provided by OEPA.

AGENCY PRIORITIES ADDRESSED

- Cyanotoxin reaction kinetics: concentration-time (CT) tables for other microcystin variants via chlorine and permanganate

THE BOTTOM LINE

Researchers are enhancing current methods for drinking water treatment by adding UV light disinfection to established treatment protocols that use chlorine.



Potential Sources of Exposure to Harmful Algal Blooms in Northwest Ohio Residents

RESEARCH PROJECT TITLE:

Characterization of recreational exposures to cyanotoxins in western Lake Erie basin

Principal Investigators: April Ames & Michael Valigosky, The University of Toledo

PROJECT SUMMARY

Exposure to microcystins and other harmful algal bloom toxins can come in a number of forms. Most research and prevention measures focus on drinking water, while some studies have examined the effects of swimming in or otherwise coming in direct skin contact with contaminated water.

Researchers collected information from individuals who use Lake Erie for recreation or during work to determine when, where and how different kinds of water exposure may be happening. The end goal in the next phase of the research (funded by HABRI round 3) is to connect those potential exposures to any self-reported health impacts, such as skin rashes or respiratory issues, which are common examples of health effects caused by cyanotoxins.

The researchers received 327 survey responses from recreational users who may be exposed to cyanotoxins through water-related activities like swimming or boating. Respondents were primarily male, college-educated recreational users who mostly spent time around Maumee Bay and the Lake Erie Islands. A majority of respondents use Lake Erie year-round, often for periods of three hours or more.

The water-related activities with the highest number of participants included walking on the shore, motorized boating, swimming, fishing and visiting nature areas. All reported activities in the survey involved some contact with lake water, and water skiing, tubing, jet skiing, wakeboarding and swimming had the greatest number of respondents who actually swallowed lake water during the activities.

This information can be used to target educational outreach efforts to specific audiences most likely to be exposed to cyanotoxins during recreational activities, and will be used to evaluate potential exposure and health effects during the next stage of the project.

AGENCY PRIORITIES ADDRESSED

- Human health and toxicity—health effects of cyanotoxins on children and adults from recreational exposures including incidental ingestion, inhalation and dermal contact

THE BOTTOM LINE

Researchers surveyed lake users and those who work on Lake Erie as part of an effort to identify those activities, including when and where they happen, that may result in potential exposures to microcystin during recreation or work.



Toxic Effects of Ingesting Microcystin on Lab Mice

RESEARCH PROJECT TITLE:

A comprehensive approach for evaluation of acute toxic responses after microcystin ingestion

Principal Investigators: Jiyoung Lee & Christopher Weghorst, The Ohio State University

Partners: Charles River Laboratories, The University of Toledo

PROJECT SUMMARY

Ingesting microcystin toxin can have acute negative effects on the liver and other organs. However, most studies of these effects have been done in mice or rats, via injection of toxin into the belly. This research aims to apply an ingestion exposure approach to microcystin toxicity in mice, with future plans to translate these findings into a better understanding of similar effects on human health.

After a literature review that suggested a very wide range of toxin dosages for the experiments and conversations with U.S. EPA toxicologists, the researchers decided on three dosages. 5000 micrograms of microcystin per kilogram of body weight per day is the median lethal dose (LD50) required to kill 50% of a test population. Two other sets of mice either received a sublethal dose of 3000 micrograms or were part of a non-toxin control group. The study used both male and female mice to detect any sex-based differences.

Results show higher than normal markers that indicate liver damage and reduced liver function in all mice that were exposed to microcystin, with some test results showing that female mice are affected more strongly than male mice. In the toxin-exposed mice, the cause of death was liver hemorrhage – severe bleeding – brought on by microcystin exposure.

Study results will form a foundation for future studies into the effect of microcystin on the liver, giving researchers a method of oral toxin exposure that more closely mimics human exposure. They were also able to build collaborations with other universities, laboratories and agencies, which will form the basis of future research into the effects of microcystins on liver function and identifying biomarkers that show early signs of negative health impact.

AGENCY PRIORITIES ADDRESSED

- Acute toxicity of microcystins

THE BOTTOM LINE

A study on laboratory mice has shown that oral exposure to microcystin, the toxin produced by harmful algal blooms, causes acute liver damage and subsequent death, with female mice showing more elevated markers of liver damage in their blood than male mice.



Low Levels of Microcystins Found in Lake Erie Fish

RESEARCH PROJECT TITLE:

Development of the MMPB method for quantifying total microcystins in edible fish tissues

Principal Investigator: Stuart Ludsin, The Ohio State University

PROJECT SUMMARY

Microcystin, a type of toxin produced during harmful algal blooms, has been implicated in a number of health issues, from skin rashes to liver and nervous system damage. Microcystin-containing water is the cause of toxin exposure in most cases, but researchers are also looking into possible exposure from food, specifically Lake Erie fish harvested during the bloom season.

Lake Erie fish like walleye and yellow perch often swim through algal blooms, moving potentially contaminated water through their gills or eating prey that contain microcystin. What isn't known so well is whether those fish actually retain in their edible tissues (fish fillets, essentially) any of the algal toxin they are exposed to, and if they do, whether those toxin concentrations are high enough to be of concern.

Building on previous HABRI research, scientists have developed a protocol for using a testing method called MMPB to quantify total microcystin in fillet samples, to complement a previously developed method called LC-MS/MS that detects specific types of microcystin. The MMPB approach will help agencies like OEPA potentially revise fish consumption advisories based on a conservative estimate of potential microcystin toxicity, as the more detailed LC-MS/MS approach offers information about only a subset of the most toxic forms of microcystin. Both techniques are labor-intensive, but tend to be more accurate and less prone to false positives than the ELISA testing method that has historically been used.

Results from 2015-2017 monitoring of microcystin in Lake Erie using LC-MS/MS showed that there is some toxin accumulation in the fillets of walleye, yellow perch and white perch, but microcystin levels are below the threshold of concern based on World Health Organization guidelines, especially if current OEPA Sport Fish Consumption Advisory guidelines are followed. These guidelines recommend that no more than two yellow perch meals are eaten per week, with no more than one meal for other Lake Erie species like walleye, white bass or white perch. Due to some delays verifying the accuracy of the newly developed MMPB method, final results are not yet available for estimating risk with this more conservative testing method. Preliminary findings from an inter-laboratory comparison, however, suggest that this method is sound and can be used in the future by the state.

AGENCY PRIORITIES ADDRESSED

- Total microcystins–MMPB method: interlab validation of method for water and fish tissue matrices

THE BOTTOM LINE

Researchers are expanding the tools state agencies can use to guide Lake Erie residents in the safe consumption of local food fish.



Sampling Networks Involve Farmers Right From the Start

RESEARCH PROJECT TITLE:

Farmer/farm advisor water quality sampling network

Principal Investigator: Greg LaBarge, The Ohio State University

Partner: Ohio State University Extension

PROJECT SUMMARY

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, along with a renewed focus on preventing future problems.

209 farmers in the western Lake Erie basin worked 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 OSU Extension, these farmers collected information about conditions in 329 fields throughout the 2015-2017 field seasons, covering 15 counties and more than 11,000 acres of farmland.

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 also provides valuable feedback loops that help them learn directly from the data they collect. For example, one farmer directly noted how cover crops reduced water and nutrient runoff from his field sites, encouraging an extended use of cover crops for water conservation in the future.

Overall results indicate a general relationship between higher soil phosphorus and higher phosphorus concentrations in water flowing from fields, but there was a lot of variation seen. This means that soil phosphorus testing can provide some measure of risk for phosphorus loss from the field, but other factors such as soil type, distance from the water and tillage choices play a significant role in that phosphorus loss as well.

Ultimately, the information can be used to test model predictions, ensuring that watershed managers, state agencies and legislators 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.

AGENCY PRIORITIES ADDRESSED

- Identify the farming activities happening on the land and their timing, e.g., when nutrients are applied, how and where they are applied, the amount applied, the way they are applied and tillage practices

THE BOTTOM LINE

Assistance for farmers to identify the best techniques that optimize both agriculture outputs and water quality.

Treatment Optimization

1. Cyanotoxin Reaction Kinetics (Highest Priority)

This information is needed to better optimize use of chlorine and permanganate within the treatment process and estimate the removal rates that can be achieved under various oxidant doses and pH regimes.

- a. CT tables for MC-LR destruction via permanganate (variable pH/temp/concentration ranges). A rate constant was established by Rodriguez (2007) at a pH of 7.2, but little data is available for pH's >8. Typical Lake Erie and other inland lake blooms have pH >9, so data in the 8-9.5 range is needed.
- b. CT tables (or basic reaction kinetics) for saxitoxin destruction via chlorine (variable pH/temp/concentration ranges).
- c. CT tables (or basic reaction kinetics) for saxitoxin destruction via permanganate (variable pH/temp/concentration ranges).
- d. CT tables (or basic reaction kinetics) for other MC variants via chlorine and permanganate (need to evaluate if variants behave similarly). Consider evaluating desmethyl microcystin variants (common to Ohio) or other Ohio variants (could also base on differing properties of variants). Some microcystin variant work was conducted by Acero (2005), Ding (2010), and Ho (2006), but was focused on the MC-RR, MC-YR, and to a limited extent MC-LA, MC-LY, and MC-LF variants (no desmethyl variant studies). Rodriguez (2007) studied the effect of permanganate on MC-RR and MC-YR, but only at pH range of 6-8 (more work needed at higher pH's).

2. Cell Lysis (Highest Priority)

This research is needed to evaluate effect of permanganate on cell lysis. Many water systems use permanganate to control zebra mussels and optimize other treatment objectives. Knowing the minimum dose necessary to cause cell lysis will help water systems minimize cell lysis and better optimize treatment for cyanotoxin removal.

- a. Evaluate effect of permanganate on cell lysis and microcystins destruction for genera other than *Microcystis*. Build off of U.S. EPA *Microcystis* research (2015), evaluate other existing data, and replicate U.S. EPA work on other genera commonly found in Ohio: *Planktothrix/Oscillatoria* (highest priority), *Anabaena/Dolichospermum*, *Aphanizomenon*, *Cylindrospermopsis*, *Lyngbya*.

3. Carbon (High Priority)

- a. Survey literature on effectiveness of granular activated carbon (GAC) on microcystins removal (EBCT effects? reactivation frequency? effect of biofiltration?)
- b. Conduct Rapid Small Scale Column Tests (RSSCTs) to evaluate effectiveness of different types of GAC (build on existing AWRP data: evaluate higher MC-LR doses and longer EBCT) on saxitoxin, MC-LR and other common Ohio microcystin variants. The effect of TOC/NOM on toxin adsorption capacity should also be evaluated.
- c. Determine saxitoxin adsorption capacity for different types of powdered activated carbon (build on existing research, evaluate effect of pH on adsorption capacity).

4. Treatment Optimization (High Priority)

- a. Evaluate options for short-term conventional treatment optimization within a water plant (coagulants, velocity gradients, mixing rates, paddle speeds, etc.),
 - i. Specifically look at effects of slowing down mixer speeds (Is there a suggested upper velocity gradient (G) value for mixing (coagulation/rapid mix) so as to avoid physically breaking up the cyanobacteria cell, but yet not hinder the coagulation and flocculation process? What are recommendations for upper G value or RPM of mixers? Suggested range in which to keep peripheral speed of paddles (ft/s); or suggested upper G value paired with detention time (T) to obtain adequate coagulation? Should dosing be modified/or other coagulants or filter aids/polymers be used?)
 - ii. Overall, conduct full-scale studies on effect of treatment train optimization on a conventional plant for algal toxin removal, both for cell removal (intercellular toxin) and extra-cellular toxin removal.

Cyanotoxin Toxicity Research

5. Saxitoxin Toxicity Literature Review (Highest Priority).

Compile and summarize toxicity data available for saxitoxins, with a focus on oral (drinking water) exposure route.

6. Acute Toxicity of Microcystins (May not be feasible for these projects, but it is a need). Complete an acute drinking water microcystin exposure toxicity study. Ideally, this study should be a 7-day exposure study that includes at least two strains of mice, both genders, and various oral doses (at least 4). If possible, the study should evaluate multiple histopathology endpoints (liver, kidney, reproductive organs). Initial focus should be on microcystin-LR, but can be expanded to other common variants if resources are available.

7. Acute Toxicity of Saxitoxins (May not be feasible for these projects, but it is a need). Complete an acute drinking water saxitoxin exposure toxicity study. Ideally, this study should be a 7-day exposure study that includes at least two strains of mice, both genders, and various oral doses (at least 4). If possible, the study should evaluate multiple histopathology and/or electrophysiology endpoints (brain, spinal cord, peripheral nerves) and may include neurological response. Initial focus should be on saxitoxin, but can be expanded to other common variants if resources are available.

8. Cyanotoxin Reaction Kinetics (Item 1) – Expanding these studies to application for:

- a. smaller scale (lower volume) drinking water treatment systems such as ponds or springs,
- b. application for treatment at low level detections in a public water system that exceed drinking water health advisory levels where health care facilities or food service/retail food operations want to install treatment to remove low levels of cyanotoxin.

9. Carbon Treatment Efficacy for Microcystin, Saxitoxin, Cylindrospermopsin and Anatoxin-a (Item 3) for use in:

- a. smaller scale drinking water treatment systems such as ponds or springs.
- b. application for treatment at low level detections in a public water system that exceed drinking water health advisory levels where health care facilities or food service/retail food operations want to install treatment to remove low levels of cyanotoxin.

10. Infiltration of Cyanotoxin into Ground Water Beneath the Lake Erie Islands and Potential Impacts on Drinking Water Wells.

Identification of infiltration pathways and mechanisms can also be applied to inland lakes hydraulically connected to ground water.

11. Human Health and Toxicity – Health Effects of Consumption of low levels of cyanotoxins at or exceeding U.S. EPA Health Advisory Levels (microcystin, saxitoxin, cylindrospermopsin, anatoxin-a) on sensitive populations including pregnant women, nursing mothers, immune compromised individuals, individuals with liver and/or kidney impairment or disease.

12. Human Health & Toxicity – Health Effects of Cyanotoxins on children and adults from recreational exposures including incidental ingestion, inhalation and dermal contact.

13. Prevalence and Occurrence of Algal Blooms and Cyanotoxins in Ponds and Springs Used for Private Drinking Water Supplies. These systems are commonly shallower and have less water volume and may be more susceptible to the formation of algal blooms.

Reservoir Management

14. Algaecides Many water systems on inland sources rely on algaecide as a source control strategy, but guidance on proper application rates and timing is often limited. Research on application rate and timing will improve the implementation effectiveness of this reservoir management strategy.

- a. (High Priority) Survey of existing research on proper dose/application rate and timing for copper and hydrogen-peroxide-based algaecides on cyanobacteria blooms (different genera and cell counts, effect on akinetes).
- b. (Moderate Priority) Survey of existing research on algaecide effect on community dynamics and possible long-term implications of use (specifically copper resistance).

- c. (Moderate Priority) New research, if needed, to fill data gaps.

15. Sonication (use as reservoir management strategy) (Moderate Priority) Little is known on this relatively new reservoir management strategy. Research on its effectiveness for HAB control and the effect on cell lysis is needed prior to use on Ohio source waters.

- d. Evaluate effect on cell lysis (release of intercellular toxins after 1, 10, 30 days).
- e. Evaluate effect on HABs formation (inhibition).

Bloom Dynamics

16. Movement of HABs Within Water Column

(High Priority) A better understanding of cyanobacteria movement within the water column may assist water systems with avoidance strategies (i.e. temporarily turn off intake when cyanobacteria are present at intake depths).

- a. Improve understanding of movement of cyanobacteria that contain buoyancy regulating aerotopes (Predictable diurnal cycle? Timing? Light and wind effects?). Initial work should focus on *Microcystis* bloom in Lake Erie.

17. Triggers for Toxin Production and Release

(Lower Priority) If triggers for toxin production, release and degradation are better understood, it could translate into improved reservoir management and cyanotoxin avoidance strategies.

- a. Continue ongoing research in this field (nitrogen, trace metals, light intensity, temperature, other potential triggers).
- b. Determine triggers for cyanobacteria to release cyanotoxins (Effect of cyanophages? Differences between genera or strains?).
- c. Determine effects of light, temperature, biotic community and other factors on cyanotoxin persistence/degradation.

Analytical Methods

18. Total Microcystins – MMPB Method (High Priority)

More research is needed on the MMPB method (total microcystins) for water and fish tissue matrices. Some research suggests the ELISA method is not suitable for tissue matrices, so an alternate method is needed for fish tissue analysis of total microcystins.

- a. Interlab validation of method for water and fish tissue matrices.
- b. Further comparison of MMPB with ELISA on real-world samples (water matrices).

19. Cyanobacteria qPCR (Moderate Priority) qPCRs that can simultaneously identify cyanobacteria and cyanotoxin production genes show great promise for use as a screening tool. Research on these methods would lead to more reproducible results and a better understanding of toxin production.

- a. Interlab validation of multiplex qPCR.
- b. Comparative analysis of extraction techniques on real-world samples (various genera).
- c. Use of qPCR to identify which genera in a mixed bloom are producing toxins (better understand toxin production).

Nutrient Load Reduction Methods

20. Managing Agricultural Runoff (High Priority)

- a. Implementation of drainage retention ponds/dry dams in an agricultural setting. Are they practical, what are the barriers for implementing them, are they effective in holding and releasing runoff and drainage (field tile) water—can they help remove nutrients? What are the various sizes necessary to be effective based on field size, drainage area, etc.? Could they be incorporated into a permanent buffer/riparian corridor program? Does this strategy require compensating the farmer for utilizing any portion of the farm and would farmers be interested?
- b. Consider financial incentives for multiple adjacent farmers near a tributary to implement controlled drainage. Monitor nutrient levels in tributary both pre- and post-implementation to assess the effectiveness of controlled drainage on a landscape scale.
- c. Examine the effectiveness of natural wetlands in removing excess nutrients. Monitor existing natural flow through wetlands to determine the amount of

nutrients retained in the wetland versus straight drainage from agricultural fields. Investigate various natural wetland flow-through systems to determine which design is most efficient at nutrient reduction.

- d. Pilot test unique economic incentive programs to reduce nutrient runoff at the watershed or sub-watershed level.

21. Edge of Field Studies to Better Understanding of How Different Agronomic Practices Affect Nutrient Loading.

22. Assessment of Updated Tri-State Nutrient Standards to be sure that nutrient recommendations are adequate and a balance between production and environmental needs.

23. Managing Nutrients in Dredged Material (Moderate Priority) More information is needed about the fate and transport of nutrients in dredged material. This could inform the state's beneficial use strategies.

GREAT LAKES WATER QUALITY AGREEMENT

- Collect data necessary to determine nutrient loading and flow weighted mean concentrations at priority tributaries in Ohio (Maumee River, Toussaint Creek, Portage River, Sandusky River, Huron River, Vermillion River, Cuyahoga River, Grand River).

- ▶ Recommend using Heidelberg sampling protocol and suite of parameters

- Develop watershed loading models for nutrients (including in-stream nutrient transformation) and sediment for Ohio priority tributaries.

- ▶ Rationale: Will allow managers to understand the characteristics of the transmission and movement of sediment and nutrients within each watershed. It should also aid in evaluating and prioritizing which BMPs should be implemented at which locations and the expected impact of management actions within each watershed.

- Gather soil test P levels for all fields on a regular basis.

- Update soil/crop fertility guidelines for build-up, maintenance and drawdown fertilizer application recommendations.

- Identify the farming activities happening on the land and their timing, e.g., when nutrients are applied, how and where they are applied, the amount applied, the way they are applied, and tillage practices.

- Develop an inventory of aggregated nutrient management practices on an annual basis for use in watershed modeling and to assess progress of implementation of practices in relation to annual tributary mouth loading data.

- Continue taking open lake measurements of concentrations of total phosphorus and DRP in March each year.

- Gather more accurate data on nutrient loads from atmospheric deposition.

- Develop better information on quality and quantity of urban stormwater.

Since 2015, the Ohio Department of Higher Education has allocated **\$7.5 million** to solving the harmful algal bloom problem in Lake Erie.

HABRI arose out of the 2014 Toledo drinking water crisis when elevated levels of the algal toxin microcystin in Lake Erie threatened drinking water for over



500,000

PEOPLE IN NORTHWEST OHIO



The Ohio Environmental Protection Agency added **\$500,000 in funding** for 2018 HABRI projects.

Matching funds from participating universities doubled the impact of ODHE's HABRI investment to more than

\$15

MILLION in research funding.

TO DATE

91

Undergraduate Students

+

86

Graduate Students

have participated in *hands-on learning* opportunities offered by HABRI researchers.

10 UNIVERSITIES ACROSS THE STATE OF OHIO

are working on solving the harmful algal bloom problem.



HABRI breaks down research questions into bite-sized chunks that scientists can answer in **two years or less**.

HARMFUL ALGAL BLOOM RESEARCH INITIATIVE

Year 3 Project Update to the
Ohio Department of Higher Education

OHSU-TB-1516

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