2017

HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

YEAR 2
PROJECT UPDATE

Track Blooms From the Source

Produce Safe Drinking Water

Protect Public Health

Engage Stakeholders



HARMFUL ALGAL BLOOM

RESEARCH INITIATIVE

YEAR 2 PROJECT UPDATE | JULY 2017

IN THE SUMMER OF 2014, toxic 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 first results are in from this Harmful Algal Blooms Research Initiative (HABRI), and state agencies are now better prepared to prevent and handle water issues from harmful algal blooms.

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Ohio Sea Grant College Program
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Key Federal Partners

National Aeronautics and Space Administration

National Oceanic and Atmospheric Administration

U.S. Department of Agriculture

U.S. Environmental Protection Agency

U.S. Geological Survey

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) will provide 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, this report	$2 Million	ODHE
Round 2	14	2016-2018	In progress	Preliminary, this report	$2 Million	ODHE
Round 3	TBD	2018-2020	Solicitation phase	N/A	$2.5 Million	ODHE and OEPA

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

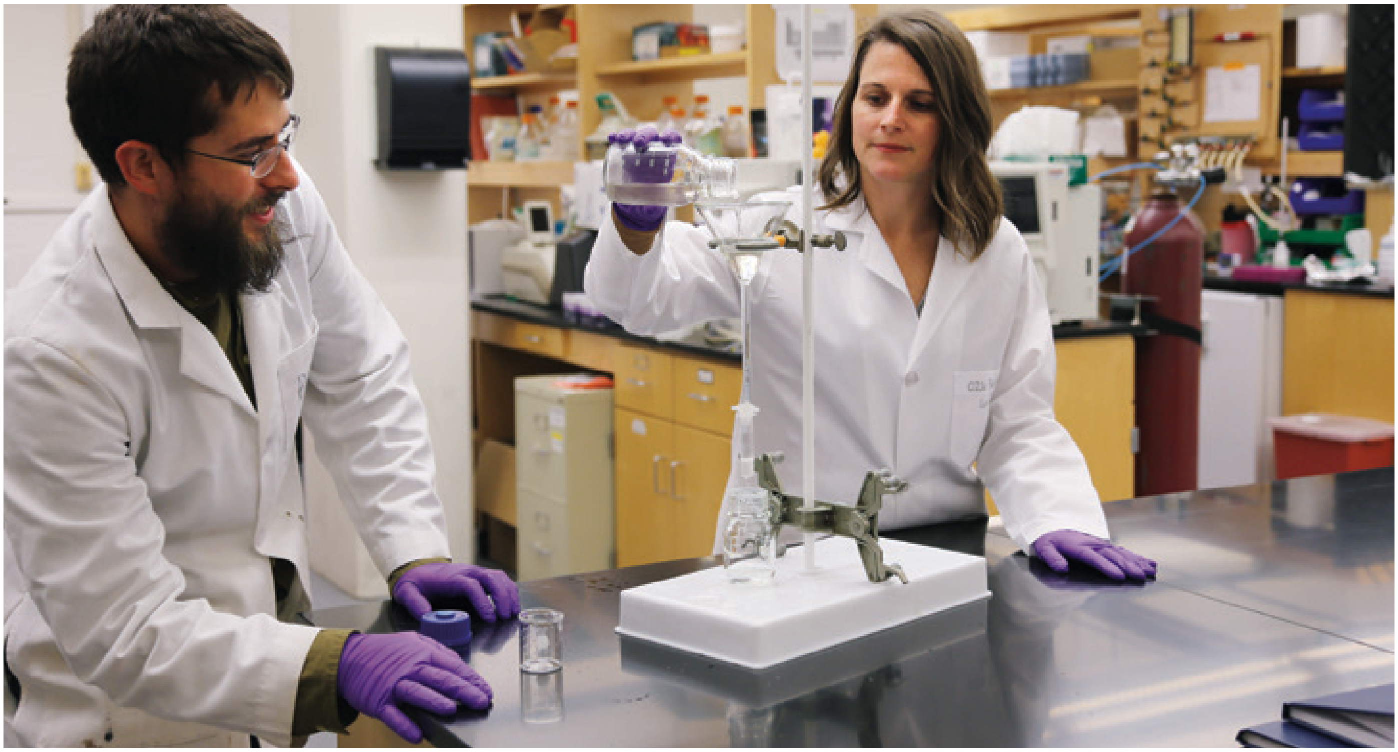
when elevated levels of the algal toxin microcystin in Lake Erie **threatened drinking water for over**

500,000

people in northwest Ohio.

"HABRI has put Ohio at the leading edge of coordinated HABs management compared to other state and even national counterparts. Being able to comment on the research projects from the proposal stage onward, we can make sure that the results will be applied and scalable."

— **Beth Messer, Acting Chief**
Division of Drinking and Ground Waters, Ohio Environmental Protection Agency



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 now in, along with preliminary results 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 will 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. The Ohio Department of Higher Education launched HABRI to get Ohio ahead of the problem and to prevent a situation like Toledo's 2014 "Do Not Drink" advisory from happening again. HABRI is only two years old, but it has already yielded results.

- Early warning systems in Maumee and Sandusky bays have given water treatment plants a much higher-resolution picture of what's coming down the pike from Lake Erie.
- HABRI research has provided new answers and practical guidance about producing safe drinking water for cities and towns dealing with algal toxins in their water sources.
- HABRI research has started to fill critical knowledge gaps about the risks that algal toxins present for human health.
- HABRI has driven information sharing and priority setting between universities and agencies, positioning Ohio to better prevent and manage future crises.
- A more integrated process has emerged for sample collection and analysis in the state.

HABRI: What We Do

Thirty-three 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*
Track blooms from the source	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.	• 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
Produce safe drinking water	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.	• 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
Protect public health	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.	• 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
Engage stakeholders	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.	• 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 50-54.*

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FOCUS AREAS

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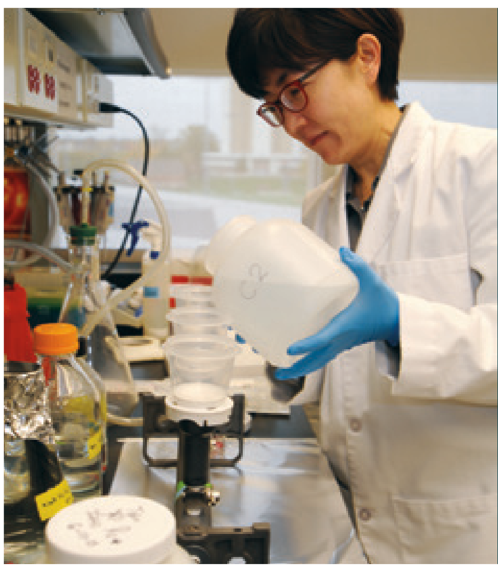
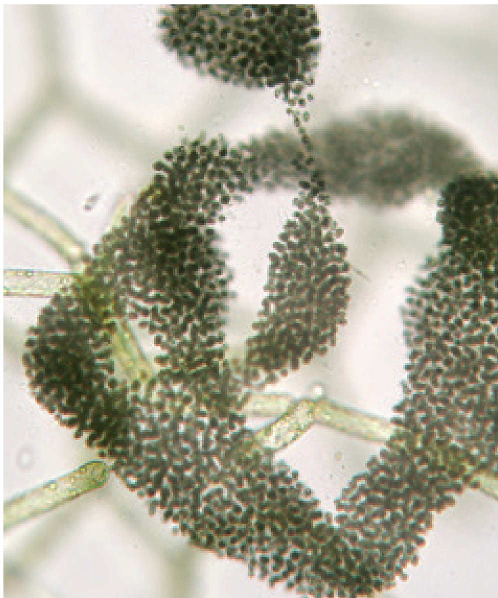




Track Blooms From the Source

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

ROUND 1

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

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

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

ROUND 2

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: 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

PROJECT SPOTLIGHT

Track Blooms From the Source

Early-Warning Systems for Lake Erie Algal Blooms

With harmful algal blooms, advance warning is power when it comes to safe drinking water. Two new integrated monitoring networks for Lake Erie's western basin, where harmful algal blooms are most common, alert plant operators about bloom activity near water treatment plant intake zones. Two HABRI-funded water quality monitoring buoys, or sondes, have been linked with 16 others in the Great Lakes Observing System (GLOS) and are augmented by weekly cruises between the Oregon and Toledo water intake points during summer. The monitoring arrays provide real-time data about water quality—including the presence of algae and algal toxins—available online and reported in weekly emails to water utility managers and other stakeholders.

Two HABRI-funded water quality monitoring buoys, or sondes, have been linked with 16 others in the Great Lakes Observing System (GLOS) and are augmented by weekly cruises between the Oregon and Toledo water intake points during summer.

HABRI researchers at the University of Toledo and Bowling Green State University who are running these monitoring systems were able to warn water treatment facilities of approaching blooms in the western Lake Erie Basin during both the 2015 and 2016 seasons. In the 2016 event, researchers alerted the Toledo and Oregon water treatment plants about a harmful algal bloom in Maumee Bay that was located just five miles from the water intakes, although the plants' own buoy and water samples didn't show a bloom. The water treatment facilities were then able to adjust their internal procedures to handle the water safely.

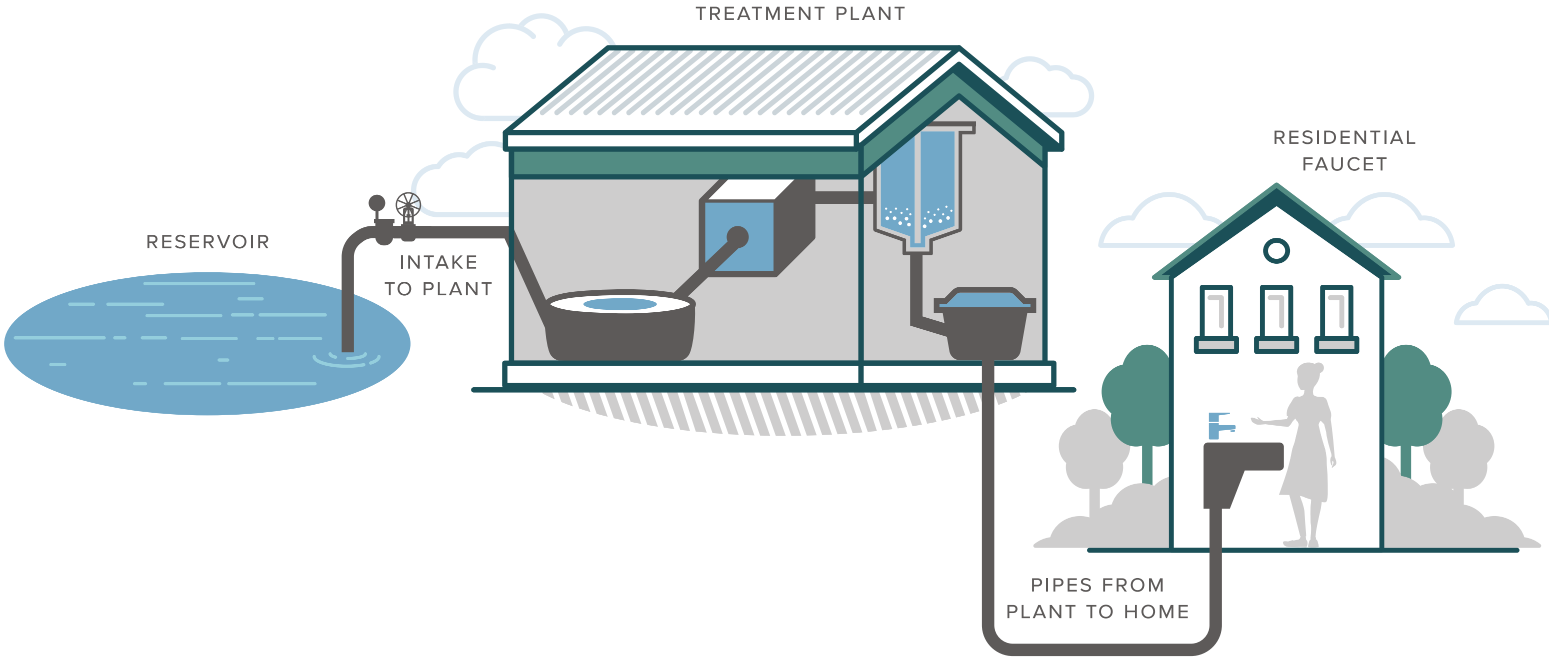
A related HABRI project focuses upstream of Lake Erie, monitoring both nutrient amounts and their sources (fertilizer, manure, human or wild animal waste) in the rivers and streams flowing to Lake Erie. This project integrates and augments an existing array of river monitoring stations maintained by a combination of federal, state and university partners to identify possible high phosphorus-contributing locations and different sources of phosphorus runoff that may contribute to loading into Lake Erie.

The partners found that small losses of phosphorus due to current agricultural practices are prevalent throughout watersheds and are thus a major contributor to phosphorus runoff into the lake. This suggests that changes in those practices might make a substantial difference in reducing some of the spikes in phosphorus associated with heavy rainfall.

Combining data from GLOS with information from river sensors and existing climate models will also 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.

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

ROUND 1

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

Investigation of Water Treatment Alternatives in the Removal of Cyanotoxins
Lead: University of Toledo

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

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

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

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

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

Development of Microcystin Detoxifying Water Biofilters
Lead: University of Toledo

ROUND 2

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

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

Stopping Algal Bloom Toxins at the Kitchen Tap

Researchers at the University of Toledo are taking drinking water protection out of the treatment plant and into homes by testing the effectiveness of reverse osmosis (RO) membranes, an essential component of drinking water purification systems installed under many residential kitchen sinks, at removing algal toxins from drinking water.

Reverse osmosis 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 would be an obvious additional benefit.

Partnering with NSF International (formerly the National Sanitation Foundation), the research focuses on 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, with the final certification protocol complete in early 2018.

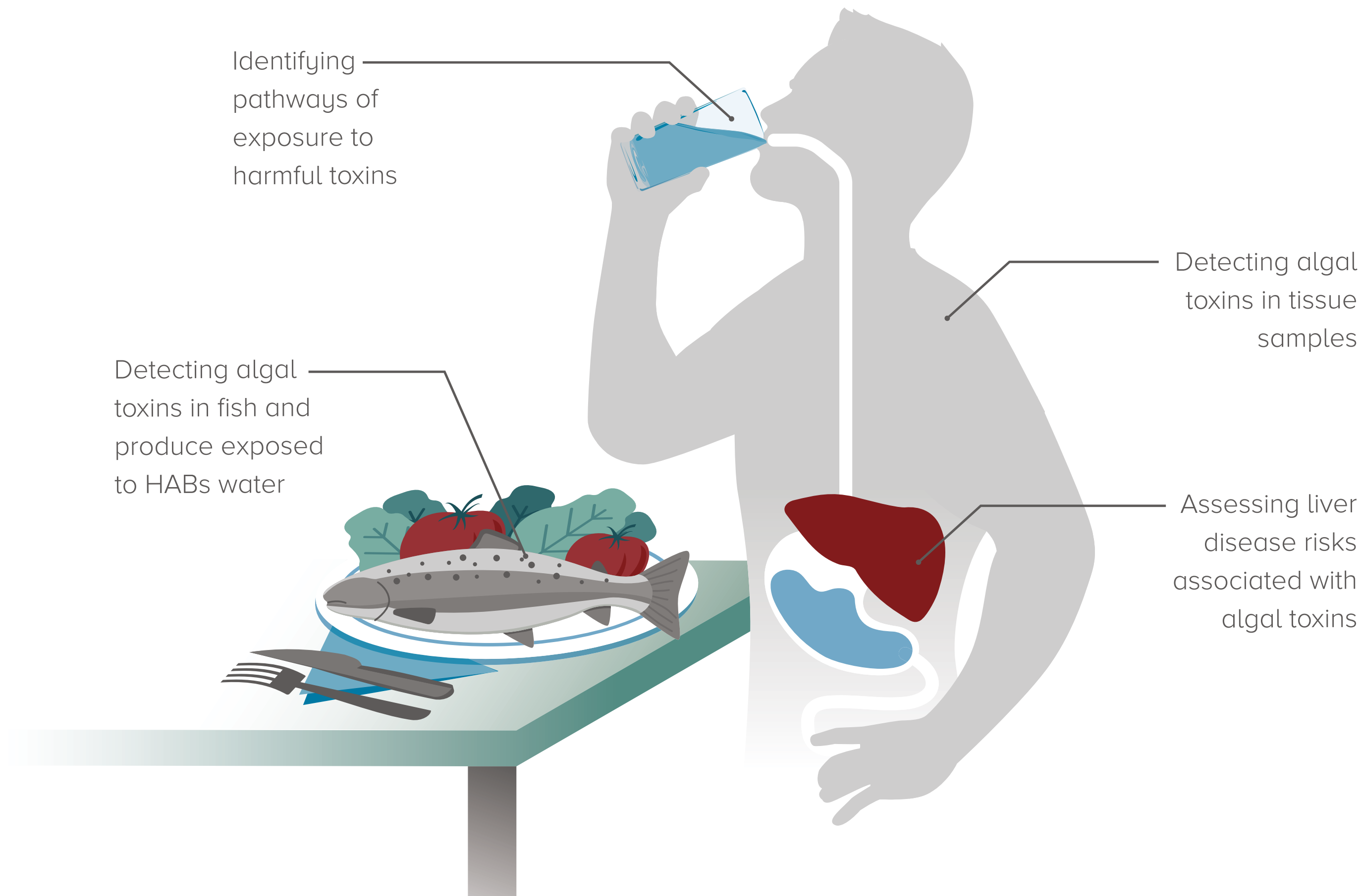
One of the challenges the researchers face is the chlorine that’s added to drinking water to help disinfect it: the chemical attacks the filter membrane and can reduce its ability to filter out toxins. So they’re developing some “accelerated aging” protocols based on previous research that shows that higher chlorine concentrations over a short time do the same damage as low concentrations over a longer time. This makes it possible to study chlorine’s effects in detail without having to wait for it to act on the filter membranes in real time.

The chlorine trials are first completed on just the filter system components, to see in detail how the different membrane and support layers are affected. Once those characterizations are completed, the researchers will move on to drinking water that includes known levels of toxin to assess the filter system’s effectiveness and complete the certification protocol.

The goal is to develop a certification process for these home membrane systems that shows that they remove microcystin from drinking water, with the final certification protocol complete in early 2018.

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

ROUND 1

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

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

Impact of Microcystin on Pre-Existing Liver Disease
Lead: University of Toledo

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

ROUND 2

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

A Comprehensive Approach for Evaluation of Acute Toxic Reponses 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

Tracking Microcystin Exposure in Fish for Human Consumption

Lake Erie fish such as walleye and yellow perch often swim through algal blooms, absorbing potentially contaminated water through their gills and eating up smaller animals that in turn may have been exposed to toxin.

What isn't known so well is whether those fish actually retain any of the algal toxins they are exposed to, and if they do, whether those toxin concentrations are high enough to be of concern. Starting with the first round of HABRI funding, researchers at The Ohio State University have shown that there is some toxin accumulation, but findings also support the current Ohio Department of Health general guideline of eating no more than one fish meal per week from any Ohio water body.

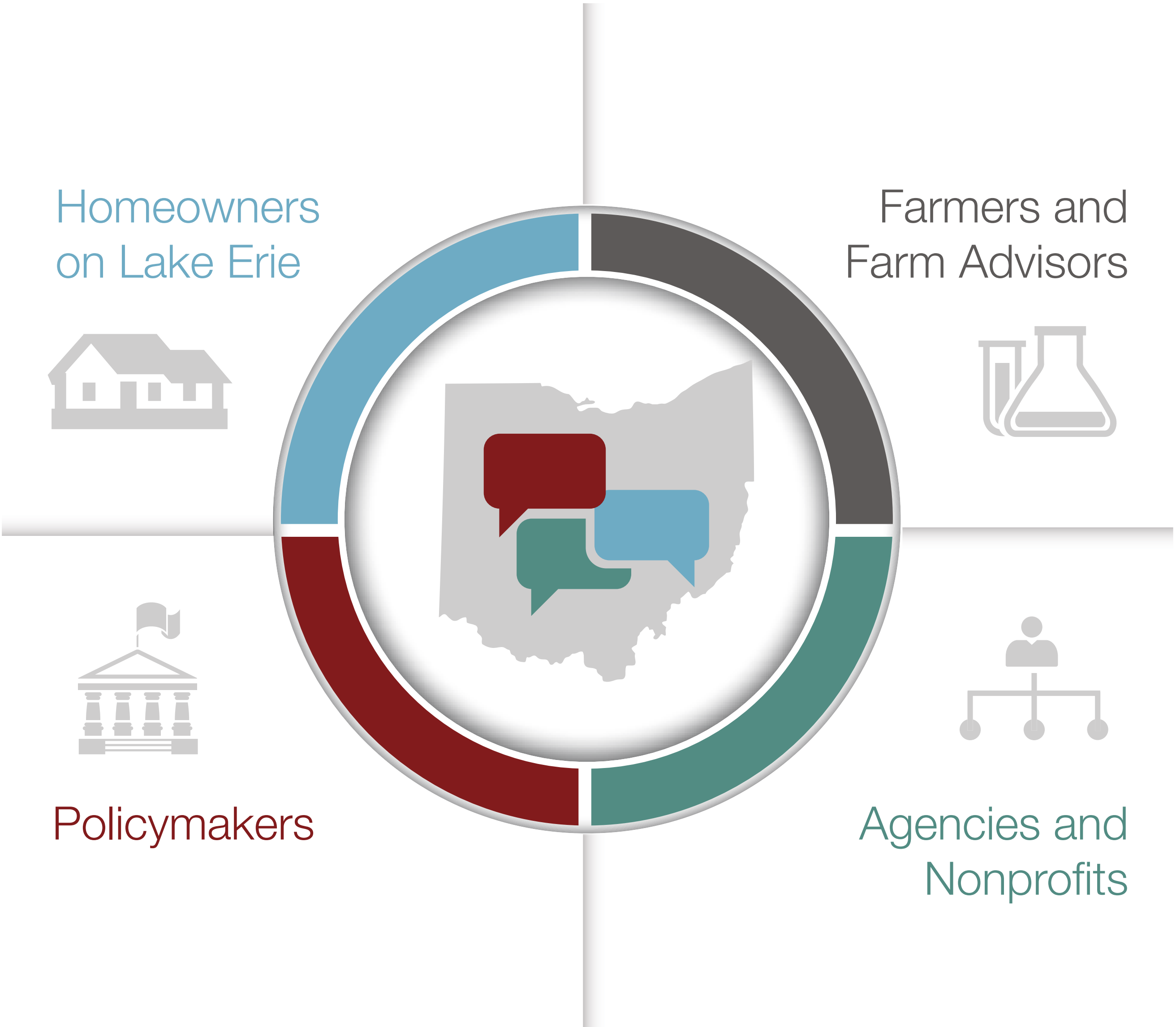
The researchers used a new sensitive detection procedure to process fish samples from Lake Erie and Grand Lake St. Marys for the Ohio Environmental Protection Agency and the Ohio Department of Natural Resources. Results from fish caught in 2015 show that out of 73 analyzed fish, six had detectable levels of microcystin in edible tissues—which don't include the liver and other organs—and those levels were still well below consumption limits. Although none of the fish samples showed elevated levels of microcystin in the muscle tissue, fish didn't necessarily need to be swimming in a harmful algal bloom to have detectable microcystins in their tissues. Even some caught after a bloom event was over or caught in parts of Lake Erie relatively far from bloom areas contained very low levels of algal toxin.

As part of the second round of HABRI funding, the team is also working with other laboratories in Ohio and Florida to validate their new detection techniques. An additional testing method called MMPB quantifies total microcystin in tissue samples (instead of detecting specific types that may not add up to total microcystin concentrations with other methods). That approach allows agencies to issue any needed fish consumption warnings based on a conservative estimate of potential toxicity, while the more detailed analysis by type offers information specifically about some of the most toxic forms of microcystin.

Results from fish caught in 2015 show that out of 73 analyzed fish, six had detectable levels of microcystin in edible tissues—which don't include the liver and other organs—and those levels were still well below consumption limits.

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

ROUND 1

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

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

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

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

Balancing Economic Tradeoffs with Zebra Mussel and Algal Bloom Management

Zebra mussels, an invasive species present in Lake Erie, have been shown to avoid *Microcystis*, the cyanobacteria that produce harmful algal blooms, when feeding. This behavior suggests that the mussels may actually be making harmful algal blooms worse by removing competition and allowing unhindered growth of toxic algae.

Those algal blooms, in turn, also take a toll on local economies, from recreational income to housing prices. This project aimed to develop an estimate for that loss in comparison to the cost of managing algal blooms to help local officials make cost-effective decisions when dealing with HABs.

The researchers found that housing values decrease by 7 to 16 percent when algal blooms in the area surpass the levels designated as safe for drinking water by the World Health Organization. Surveys at popular recreation spots also showed that anglers and beachgoers tended to substitute locations not affected by algal blooms when their favorite spots were closed, but that some people also decided to visit Lake Erie less often because algal blooms forced them to change their plans in the past.

The researchers found that housing values decrease by 7 to 16 percent when algal blooms in the area surpass the levels designated as safe for drinking water by the World Health Organization.

Currently, the researchers are combining the survey data with housing market information to create a comprehensive model of how zebra mussels and algal blooms affect the Lake Erie economy. The optimal management model being developed from this information will be applicable only to Lake Erie, but additional proposals to expand the model to the entire Great Lakes region are in the works.

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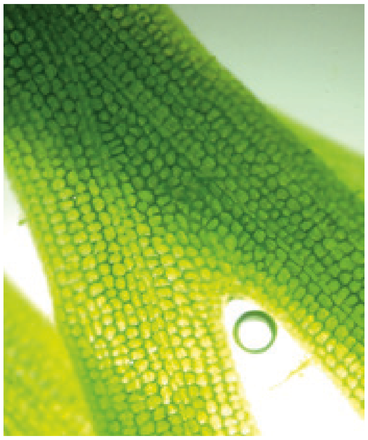


Early Warning System for Lake Erie Algal Blooms

RESEARCH PROJECT TITLE:

HAB Detection, Mapping, and Warning Network: Sandusky Bay

Principal Investigator: George Bullerjahn, Bowling Green State University
Partner: Kent State University, Michigan State University

PROJECT SUMMARY

This project contributed to the development of an algal bloom warning network for Lake Erie's western basin, where harmful algal blooms are most common. Tailored specifically for their locations, the network provides 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 plant shutdown. Maintaining the buoy in the future will continue to extend that early warning capacity to 12-24 hours before contaminated water reaches the plant intake.

The buoy also contributed information to the study of Sandusky Bay's *Planktothrix* bloom, a different variety of toxic cyanobacteria than the bloom in the main western basin. Results suggest that nitrogen, an essential nutrient for algal growth just like phosphorus, plays a large role in fueling this bloom and needs to be considered in management efforts that aim to address water quality in the bay.

Data sharing with other monitoring systems farther upriver, along with existing climate models, will also 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.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

Clean drinking water for Ohio residents and a better understanding of different types of algal blooms.

Early Warning System for Lake Erie Algal Blooms

RESEARCH PROJECT TITLE:

HAB Detection, Mapping, and Warning Network: Maumee Bay Area

Principal Investigator: Tom Bridgeman, University of Toledo

PROJECT SUMMARY

This project focuses on tracking the movement and intensity of harmful algal blooms (HABs) that form in Maumee Bay and then move toward the Toledo and Oregon, Ohio water treatment plant intakes to develop warning networks for Lake Erie's western basin, where harmful algal blooms are most common.

The network, which includes other HABRI projects as well as non-HABRI research, provides basin-wide data coverage of bloom-affected areas by streaming data from water quality buoys and sensors positioned near water treatment plant intakes to a public online database called GLOS (Great Lakes Observing System) Data Portal. The researchers also send weekly emails to water utility managers and other stakeholders to report results from weekly sampling cruises between the Oregon and Toledo water intakes.

During the 2016 bloom season, the researchers were able to warn the water treatment plants about a harmful algal bloom in Maumee Bay that was located just five miles from the Toledo and Oregon water intakes, although the plants' own buoy and water samples didn't show a bloom. City officials have expressed their appreciation for the warning network and its potential for helping to prevent another water crisis like the 2014 drinking water ban in Toledo.

Combining data from GLOS with information from river sensors and existing climate models will also 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.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

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. Publicly available real-time HABs data can assure lake users that during much of the summer season, HAB levels are very low.

Where Did This Phosphorus Come From?

RESEARCH PROJECT TITLES:

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

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

Principal Investigators: Laura Johnson, Heidelberg University and Paula Mouser, The Ohio State University

Partner: Bowling Green State University

PROJECT SUMMARY

Ohio researchers are working to identify the best strategies to reduce the amount of phosphorus that runs off of farm fields that reside in the Lake Erie watershed to help improve the overall health of the lake. Experts say soluble phosphorus runoff from farms is an important cause 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 (NCWQR) is using automated sampling equipment and sensors to test water samples throughout Rock and Honey Creeks (sub-watersheds of the Sandusky), and the Blanchard River (sub-watershed of the Maumee) to identify possible high phosphorus-contributing locations and different sources of phosphorus runoff that may contribute to loading into Lake Erie. Researchers at Bowling Green State University are conducting similar measurements in the Upper Portage River watershed.

The NCWQR found that phosphorus concentrations from each of the watersheds were similar before, during and after storms, indicating that current agricultural practices across the majority of farms are leading to constant small losses of phosphorus that fuel algal blooms downstream.

Scientists at The Ohio State University and at Bowling Green State University are also using molecular analysis and stable isotope techniques to develop chemical signatures in order to detect where phosphorus entering Lake Erie came from: farm fields, cattle operations, sewage treatment plants or other sources. The research team has received additional funding and will build on past data identifying these sources to then better determine the relative importance of the various sources of phosphorus runoff throughout the watersheds included in the studies.

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 decrease the amount of 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

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.

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

RESEARCH PROJECT TITLE:

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

Principal Investigator: Tom Bridgeman, University of Toledo

Partners: NOAA, Bowling Green State University, Sinclair Community College

PROJECT SUMMARY

Researchers from the University of Toledo, along with scientists from NOAA, Bowling Green State University and Sinclair Community College, are working on ways to understand the vertical movement of different types of algae—such as green algae, cyanobacteria and diatoms—throughout the water column 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 harmful algal bloom season, 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 through the water column during two separate days and nights. In a related project, a drone equipped with a specialized camera developed by NASA scanned the lake surface for floating cyanobacteria.

The results left the investigators "pretty puzzled." During rough lake conditions that should lead to an even mixing of algae types, green algae were still somewhat concentrated near the surface, while cyanobacteria (which produce the problematic toxin in harmful algal blooms) were more evenly spread out. Only at night were all types of algae distributed evenly in the water column.

In calm conditions, the expected mid-day surface scum of cyanobacteria did not appear. Instead, green algae were again denser near the surface, while at night the even distribution of algae types was only disrupted by diatoms, which sank closer to the bottom of the lake. The confusing results may have been due in part to the unusually small HAB caused by near-drought conditions in 2016.

A planning meeting before the next field season will bring together a number of related research groups to work out details for additional sampling trips during the 2017 bloom season, and to discuss potential explanations for this odd pattern. For now, the researchers are hitting planned milestones as expected, and they have ironed out a number of kinks, from flight permits to sampling equipment breakdowns, that will make this year's field season more efficient.

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 times of day and weather conditions for collecting drinking water during harmful algal bloom season.

Pictured above: Autonomous underwater vehicles 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 is to determine whether high density of algae is connected with high toxin levels, and whether environmental conditions such as temperature or waves drive the shift from non-toxic to toxic blooms. Based on a request from the Ohio Environmental Protection Agency, the researchers also included a *Planktothrix* bloom in the Maumee River that occurred during their sampling period.

Genetic analysis of water samples collected in Sandusky Bay during various weather conditions in the summer of 2016 showed large shifts between toxic and non-toxic *Planktothrix* types throughout the season. However, there was little correlation between toxin levels and the amount of toxic *Planktothrix* types, which the researchers attribute to rapid changes in water movement that continually mix toxic and non-toxic algae.

By contrast, sampling in the Maumee River 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.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

Researchers are examining 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.

Algal Blooms Don't Just Happen in Near-Shore Waters

RESEARCH PROJECT TITLE:

An Investigation of Central Basin Harmful Algal 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, nervous system and skin.

Stone Lab vessels are sampling four fixed locations once a week, collecting data on dissolved nutrients, water temperature and algal types. In addition, the researchers work with NOAA and other scientists to chase blooms as they occur to determine which types of algae are involved and pass that information on to other agencies.

One example included a bloom of what turned out to be *Dolichospermum* (formerly called *Anabaena*) near Fairport Harbor, Ohio in July 2016. Stone Lab scientists had detected the bloom near Avon a few days earlier and notified NOAA and the Ohio EPA so warnings could be updated. The toxin microcystin was not detected in any of the samples taken, but interestingly, conditions at the time were far from textbook for this type of algae, with nitrate, phosphorus and dissolved oxygen concentrations almost the opposite of what the species usually prefers.

Sampling will continue for the next year, while related research projects will continue to investigate what triggers algal blooms to become toxic.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

Routine sampling is expanding harmful algal bloom monitoring into the central basin of Lake Erie, which will enable agencies to better keep track of Lake Erie's overall algal bloom situation.

Pictured above: An algal bloom around South Bass Island colors Lake Erie waters green. The Harmful Algal Bloom Research Initiative (HABRI) seeks to reduce and prevent blooms and their impacts on Lake Erie residents through research and outreach.

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

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, policymakers have set 2025 as the target year to reduce phosphorus loading by 40 percent, with an interim goal of a 20 percent reduction by 2020, as part of the Great Lakes Water Quality Agreement.

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 will be used to evaluate how adoption of conservation measures over time would impact overall water quality, along with predicted effects of climate change.

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 provides important guidance for the project. In September 2016 the team sought feedback from representatives from the Blanchard River Watershed Partnership, the Defiance Soil and Water Conservation District, the Environmental Defense Fund, the Great Lakes Alliance, the Joyce Foundation, the National Wildlife Federation, Ohio Corn and Wheat, the Ohio Dairy Producers Association, the Ohio Department of Agriculture, the Ohio Environmental Council, the Ohio Environmental Protection Agency, the Ohio Farm Bureau Federation, Ohio Pork, OSU Extension, Soy Ohio, The Nature Conservancy and USDA-NRCS.

The meeting included a productive conversation about agricultural conservation options to analyze with the models, such as changing fertilizer and manure application rates, timing and level of incorporation into the soil, in addition to growing cover crops, managing subsurface drains and restoring headwater wetlands.

Results from the modeling efforts that followed this discussion were shared in an advisory group meeting in March 2017 to discuss preliminary results and make plans for developing conservation adoption strategies over time and under anticipated changes in climate.

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 will guide final development and testing of a model that will provide science-based guidance on how to best achieve target phosphorus runoff reduction goals.

Monitoring Lake Erie Even in the Depth of Winter

RESEARCH PROJECT TITLE:

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

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

Partner: U.S. Coast Guard

PROJECT SUMMARY

Although harmful algal blooms happen in the summer, the algae themselves are year-round residents of the water bodies they inhabit—but very little is known about other times in the annual cycle of blooms. In particular for Lake Erie, ice cover and extreme weather conditions in winter and spring prevent regular monitoring and safe sampling.

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 and 2017, the researchers collected 60 surface water samples for analysis, specifically looking at nutrients such as phosphorus, as well as phytoplankton biomass to determine how algae were growing below the ice. The two winters coincided with low-ice years on Lake Erie, possibly providing a look into the lake's ice-free future due to a warming climate.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

Collaboration with Coast Guard personnel has provided scientists with the opportunity for Lake Erie sampling during hard-to-access winter and spring months.

Above and Right: 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.

Keeping Water Systems Safe, Long Past an Imminent Threat

RESEARCH PROJECT TITLE:

Transport and Fate of Cyanotoxins in Drinking Water Distribution Systems

Principal Investigators: Youngwoo Seo, University of Toledo and Dominic Bocelli, University of Cincinnati

PROJECT SUMMARY

Research at the University of Toledo examined 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. The team is partnering with the city of Toledo, whose water supply was heavily affected by an August 2014 harmful algal bloom in western Lake Erie.

While reducing harmful algal bloom toxins at water treatment plants is a well-studied process, how toxins travel through and potentially remain 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 determined how cyanotoxins interact with various pipe and storage tank materials in laboratory experiments. They found that chlorine doses already used to disinfect drinking water can also be effective in ensuring microcystins do not stick to water pipes, and created a chlorine dose table to detail this information for water treatment plants in an easily applied way. They also found that high-density polyethylene pipes absorb the highest amount of microcystin, suggesting that updates to municipal water systems in areas commonly affected by harmful algal blooms may want to avoid that particular material. Experimental results were used to model the spread of microcystin within a drinking water system to identify potential "hot spots" for decontamination.

AGENCY PRIORITIES ADDRESSED

- Cyanotoxin reaction kinetics: 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

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.

Offering Water Treatment Alternatives for Algal Toxin Removal

RESEARCH PROJECT TITLE:

Investigation of Water Treatment Alternatives in the Removal of Cyanotoxins

Principal Investigator: Youngwoo Seo, University of Toledo

Partners: University of Kentucky, University of Cincinnati, The Ohio State University

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 microcystins 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 options during harmful algal blooms.

A research team at the University of Toledo has examined biological filter systems as well as treatment with potassium permanganate. Biofilters use microcystin-degrading bacteria to remove toxins from drinking water. Potassium permanganate neutralizes algal toxin, but also destroys algal cells. That destruction can potentially lead to additional toxin release.

Using water samples from Ohio reservoirs as well as lab samples with pure toxin strains, the researchers were able to determine an optimal dose of permanganate that neutralized toxin while keeping algal cell destruction to a minimum. Two bacterial strains also showed promise for use in biofilters, and evaluation of those biofilters at the Toledo water treatment plant is showing promise.

Information and results have been shared with the city of Toledo as well as statewide water managers, and collaborations with water treatment plants will continue after the project concludes.

AGENCY PRIORITIES ADDRESSED

- Treatment optimization: evaluate options for short-term conventional treatment optimization within a water plant

THE BOTTOM LINE

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

Using Bacteria to Break Down Algal Toxins in Water Treatment Plants

RESEARCH PROJECT TITLE:

Identifying Bacterial Isolates for Bioremediation of Microcystin-Contaminated Waters

Principal Investigator: Xiaozhen Mou, Kent State University

PROJECT SUMMARY

Because of their unusual shape, microcystins do 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 microcystins and related chemicals as a food source—a fact that water treatment plants would like to take advantage of.

A team of microbiologists at Kent State University has been collecting water and sediment samples since 2013 to find bacteria that thrive when exposed to microcystins, the toxins produced by many harmful algal blooms. Now they are purifying cultures of the bacteria to see if they can be used as part of bioremediation systems in water treatment plants.

Results show that of the nearly 500 bacteria strains isolated from Lake Erie water and sediments, 40 are able to degrade microcystins. The researchers also collected data on the shape, size and genetic make-up of those bacteria and tested their ability to break down microcystins under various temperatures and pH levels. This information is informing separately funded projects from the Ohio Department of Higher Education and the National Science Foundation that aim to use some of these bacteria in the development of biofilters for eventual use in drinking water treatment.

AGENCY PRIORITIES ADDRESSED

- Treatment optimization: evaluate options for short-term conventional treatment optimization within a water plant

THE BOTTOM LINE

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

How Much Charcoal Does It Actually Take to Remove Algal Toxins from Drinking Water?

RESEARCH PROJECT TITLE:
Guidance for Powdered Activated Carbon Use to Remove Cyanotoxins

Principal Investigator: John Lenhart, The Ohio State University

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 adsorb 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 at The Ohio State University has developed guidelines for water treatment plant operators to help them know exactly which dosage of powdered activated carbon to use under which conditions. These guidelines 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 adsorbs toxins.

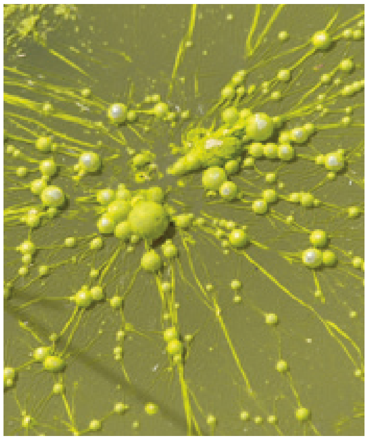
Highlights from the study results, which have been passed along to the Ohio Environmental Protection Agency, suggest that wood-based activated charcoal is the best choice for removing algal toxins, especially because it interacts with the toxin and any organic matter in the water more quickly than coal-based activated carbon. Coconut-based activated carbon, a common choice in water pitcher filters, was found to be a poor option for removing microcystin.

AGENCY PRIORITIES ADDRESSED

- Carbon treatment efficacy for microcystin, saxitoxin, cylindrospermopsin and anatoxin-a for use in 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

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.



Recruiting Viruses in the Fight Against Harmful Algal Blooms

RESEARCH PROJECT TITLE:

Prevention of Cyanobacterial Bloom Formation Using Cyanophages

Principal Investigator: Jiyoung Lee, The Ohio State University

PROJECT SUMMARY

Environmental health scientists at The Ohio State University are 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 toxins produced by the cyanobacteria, also known as blue-green algae, that cause harmful algal blooms.

Scientists believe 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, but haven't been studied much in lake water yet.

The research team discovered a cyanophage, now named Cyanophage LEP, that infects toxic *Microcystis* algae and interferes with growth and pigment production. This interference not only turns the algae from bright green to yellowish green, but also disrupts photosynthesis and structurally ruins cyanobacteria cells, based on electron microscope observations.

AGENCY PRIORITIES ADDRESSED

- Determine triggers for cyanobacteria to release cyanotoxins

THE BOTTOM LINE

This pioneering project has identified the first type of cyanophage that can destroy *Microcystis* from Lake Erie. The researchers next hope to discover a way to use these viruses to both limit cyanobacteria in targeted locations such as near a water intake, and to use them in water treatment plants in place of chemicals like chlorine and ozone.

Double-Checking the Accuracy of Common Testing Methods for Algal Toxins

RESEARCH PROJECT TITLE:

Investigation of ELISA and Interferences for the Detection of Cyanotoxins

Principal Investigator: Dragan Isailovic, University of Toledo

PROJECT SUMMARY

A research partnership among the University of Toledo, The Ohio State University and the University of Cincinnati aims to investigate potential problems with a standard 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.

This research team tested 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.

In order to know for sure, the research team checked ELISA's answers against results from a much more time-consuming but reliable method, liquid chromatography-mass spectrometry (LC-MS), which focuses on the most common types of microcystins. They found that the two methods showed generally similar trends for total microcystin levels in lake water, while in some cases the LC-MS results showed higher toxin levels than ELISA, which looks at overall toxin levels.

The team concluded that each method can provide valuable answers to water treatment plant managers and public health officials, as long as the limitations of each are taken into account.

THE BOTTOM LINE

More certainty for public officials monitoring and communicating water quality information about harmful algal blooms.

Treating Drinking Water to Remove Toxins

RESEARCH PROJECT TITLE:

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

Principal Investigators: Isabel Escobar, University of Kentucky and Youngwoo Seo, University of Toledo

PROJECT SUMMARY

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 solution of microcystin-LR, one of the most common forms of the toxin, can lead to 100 percent toxin destruction. Further experiments are in progress to achieve similar results at ozone concentrations and treatment times that work with treatment plant procedures. Several kinds of filter membranes are also showing promising results, removing up to 96.9 percent 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.

AGENCY PRIORITIES ADDRESSED

- Treatment optimization: evaluate options for short-term conventional treatment optimization within a water plant

THE BOTTOM LINE

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

Shining a Strong UV Light on Water Treatment Methods

RESEARCH PROJECT TITLE:

Treatment of Cyanotoxins by Advanced Oxidation Techniques

Principal Investigator: Dionysios Dionysiou, University of Cincinnati

PROJECT SUMMARY

Research from the University of Cincinnati is looking into finding new and cost-effective ways to remove and destroy cyanotoxins from drinking water by combining traditional chlorine-based treatment with new approaches to destroying algal toxins.

Using various technologies to treat different stages of water from surface water treatment plants, the research team explored different doses and types of degradation processes to see which will destroy the algal toxin microcystin-LR the fastest. The processes tested in the lab include combinations of chlorination and ultraviolet (UV) rays. A related project at the University of Toledo expanded the range of methods tested with ozonation and filtration.

The researchers found that adding UV light treatments to the chlorination step reduced the amount of chlorine needed by two-thirds. As water treatment plants are updating their technology, these findings can provide guidance on how to produce high-quality drinking water at a lower cost. A partnership with a surface water treatment plant is already putting the research into practice, and managers have expressed interest in further details on using UV light to make their processes more efficient.

AGENCY PRIORITIES ADDRESSED

- Treatment optimization: evaluate options for short-term conventional treatment optimization within a water plant

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.

Upgrading Water Treatment Filters With Friendly Bacteria

RESEARCH PROJECT TITLES:

Development of Microcystin-Detoxifying Water Biofilters

Discovery of Enzymes and Pathways Responsible for Microcystin Degradation

Principal Investigators: : Jason Huntley, 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. The researchers involved in this project have isolated and identified 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. And of course, those toxin-degrading enzymes can't be ones that cause disease in humans or animals.

The research group had hoped to find already known MC-LR degradation genes, based on studies from Australia, Japan and China. However, those genes were nowhere to be found in Lake Erie bacteria, so new genetic pathways have to be identified.

Current work focuses on using next generation genomic sequencing technology to examine the genetic information from these bacteria in the presence and absence of MC-LR. The toxin triggers an increase in the production of enzymes that attack it, so a gene that is observed in a higher number of copies when MC-LR is present is a likely candidate for further use.

So far, the researchers haven't been able to identify the degradation pathway in a single type of Lake Erie bacteria, but they recently narrowed down the list to groups of five bacteria. They're now working on confirming and replicating these results, as well as quantifying just how much microcystin the groups can break down, before digging deeper into the smaller list of options to find candidates for production of enzymes that can be used in water treatment.

In addition, they've started to grow these groups of bacteria on silica-based substrates, in preparation for larger-scale studies on the sand filters commonly used in water treatment plants. The eventual goal is to add microcystin-degrading bacteria to already existing filtration systems to improve and enhance water treatment in a safe and cost-effective manner.

The team has partnered with investigators at a number of Ohio universities to achieve these results, including the University of Toledo, Bowling Green State University, The Ohio State University and Kent State University.

THE BOTTOM LINE

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

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 their current 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 are now working on guidelines for optimal use of activated carbon in drinking water treatment, and on designing new carbon nanofilters that may be more effective than activated carbon in removing various cyanotoxins.

Preliminary 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.

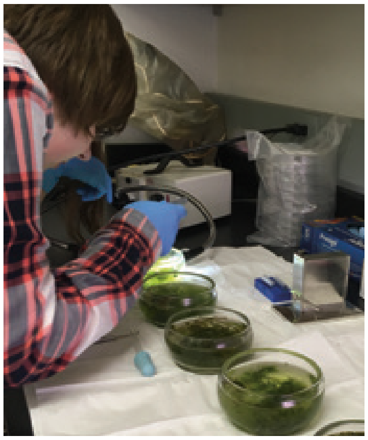
Currently, the team is using synthetic water, which represents a kind of "average" of surface waters in Ohio, to determine how well their techniques remove dissolved cyanotoxins. The plan for next year is to then add natural organic matter to the synthetic water to better mimic natural water conditions. Once they better understand the influence of that organic matter on toxin removal, they'll begin testing on water samples drawn from Lake Erie and its tributaries. The scientists have also created some of the carbon nanofilters they will be testing for toxin removal efficiency during the project's second year.

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 addition to clogging pipes and interfering with various water treatment steps, algal masses in reservoirs could be composed of cyanobacteria capable of producing toxins—*Microcystis* or *Aphanizomenon*, for example. 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 are now working to better understand that balance in four Ohio reservoirs: two near Akron, one near Willard, and one near Norwalk. The team is working with the associated water treatment plants to obtain samples and information on algaecide use to integrate all information from the study into a set of best practices for improving water treatment effectiveness and reducing costs where possible.

The goal is to create tailored solutions to various treatment goals for each reservoir, with the primary goal of minimizing the impact of algae removal while limiting toxin release from dead algal cells. So far, experiments have shown that factors like reservoir volume and shape, the types of algae present, the types of algaecide and concentration used, and overall water chemistry all affect treatment outcomes.

During the first year of the study, optimal dose experiments with all three algaecides have been completed for the city of Akron and city of Willard reservoirs, and one set of laboratory experiments for the city of Norwalk was recently finished as well. Additional dosage experiments, flow-through studies for a more real-world picture of water treatment, and final discussions with utilities managers are on track for the second project year.

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 are developing optimal dosage protocols, balancing algae removal with avoiding toxin release, for algaecide use in four Ohio reservoirs that provide drinking water to area residents.

Above: Algaecide dosage experiments were used as a week-long 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, 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 (RO) membranes, an essential component of drinking water purification systems installed under kitchen sinks in many homes, can remove algal toxins from drinking water.

Reverse osmosis 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.

Partnering with NSF International (formerly the National Sanitation Foundation), 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, with the final certification protocol complete in early 2018.

One of the challenges the researchers face is the chlorine that's added to drinking water to help disinfect it: The chemical attacks the filter membrane and can reduce its ability to filter out toxins. So they're developing some "accelerated aging" protocols based on previous research that shows that higher chlorine concentrations over a short time age filters the same as low concentrations over a longer time.

The chlorine trials are first completed on just the filter system components, to see in detail how the different membrane and support layers are affected. Once those characterizations are completed, the researchers will move on to drinking water that includes known levels of toxin to assess the filter system's effectiveness and complete the certification protocol.

THE BOTTOM LINE

Researchers are demonstrating the ability of commercially available home water purification systems to remove microcystin toxin from tap water.

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 are now working to make that treatment technique more effective by adding UV light and a permanganate oxidant into the equation.

The laboratory experiments so far have shown that rates of toxin degradation and destruction are higher in the presence of UV light at chlorine doses comparable to typical water disinfection procedures. It also looks like the combination of UV and chlorine is effective in pH ranges that occur during algal blooms, bringing the researchers another step closer to eventually 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. Researchers are working to understand how permanganate can be applied so that organic matter such as plant debris, mud and other things often suspended in lakes and streams doesn't affect the treatment protocols in a negative way.

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, based on information provided by the Ohio Environmental Protection Agency.

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.

Is Algal Bloom Toxin Exposure Linked to Liver Cancer Development?

RESEARCH PROJECT TITLE:

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 cyanobacterial 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.

While cyanotoxins have been suspected by the International Agency for Research on Cancer to be cancer-causing in humans, what researchers don't know for sure is how carcinogenic, or cancer-causing, the toxins might be.

Enter scientists in the College of Public Health at The Ohio State University. Their pilot research project examined whether chronic exposure to drinking water containing microcystins as well as other components in cyanobacteria increases liver cancer development in mice.

Results indicate that chronic exposure to drinking water containing algal toxins, at concentrations at or near recreational water exposure limits, could be connected to a promotion of liver cancer development, especially in organisms with a genetic predisposition to cancer. While chemically-initiated mice exposed to algal toxin-containing drinking water did not develop significantly higher numbers of liver tumors than those exposed to clean drinking water, the tumors that did form in the livers of mice ingesting the toxins were more advanced. The researchers plan to continue this research via a larger proposal submitted to the National Institutes of Health.

AGENCY PRIORITIES ADDRESSED

- Acute toxicity of microcystins

THE BOTTOM LINE

Public health scientists are examining whether microcystins in drinking water increases the occurrence and/or progression of liver cancer in mice ingesting the toxins. Knowing more about the effects of such chronic exposure will provide insights into potential health risks experienced by Lake Erie residents.

Checking For Microcystin in Fish and Produce

RESEARCH PROJECT TITLE:

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

Principal Investigator: Stuart Ludsin, The Ohio State University

PROJECT SUMMARY

Microcystin, one of the major toxins produced by harmful algal blooms, has been implicated in a number of health issues, from skin rashes to liver and nervous system damage. A main focus of preventing these negative health impacts has been limiting exposure to contaminated water, but researchers at The Ohio State University have been looking at things from a different angle: microcystin exposure from food.

Lake Erie fish like walleye and yellow perch often swim through algal blooms, absorbing potentially contaminated water through their gills and eating up smaller animals that in turn may have been exposed to toxin. Likewise, vegetable crops watered with water from a source with harmful algal blooms may also be at risk for accumulating toxin in the edible parts of the plant.

Researchers have examined whether fish actually retain the algal toxin they are exposed to, and whether those concentrations are high enough to be of concern. Although results have shown that in both cases there is some toxin accumulation, findings support the current Ohio Environmental Protection Agency (OEPA) general guideline of eating no more than one fish meal per week from any Ohio water body.

The researchers developed a procedure to use liquid chromatography tandem-mass spectrometry (LC-MS/MS) with the fish samples, as that method has been shown to offer more reliable results than the current testing method. With help from Ohio State's Food Innovation Center, the scientists are now able to quantify nine different types of algal toxins from fish tissue samples, including some of the most abundant and toxic forms of microcystin.

They've already used that procedure to process fish samples from Lake Erie and Grand Lake St. Marys for OEPA and the Ohio Department of Natural Resources. Results show that in the few fish that showed detectable levels of microcystin in edible tissues, which don't include the liver and other organs, those levels were still well below consumption limits.

With one lab focused on analyzing fish samples, another laboratory team grew three types of vegetables—lettuce, carrots and green beans—while watering them with microcystin-contaminated water at different concentrations. After harvest and testing, they found that green beans accumulate more toxin than carrots, both accumulate more toxin than lettuce, and more toxin accumulates in the roots than the leaves.

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Continued:

Checking For Microcystin in Fish and Produce

In addition to toxin accumulation in both plants and the soil surrounding them, the team found that microcystin exposure can stunt plant growth, distort shape and cause yellowing, making the vegetables less valuable as commercial crops. To avoid these issues, the researchers suggest regular water testing and finding an alternative source of water for irrigation if elevated toxin levels are found. If the toxin is found in soil, rotating cropland gives the toxin time to degrade before planting new crops. At the moment, this isn't much of a concern for Ohio crops because most farms use groundwater for irrigation, but it's valuable information in other areas of the world, where farmers may not have that option.

Based on these results, OEPA has also been investigating the potential for microcystin to accumulate in water treatment plant residuals—what's left over after clean water is sent back to consumers—and can limit use of those residuals as fertilizer if that is the case.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

Researchers are investigating the impact of harmful algal blooms on food fish caught in Lake Erie, and on produce watered with Lake Erie water.

Produce for the study was grown in greenhouses at Ohio State, and watered with water containing known amounts of microcystin toxin. Results showed stunted growth with higher toxin concentrations.

How Does Microcystin Toxin Affect People With Pre-Existing Liver Disease?

RESEARCH PROJECT TITLE:

Impact of Microcystin on Pre-Exisiting Liver Disease

Principal Investigators: David Kennedy and Steven Haller, University of Toledo

PROJECT SUMMARY

Microcystins, the toxin group produced by harmful algal blooms in Lake Erie, are known to negatively affect the liver, nervous system and skin. Other HABRI projects are focusing on whether that liver damage includes an increased cancer risk, while this project focuses on non-alcoholic fatty liver disease (NAFLD), the most common liver disorder in the United States.

Criteria for healthy exposure limits to algal toxins were developed based on healthy animal models, without existing liver problems, so the implications of these toxins for all types of patient populations are not well understood. The researchers used laboratory mice bred to exhibit symptoms similar to NAFLD and exposed them to what is considered a low toxin dose with no observable health effects.

Results showed an increase in liver damage in the treated mice, suggesting that further research may be needed to evaluate current exposure limits (in drinking water as well as through recreational water use) specifically for populations with existing liver disease. The findings also offer a baseline for additional research into diagnosing microcystin exposure and developing effective therapies for the consequences of microcystin toxicity in these vulnerable patients.

AGENCY PRIORITIES ADDRESSED

- Acute toxicity of microcystins

THE BOTTOM LINE

People who are predisposed to or already have liver damage may be more susceptible to microcystin's negative health effects, and public health recommendations for exposure may need to be adjusted to account for that increased susceptibility.

Development of Lab Tests for Microcystin Exposure

RESEARCH PROJECT TITLE:

Method Development for Detecting Toxins in Biological Samples

Principal Investigators: Dragan Isailovic and Kenneth Hensley, University of Toledo

PROJECT SUMMARY

Researchers at the University of Toledo have developed 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.

The team has refined a laboratory method to measure how much of the family of algal toxins of greatest concern—the microcystins—can be found in the human body. They're 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.

Currently, the researchers are able to quantify microcystins in concentrations between 1 ppb (part per billion, a measure of toxin concentration in water) and 100 ppb. Drinking water advisories are generally issued at 1.6 ppb, and no contact with contaminated water is recommended at concentrations above 6 ppb.

AGENCY PRIORITIES ADDRESSED

- Human health and toxicity–health effects of consumption of low levels of cyanotoxins at or exceeding U.S. EPA Health Advisory Levels on sensitive populations including pregnant women, nursing mothers, immune compromised individuals, individuals with liver and/or kidney impairment or disease

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 of coming into contact with algal toxins.

Health Effects 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 and Michael Valigosky, University of Toledo

PROJECT SUMMARY

While human exposure to harmful algal bloom toxins via drinking water is a major area of research, not much attention has been paid to recreational and work exposure through fishing, swimming or boating. Researchers at the University of Toledo surveyed recreational water users and those who work on or close to Lake Erie to determine when, where and how potential exposures may be occurring.

The researchers received 327 survey responses from recreational users who may be exposed to cyanotoxins through swimming or boating. The group is solidifying sampling methods for airborne exposure to aerosolized microcystin through a related project funded by the University of Cincinnati, and they have about 150 potential subjects for more detailed surveys in the future. They also have commitments from groups that represent those who work on or close to the lake—charter boat captains and fishing boat crew, for example—to participate in data collection on occupational exposure via air sampling on some of their boats.

These surveys prepared the research team for future funding, where they will examine the health impacts from recreational and occupational exposure to cyanotoxins. They'll also measure aerosolized microcystin, which comes from harmful cyanobacteria caught up in the water spray that waves create. The end goal is to connect those exposures to any self-reported health impacts, such as skin rashes, liver problems and respiratory issues, which are common examples of health effects caused by cyanotoxins.

AGENCY PRIORITIES ADDRESSED

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

THE BOTTOM LINE

Researchers surveyed recreational water users and those who work on Lake Erie to determine sources and timing of potential exposure to cyanotoxins. They will use this and additional survey data in the future to determine if there is an association with negative health effects and whether airborne algal toxin exposure may occur through boating or water spray at the shoreline.

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 and Christopher Weghorst, The Ohio State University

Partners: Charles River Laboratories, 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 via injection of toxin into the belly. This research aims for a more realistic approach to microcystin exposure by giving the mice toxin via a feeding tube to better understand and treat those effects on humans in the future.

After a literature review that suggested a very wide range of toxin dosages for the experiments, the researchers have completed a preliminary study to decide on three dosages: 5,000 micrograms of microcystin per kilogram of body weight per day, as well as 3,000 micrograms and a toxin-free control group. This main study is currently under way, using both male and female mice to detect any sex-based differences.

Study results will form a foundation for future research into the effect of microcystin on the liver, giving researchers a method of oral toxin exposure that more closely mimics human exposure.

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

Microcystins, a group of toxins produced by harmful algal blooms, have been implicated in a number of health issues, from skin rashes to liver and nervous system damage. Contaminated water is implicated in most cases of toxin exposure, but researchers are also looking into eating lake fish as a possible exposure pathway.

Building on previous fish research described in this report, scientists are now working with a testing method called MMPB to quantify total microcystin in tissue samples, to complement a previously developed method called LC-MS/MS that detects specific types of microcystin. That approach allows agencies like the Ohio Environmental Protection Agency to issue any needed drinking water or fish consumption warnings based on a conservative estimate of potential toxicity, while the more detailed analysis by type offers information specifically about some of the most toxic forms of microcystin. Both techniques are more labor-intensive, but tend to be more accurate and less prone to false positives than the ELISA method that is currently used in most agency labs.

So far results have shown that there is some toxin accumulation in Lake Erie fish (the study is testing walleye, yellow perch and white perch), but no reason to completely avoid consumption as long as people follow the Ohio Department of Health guideline of no more than one Ohio-caught fish meal per week. The researchers continue to improve their procedure, and aim to finalize it during the summer of 2017.

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 agencies can use to guide Lake Erie residents in the safe use of lake resources like food fish.

Mapping Social Connections in the Fight for Lake Erie's Health

RESEARCH PROJECT TITLE:

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.

The research team has developed a map of the social connections between important players in the Lake Erie watershed. Those connections were 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.

They found two major pathways of information exchange: a top-down approach by state and federal organizations that mostly related to financing and project funding, and a collaborative non-profit network that connects stakeholders across the state. The network also showed large differences between the different watersheds, suggesting that further study may help focus outreach efforts in each region.

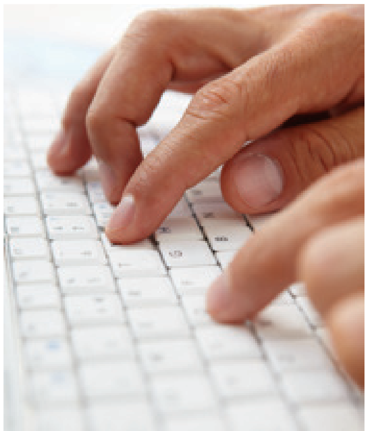
The final network map will inform decision making and education efforts, and will show communities how they can more effectively collaborate to improve water quality. Future research will link this social data set with environmental and water quality data to determine if there is a link between network connections and improvement in water quality.

AGENCY PRIORITIES ADDRESSED

- Other: mobile and web communications with stakeholders

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.



Building Resources for Lake Erie Managers and Communities

RESEARCH PROJECT TITLE:

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 collected information on Lake Erie harmful algal blooms into an easily accessible web-based portal for access by interested stakeholders (***lakeeriehabsis.gis.utoledo.edu***).

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 more quickly and with less effort.

Resources include key studies, videos, reports and tools that land managers can use to inform their decision making, including results from recent and ongoing research across the region.

The team continues to 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.

AGENCY PRIORITIES ADDRESSED

- Other: mobile and web communications with stakeholders

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.

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

PROJECT SUMMARY

Fifty-six 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 such as nutrient runoff. Led by OSU Extension, these farmers collected information about conditions in 80 fields throughout the 2015 and 2016 field seasons, covering 14 counties and 3,273 acres of farmland.

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.

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. For example, one farmer directly noted the impact of cover crops on water and nutrient runoff from his field sites, confirming his intention to use cover crops for water conservation in the future.

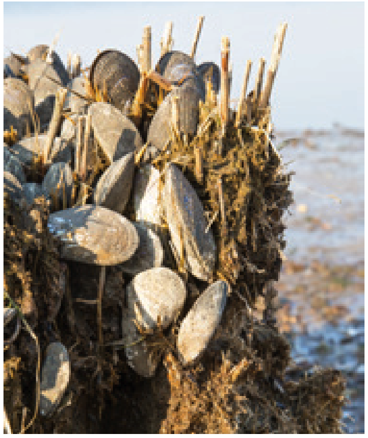
Data is still being analyzed for management and phosphorus trends on a larger scale. Ultimately, the information can be used to test model predictions, ensuring that watershed managers, state agencies and legislators have the most current information when making decisions about how best to deal with 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 identifying the best techniques that optimize agriculture outputs and water quality.



Balancing Economic Tradeoffs with Zebra Mussel and Algal Bloom Management

RESEARCH PROJECT TITLE:
Maumee Basin Lake Erie HABs Nutrient Management Options Comparative Analysis

Principal Investigator: Timothy Haab, The Ohio State University

PROJECT SUMMARY

Zebra mussels, an invasive species present in Lake Erie, have been shown to avoid *Microcystis*, the cyanobacteria that produce harmful algal blooms (HABs), when feeding. This behavior suggests that the mussels may actually be making harmful algal blooms worse by removing competition and allowing unhindered growth of toxic algae.

Those algal blooms, in turn, also take a toll on local economies, from recreational income to housing prices. This project aimed to develop an estimate for that loss, in comparison to the cost of managing algal blooms, to help local officials make cost-effective decisions when dealing with HABs.

The researchers found that housing values decrease by 7-16 percent when algal blooms in the area surpass the levels designated as safe for drinking water by the World Health Organization. Surveys at popular recreation spots also showed that anglers and beachgoers tended to substitute locations not affected by algal blooms when their favorite spots were closed, but that some people also decided to visit Lake Erie less often because algal blooms forced them to change their plans in the past. Currently, the researchers are combining the survey data with housing market information to create a comprehensive model of how zebra mussels and algal blooms affect the Lake Erie economy. The optimal management model being developed from this information will be applicable to just Lake Erie, but additional proposals to expand the model to the entire Great Lakes region are in the works.

THE BOTTOM LINE

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

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 USEPA 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 AWRF 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 US 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 from 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, and 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 (IE 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, and 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 ag fields. Investigate various natural wetland flow-thru 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 of 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.

- 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

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- 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.

HARMFUL ALGAL BLOOM RESEARCH INITIATIVE

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